New York State Museum Bulletin

Published by The University of the State of New York

No. 326 ALBANY, N. Y. April 1942

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE WELLSVILLE QUADRANGLE, NEW YORK

BY JOHN G. WOODRUFF, Ph.D

CONDUCTED IN COOPERATION WITH COLGATE UNIVERSITY AND THE UNIVERSITY OF MICHIGAN

CONTENTS

ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1942

New York State Museum Bulletin

Published by The University of the State of New York

No. 326 ALBANY, N. Y. April 1942

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE WELLSVILLE QUADRANGLE, NEW YORK

BY JOHN G. WOODRUFF, Ph.D

CONDUCTED IN COOPERATION WITH COLGATE UNIVERSITY AND THE UNIVERSITY OF MICHIGAN

CONTENTS

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1942

M 359r-My 40-1500

ILLUSTRATIONS

GEOLOGY OF THE WELLSVILLE QUADRANGLE

By John G. Woodruff, Ph.D.

PREFACE

Because of the ranking importance of the Wellsville quadrangle in New York State's natural gas production and because of the small amount of geological description published for this area, this bulletin is believed to be appropriate. It is published primarily for those persons interested in the Wellsville quadrangle but may be of some value to others interested in geology. It is desired to give a rather complete description of the geology of the area and, insofar as it is convenient, to avoid the use of technical terms which may be unfamiliar to the lay reader. The maps and sections inclosed in this bulletin are primarily for the use of those persons qualified to interpret them.

The rocks found on the surface in this area are mostly of Devonian age. Some of the highest hills in the southern part of the quadrangle contain rocks of questionable Mississippian age. They apparently do not contain fossils which could be used for dating them. Some 300 to 350 million years ago the sediments derived from preexisting rocks were forming the rocks that we see there today. Most of the rocks are covered by soil produced by weathering but in many places the soil has been removed by running water or by excavations made by man. Such exposures, known as rock outcrops, have furnished the evidence for the writer's interpretation of the conditions existing when the rocks were being formed. Although the rocks in this area are very old, they are a part of the youngest geological formations found in New York State except a small representation of the Pottsville in the southwest, the Triassic, Cretaceous and Tertiary (Neocene) of the lower Hudson valley, Staten and Long islands and the relatively thin, discontinuous surface covering of glacial debris spread over most of the State by the great ice sheet, or sheets, some tens of thousands of years ago.

One well-known teacher of geology has frequently and aptly remarked to his students, "The earth is not built like an onion." The earth is not made of smooth, continuous layers of regular thicknesses of sedimentary rocks. It is true that some layers extend for thousands of square miles with little change of character. Others show a marked change in the face of an outcrop of only a few feet. The rocks in the Wellsville area are of the latter type. The shales grade laterally into sandstones or limestones (impure), the sandstones into conglomerates and vice versa. Changes are effected in the mineral content, texture, structure and chemical composition of the beds. Even the fossils of the same species show some differences in the different environments. The lack of constancy of character of the beds makes their description more difficult and probably detracts from the interest of all except the professional geologists.

A better appreciation of the description of the geology of this and other regions will be attained if the reader will first consult the New York State Museum Handbook 10, by Dr Winifred Goldring.

ACKNOWLEDGMENTS

The writer is indebted for help and counsel to a host of coworkers in geology. To those whose names are not specifically mentioned grateful acknowledgment is hereby made. Information was obtained through reading the reports of the geologists whose names are listed in the bibliography.

The patience and thoroughness of Professors E. C. Case, I. D. Scott, G. M. Ehlers and A. J. Eardley of the University of Michigan in correcting the original manuscript have added to its value. Professor W. F. Hunt has generously given his time in checking the mineral identifications of the thin sections of rocks. Professor W. H. Hobbs has helped in arranging for publication.

Doctors Charles C. Adams, Rudolph Ruedemann, Winifred Goldring and C. A. Hartnagel of the New York State Museum gave materials and valuable time and advice in the preparation of this report. Information was generously offered by the New York State Natural Gas Corporation, Wellsboro, Pa., the Columbia Gas and Electric Corporation, New York City, the North Penn Gas Company, Port Allegany, Pa. and the Cunningham Natural Gas Corporation, Bradford, Pa. Some information was received from the Empire Gas and Fuel Company, Wellsville, N. Y.

The author is particularly grateful to Professor George H. Chadwick, who, as an active worker in Upper Devonian stratigraphy, is appreciative of the problems offered by the strata in this region. Several profitable days were spent in his company during the field work. Any expression of gratitude is inadequate for the help received from Dr Kenneth E. Caster of the University of Cincinnati. Doctor

Caster is well informed on the Upper Devonian paleontology of western New York and northwestern Pennsylvania. He checked the identification of the fossil collection and gave advice in connection with the photographing of some of the fossils. Because of close association with Doctor Caster in the field and in the laboratory the conclusions are expressed with greater assurance.

Dr G. B. Richardson of the United States Geological Survey, Dr Harry N. Eaton, J. W. Sadler and Roger Williams were pleasant and helpful companions in some of the field work. The late E. J. Stein, New York State Museum photographer, was responsible for improvement of some of the fossil plates.

The writer wishes to thank Dr L. G. Glenn of Vanderbilt University for an introduction to the study of geology and Professors Harold O. Whitnall and Earl Daniels of Colgate University and Dr Bradford Willard, Pennsylvania Topographic and Geologic Survey, for reading and correcting the manuscript. Appreciation is felt for the help received from Laura Hodgson Woodruff, the author's wife and companion.

A GENERAL DESCRIPTION OF THE WELLSVILLE QUADRANGLE

LOCATION

The Wellsville quadrangle is in Allegany county, New York, located between west longitude 77°45′ and 78°00′ and between north latitudes 42°00′ and 42°15′. An area one-tenth of a mile wide has been added to the southern boundary of the quadrangle to include the boundary line between New York and Pennsylvania. The Wellsville quadrangle is bordered on the east by the Greenwood quadrangle, on the north by the Canaseraga quadrangle, on the west by the Belmont quadrangle and on the south by the Genesee quadrangle, Pennsylvania. The Hornell quadrangle joins at the northeast and the Angelica quadrangle joins at the northwest corners of this quadrangle. The total area of the Wellsville quadrangle is 229.543 square miles, 1.223 square miles being the added area to the south. This quadrangle was mapped cooperatively by the United States Geological Survey and New York State in 1923 and 1924 on a scale of 1/62,500 with a topographic contour interval of 20 feet. Bench mark elevations are fairly abundant and made the checking of barometer elevations feasible.

The area is a part of what is sometimes spoken of as the Southern Tier of New York. Roughly, it comprises the southeast fourth of Allegany county. It is a part of the Allegheny Plateau region of the Appalachian province.

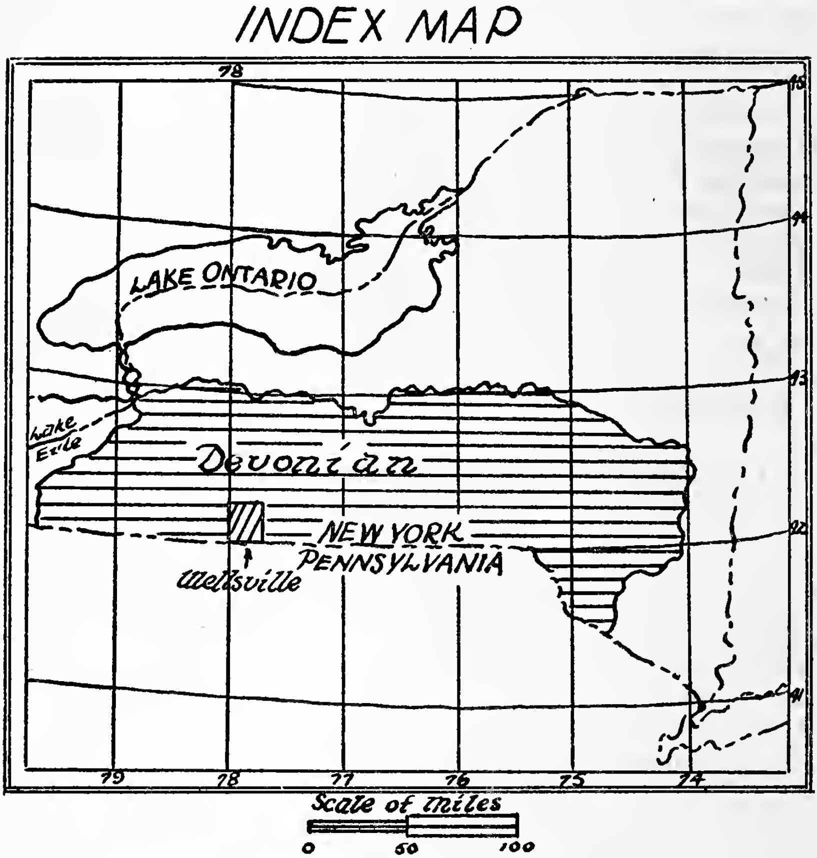


Figure 1 Sketch map showing location of Wellsville quadrangle

TOPOGRAPHY

The region has the characteristic ruggedness of the high hills and steep valleys of southwestern New York, produced by the long-continued erosion of bountifully fed streams cutting through alternating layers of hard sandstones and soft shales and modified in most of the area by the glacial activity of the Pleistocene. In a few places, as in Honeoye creek and Cryder creek, the steep-sided canyonlike valley walls tower hundreds of feet above the valley floor,

Figure 2 View showing topography of Fulmer Valley section

Figure 3 View looking down the Genesee River valley

while at others the slope rises more gradually to the highly dissected plateau which has many knobs that show an elevation in excess of 2300 feet. One point, about one mile southwest of Whitesville, has an elevation in excess of 2500 feet above mean sea level. This is one of the three points in central and western New York which reach this elevation. The other two are Alma hill (2548 feet) and White hill (2500–2520 feet), located respectively one-half mile and three and one-fourth miles west of the west-central part of the southwest section of the Wellsville quadrangle. The slope to the north of the remnants of what was probably a former peneplain is about 10 feet a mile since the elevation drops in a distance of 15 miles from 2500 feet near Whitesville to about 2350 feet two miles southwest of Alfred. The lowest point in the quadrangle is where the Genesee river leaves the area in the northwest section at an elevation of approximately 1390 feet. The greatest relief for any one square mile is about 870 feet with the hills rising on an average about 600 to 700 feet above the valley floors. See figure 2.

DRAINAGE

The Wellsville quadrangle is drained almost solely by the Genesee river. Entering the south-central section, pursuing a somewhat tortuous course and carving out steep-sided banks at places by lateral planation, it crosses a large portion of the quadrangle to a point in the northwest section in a direction N. 25°W. from the point where it entered the area. The valley carved out in the Wellsville quadrangle for a distance of about 16 miles has greatly facilitated working the areal geology, as it has cut at almost right angles the axes of the major anticlines and synclines of this area. The stream enters the quadrangle at an elevation of about 1610 feet, and after a course of 15¼ miles air line, leaves it at an elevation of about 1391 feet, giving a slope of 14.4 feet a mile. The meandering stream would have a grade of about 11 feet a mile. It is interesting to compare these figures with the slope of the peneplain remnants mentioned previously taken in nearly the same direction. See figure 3.

Somewhat paralleling the major structural features, the main tributaries flow into the Genesee at or approximately at right angles. From the north, the E.N.E. tributaries are (1) Phillips creek which enters the Genesee river at Belmont, (2) Vandermark creek which joins it at Scio (northwest section), (3) Dyke creek which joins it at Wellsville, (4) Chenunda creek which joins it just west of Stannard Corners (west-central section), and (5) Cryder creek which joins the Genesee just south of the Wellsville quadrangle near Genesee, Pa. The W.S.W. tributaries are (1) Knight creek, which joins the Genesee west of Scio, (2) Brimmer brook, which joins it west of Wellsville, (3) Ford brook, which joins it near Stannard, and (4) Marsh creek, which joins it near Mapes (southwest section). There are many smaller tributaries draining into the Genesee and numerous branches flowing into the tributaries. Most of the rock outcrops are to be found on the smaller streams which make a short steep descent from the uplands to the valley floors.

Only a very small part of the Wellsville quadrangle is not drained by the Genesee river. An area of about two square miles in the southwest part of the southwest section is drained by Honeoye creek, a tributary of the Allegheny river, and an area of about eight square miles in the northern part of the northeast section is drained by Canacadea creek, a tributary of the Canisteo river which flows into the Susquehanna river. Waters from the Wellsville quadrangle flow into Lake Ontario, the Gulf of Mexico and the Atlantic ocean. It is the one quadrangle in New York State where the drainage is so shared. The one quadrangle in Pennsylvania which shows a similar condition of drainage is the Genesee quadrangle bordering this quadrangle on the south.

CULTURE AND AGRICULTURE

The population of this maturely dissected plateau region is mostly rural and derives its income largely from farming and from the petroleum industry. The valleys are narrow and offer only a few square miles of arable soil. The major crop is potatoes and the yield is heavy on the higher ground in the southern half of this quadrangle. The soil is in a large measure derived from the red beds of the Cattaraugus. With its high iron content and sufficient sand to give needed porosity, its suitability for the raising of potatoes has long been recognized. Hay ranks second as an agricultural product. Corn, wheat, barley, buckwheat and other crops are grown on a smaller scale.

Wellsville, with a population of about 5674, is the largest town in this quadrangle and in Allegany county. It is located in the west-central section of the quadrangle on the Genesee river, which divides it into two nearly equal parts. Although it is the principal potato market for the surrounding country, its growth has perhaps been due more largely to the Sinclair Oil refinery, which employs several hundred men and was located here because of proximity to the many shallow oil fields in the southern half of Allegany county.

The other towns of more than 100 inhabitants are Andover in the northern part of the east-central section, Alfred (partly in this quadrangle) in the northeastern section, Whitesville in the southeastern section and Scio in the northwestern section. These small towns owe their existence primarily to agriculture.

Two railroads cross the quadrangle: the Erie in an east-west direction, and the Buffalo and Susquehanna in a north-south direction. Both of these follow the stream valleys. Hard-surfaced highways follow all of the principal stream valleys and the secondary dirt and gravel roads are easily traversed during the summer months.

METHODS OF FIELD WORK

The field work which is largely the basis of this paper was done during the years 1932–35. The summer of 1932 was spent in Potter county, Pennsylvania, south of the Wellsville quadrangle, in making a structural geological map. The entire summer of 1934 was used for field work, collecting materials and evidence for this paper. On various occasions the writer has had the privilege of the company of those men mentioned in the acknowledgments.

During the course of the work on the Wellsville quadrangle, the type outcrops of all beds thought to occur in this quadrangle were visited, a collection of fossils was made and in most cases samples of rock were taken. A few of the type outcrops may be considered as characterless in comparison with some of the better known formations; but they are the best available.

Fossil collections were made from about 100 stations. Dr Kenneth E. Caster, then at Cornell University, was recommended to the writer by the personnel of the New York State Museum as perhaps the person best informed on the fossils of the Upper Devonian of New York State. Identification of the fossils, some perhaps undescribed, (Shark's egg case(?) from the Wolf Creek conglomerate on Wolf creek and a plant from Cattaraugus formation near Olean Rock City) was made possible through his help. The figured specimens are in the possession of the New York State Museum.

The structural geology has been checked by three methods in common use: (1) measurement of the dip and strike of the beds, (2) determination of the elevation of key beds, and (3) use of subsurface records of shallow and deep wells, drilled for oil and gas.

(1) The dip and strike of rock in most instances were taken with a Brunton compass. The strike is considered as reliable but the

amount of dip when less than one or two degrees can be seriously questioned. Experience has shown that structural contours drawn on the basis of dips and strikes will invariably show more of a dip than is evident from the use of key beds. Some of the strikes and dips were taken with a hand level and some were checked with stadia hand level and rod. The above methods were excellent for showing the form of the structure.

(2) The Cuba sandstone was used as the key bed in the northern part of the quadrangle and the Germania sandstone (described elsewhere in this paper) in the southern half. The elevations on the top of the Cuba and at the base of the Germania were taken with a barometer set at a bench mark near the same elevation as the outcrop, the barometer readings being corrected by the use of a barometer curve. This curve or graph was made by frequent checks of the barometer on bench marks, using as coordinates the time and the increase or decrease of atmospheric pressure for that time. The error in elevation is believed to be always less than five feet and generally less than two feet.

(3) The subsurface structure based on the records of wells drilled for oil and gas, while not in perfect accord with the surface structure in the case of minor flexures, helps to complete the picture. Records of shallow wells were obtained from the Scio field, from the Ford Brook-Alma Hill section, from Fulmer valley and from many other localities. The records of deep wells drilled to the Oriskany sandstone add materially to the understanding of the subsurface structure. The elevation of the top of the well and the depth to the oil sand or some other known horizon give a somewhat complete picture of that horizon. Unfortunately the records of the shallow wells are of such a nature that it is hazardous to use some of them.

An unusual fact became apparent during work in this area. If the work is carried from the southeast toward the northwest, the lithological facies seems of prime importance and one is apt to correlate the older red beds of Chemung or earlier time with the much later Cattaraugus formation. Working from the northwest toward the southeast, one is puzzled at finding the Chemung fauna interbedded with what was called the Catskill beds. A detailed discussion of this ambiguous situation will be given later. Many early miscorrelations are traceable to failure to take it into consideration. The results described in this paper are based upon tracing beds into the Wellsville area from the southeast and the northwest.

STRATIGRAPHY

GENERAL

The rocks found in the Wellsville quadrangle may be divided into three general groups: (1) glacial and fluvioglacial, (2) alluvial and colluvial, and (3) the stratified rock of the Upper Devonian and Mississippian (?).

(1) The glacial deposits in this region form a thin veneer which, with the exception of the fluvioglacial deposits in the valleys, is never more than a few inches to a few feet thick. Rock of glacial derivation and deposition can readily be recognized by the rounding effect of erosion upon all the pieces, ranging from the fine clastics to boulder size. Even some of the flat slabs of rock produced by postglacial weathering of glacial debris have their corners and edges rounded. Most of this material has been derived from the rock of this and adjacent regions, but a few of the erratics have been brought from the Lower Paleozoic and the Precambrian beds, located to the north, some 100-200 miles or more. The outcrops to the north that are represented in this drift are those offering most resistance to abrasion and weathering, quartzitic sandstones and igneous rocks being most common.

The fluvioglacial material, similar in composition and character to the material described previously, is confined to the valleys, where it sometimes reaches a thickness of many tens of feet. These deposits are seen as benchlike structures showing nearly flat surfaces, bordering one or both sides of the lower valleys of the area.

(2) The mantle rock and soil in the Wellsville quadrangle are extremely variable, both in constituency and in depth. It was particularly noticed early in the progress of field work that most of the hills showed two angles of slope between their crests and the subjacent valleys. The more gentle slope was caused by the accumulation of talus on the lower fourth to half of the slope. Since this area was covered by the Pleistocene glacier (or glaciers), it was assumed that a large part of the talus was glacial debris. Upon examination it was found that very little of it was glacial. The great quantity of this colluvial material can be appreciated when it is realized that this area has had an elevated position for a long time. In many places in the area soil and mantle rock have great depths. The soils vary in color from dark gray (mostly in the valleys) to light gray (hills in the northern half of the quadrangle) to red and brown (in the southern half of the quadrangle), the color depending largely upon the underlying Paleozoic rocks. The soils produced

by the red and green highly ferruginous beds of the "Upper" Chadakoin and Cattaraugus are not always red. Where there is an abundance of decaying vegetation the red oxide of iron has been reduced, making the use of the soil as an index to the underlying formation hazardous. The red soils of the southern half are usually sandy; the gray soils are quite variable, some being sandy and others containing more clay.

(3) The stratified rock, of which this paper largely treats, has exposed in the Wellsville quadrangle a total section of slightly more than 1400 feet (estimated to be 1420 feet). Most of this section can be seen in outcrop, but very little of it can be seen in any one continuous section. There are only three outcrops in excess of one hundred feet of rock in a nearly continuous section: one on the north side of Vandermark creek, two miles east of Scio (147 feet); another, one mile south of Alfred, one-fourth mile northwest of the Erie railroad (133 feet); and the third, three-fourths mile south of Elm Valley on a secondary road (138 feet). The first two are of the Machias and Cuba, the third is of the Whitesville and Germania (first used in this paper) formations. The first two have covered intervals of a few feet and the last is a poor exposure. Although outcrops of more than 20 feet are rare in the area, those of less are fairly numerous. If it were not for the repetition of beds of similar lithological texture, structure and composition, and for the frequency of change laterally in most of the beds, the area would not be difficult to map geologically.

The compiled section with the specific units and their thicknesses is shown in figure 4. For details of this section refer to sections 1 and 2 in pocket. A discussion of the validity of the specific units is given in the descriptive portion. The beds below the Cattaraugus, figure 4, are known to many geologists as the "Upper Chemung."

The lowest beds exposed in the quadrangle are the Machias beds limited to the valleys in the northern half (with one exception) and almost to the northern third of it. The exception occurs at the point where the Genesee river has cut through an anticline near Shongo. The lowest beds are only a little more than 100 feet above the "Upper" Rushford sandstone (Shumla). In succeeding order the formations higher in the stratigraphic column are exposed as one traverses southward across the quadrangle. Since the regional dip is to the south of west, the older beds are in the northeast, the younger in the southwest part of the area, where, one-half mile west, in the Belmont quadrangle, the Olean conglomerate occurs only about 30 to 40 feet above the youngest Paleozoic rocks of the Wellsville quadrangle. That outcrop is the most easterly outcrop of Olean conglomerate (Pottsville) in New York State. Of course, the rocks do not appear in regular successive bands like the colors drawn upon the state geological map, but a general idea of the normal succession can be gained by such a picture. Their position in detail is much more complex, because of structural adjustments and erosion in the area.

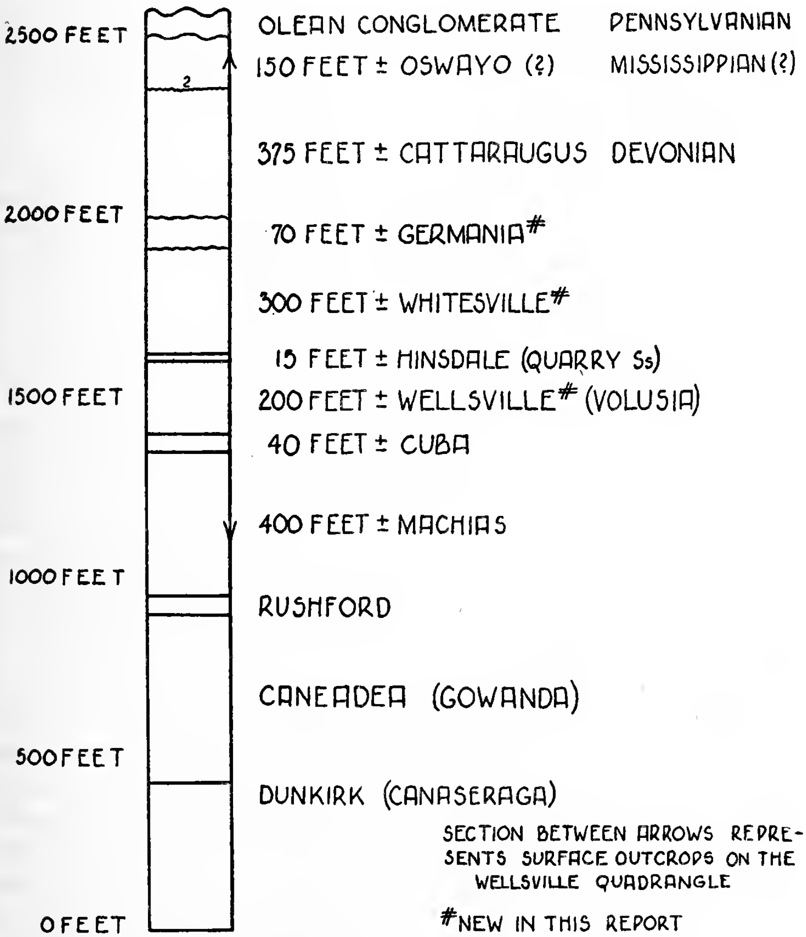


Figure 4 Geological section in the Wellsville quadrangle

UPPER DEVONIAN

Canadaway Group ("Upper")

Machias. This group name was first used by Professor George H. Chadwick. The writer accepts the name and tentatively includes the Cuba formation, which Professor Chadwick places in the Conneaut group. Some reasons for this desired change are given in the description of the Cuba.

Machias was first defined by Chadwick as follows:

> To the fossiliferous phase of the Northeast shale, with many bryozoans, I ascribe the beds in Cattaraugus county that I have called the "Machias," and which I believe to be continuous with those above the Rushford sandstones in the region north of Cuba town (Chadwick, 1933*a*, p. 202).

Northeast, (Chadwick, 1924, p. 152), which had been previously used, apparently is the equivalent of the Machias. The Machias beds in the Wellsville quadrangle are limited by the Rushford sandstones below and the Cuba above, so that name is acceptable for the beds here described.

The Machias beds are part of the "Chemung," for this general area, described by Hall (1840, p. 401–11). He mentioned in particular outcrops seen on Vandermark creek (Hall, 1840, p. 406–7) as a part of the Chemung. The beds seen there are Machias and Cuba. He describes the beds on Dyke creek (Dike, Hall) near Wellsville as being just below the old red sandstone in the Tioga section. His correlation may be correct, but a careful study of the Wellsville quadrangle leads to the belief that the beds on the Tioga river are stratigraphically lower. They have a facies similar to the higher beds of the Wellsville area. The shore line of that time was advancing toward the northwest.

Of the 250–300 feet of Machias beds examined in the Wellsville quadrangle, none of the individual members was considered to have sufficient character to warrant its use as a key bed. Some of the most apparent features of the beds are shared by the strata above the Cuba formation which overlies the Machias and which is conformable with it. One outstanding feature is the abundance of the interbedded thin layers of shales and thin flags. The color predominating is a dull green, described as olive-green but often a greenish gray. This color is a little more common to the shale members than to the sandstones which are frequently more of a gray. Iron compounds are rather abundant in both the shales and the sandstones and the weathered surfaces of the outcrops have a greenish brown appearance. While most of the shales are argillaceous, some are silty in composition. The flags are fine-grained sandstones or siltstones. Those having a maximum size-grade of less than 1/16 mm are considered siltstones. The exposed shales break down rapidly into fissile chips and parallelopiped-shaped pieces. The flags, generally from one-half inch to two inches in thickness, break into irregular small pieces.

While the previously described beds constitute far more than half of the Machias, there are occasionally more massive beds of fine to medium grained light gray sandstone. These beds are usually underlain by from 10 to 15 feet of argillaceous shale and resemble slightly the Cuba beds above. Such beds are well displayed on Phillips creek, one-half mile southwest of Withey; on Vandermark creek one-half mile southeast of Scio; and in Alfred township in the northeast section. They are 150 to 200 feet below the Cuba. At Withey, station 514, there are two such beds of sandstone in the upper part of the section, each about 10 feet in thickness. Here the upper bed is underlain by shales and thin siltstones and is shaly in character. A calcareous siltstone separates the sandstone from the shales below. It is very fossiliferous, carrying a typical Machias fauna with *Spirifer (Delthyris) mesacostalis,* the most important index fossil in the area.

Spirifer (Delthyris) mesacostalis ranges from the Portage beds below, into the Cuba sandstone above. It has never been definitely proved to have been found above the Cuba. Figure 8, page 29, shows some typical forms of *Spirifer (Delthyris) mesacostalis* in its variations in the Wellsville quadrangle. It is found in great abundance both in the sandstones and in the shales below the Cuba, being generally larger in the sandstones of the Machias than in the shales. It is also found in large size in the shales that interbed with the Rushford sandstone in the Greenwood quadrangle, which borders the Wellsville quadrangle on the east. It is usually present in the Cuba sandstone members. There it is not abundant and sometimes an hour or more was spent in diligent search before a specimen was found.

Another characteristic feature of the Machias formation is the calcareous siltstones, varying from a few inches to two feet in thickness, almost invariably carrying many *Spirifer disjunctus,* and frequently many other fossils. The amount of calcium carbonate is variable and seldom reaches a proportion which would justify calling these beds limestones. Many of them when long exposed to weathering, become yellowish or brown, from a large amount of hydrated iron oxide. The leaching out of the calcium carbonate

Figure 5

MACHIAS FOSSILS

A *Schuchertella chemungensis* (Conrad), pedicle valve, from station 559, south of Friendship.

B *Spirifer disjunctus*, brachial view, from station 468, two miles east of Scio.

C *S. disjunctus*, exterior view of the pedicle valve, from station 468.

D *Camarotoechia contracta* (Hall), from station 559.

E Idem.

F *S. disjunctus*, cardinal view, from station 468.

G *Productella* cf. *lachrymosa*, from station 559.

H *S. disjunctus*, brachial view, from station 559.

I *Schuchertella* cf. *chemungensis* (Conrad), brachial valve, from station 559.

J *Athyris angelica*, found abundantly in the argillaceous shales. Station 468a, 2 miles east of Scio.

K *Goniophora* sp., from station 678. One-half mile southwest of Belmont.

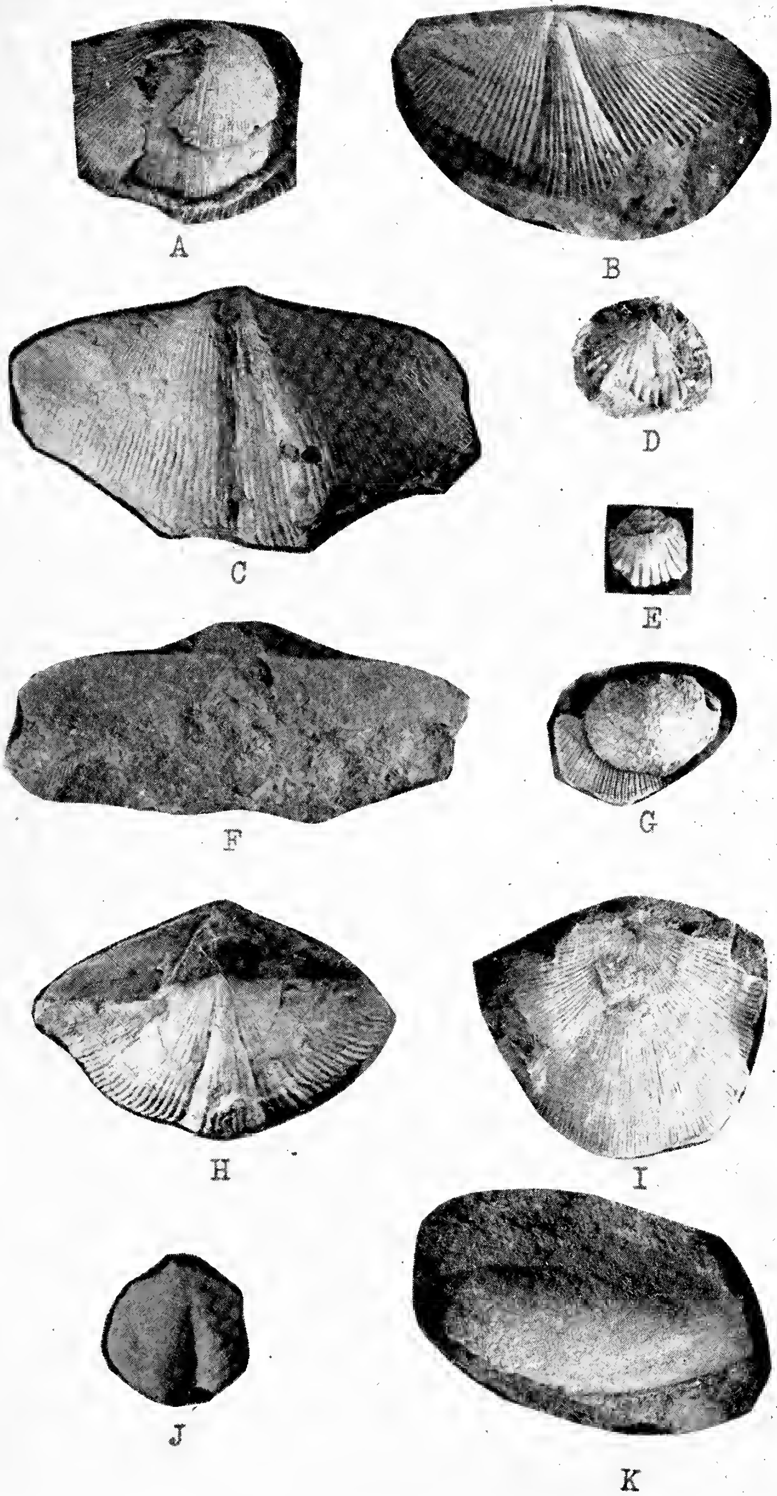


Figure 5 Machias fossils

leaves a very porous, friable rock, filled with the casts and molds of Devonian fossils. Generally the larger blocks of drift from these beds will when broken show a brown zone of weathering (from a fraction of an inch to a few inches deep) surrounding the hard gray unaltered interior. These siltstones, less often limestones, occasionally sandstones, containing variable proportions of iron compounds, calcium carbonate, clay, silt and sand, are the most striking beds not only of the Machias but of all those beds extending from the Portage to the Cattaraugus, where they were deposited in a normal marine environment. They mean "Chemung" to many workers.

There are also in the Machias other beds which deserve particular mention. These are the thin crinoidal layers at infrequent intervals in the upper part. Similar beds occur less frequently in the "Lower" Conneaut beds above the Cuba. Seldom more than two or three inches thick, they are usually brown or a dull shade of red and have an abundance of crinoid stems but seldom show a complete crinoid. None were found. Where arenaceous material predominates, only the imprints of crinoid stems are in evidence. These beds at some places have such a high iron content that they are iron ore beds, but they are not of appreciable commercial value.

Ripple-marked beds are so common at many horizons throughout all of the Upper Devonian that a specific description is of little value here. The ripple-marked gray flags are common in the upper Machias beds and are present in the lower Machias. Other sedimentary features such as mud flows, plant impressions and worm borings are common. Places where such features are best displayed are at stations 466, 514, 468, 500 and 517. By referring to map 2, in pocket, which shows the areal distribution of outcrops, the field stations may be easily checked.

For a complete faunal list of the Machias, see Chadwick's recent paper (Chadwick, 1935, p. 305–42) giving the Canadaway fauna. The fossils most abundantly found during the progress of this work are pictured in figures 5 and 8. Confidence in their identification was derived from the help of Dr Kenneth E. Caster.

Cuba formation. The beds immediately overlying the Machias formation are here designated as the Cuba formation. The reasons for changing the name Cuba sandstone as defined by Dr L. C. Glenn (1903, p. 968–71), originally described by H. S. Williams (1887, p. 63), to the name Cuba formation for the Wellsville quadrangle are given below.

Doctor Glenn writes:

From its exposure in quarries in and around Cuba this sandstone is known as the *Cuba Sandstone.* It is regarded as a lentil in the Chemung formation (Glenn, 1903, p. 969).

Describing the type locality where the Cuba sandstone has been quarried, figure 6, just above a railroad cut in bluish and green shales, near the Erie railroad station at Cuba and near there, Doctor Glenn writes:

Immediately above these shales there is a sandstone 10 to 15 feet thick, most prominently exposed in and north of Cuba in a number of quarry openings. It is a medium to coarse grained, somewhat arkosic sandstone, usually of a light cream color and smelling strongly of petroleum on freshly fractured surfaces. As seen in a quarry a few rods east of the Erie depot in Cuba there are exposed at the base 8 feet of thick bedded, hard, cream colored sandstone, above them two feet of green and brownish shale, then two feet of sandstone abundantly fossiliferous. * * * In places the stone is stained with iron along joints and seams. Fossils occur rather abundantly in certain layers and in the coarser parts an occasional small quartz pebble is found (Glenn, 1903, p. 969).

In the Olean quadrangle, where the beds described previously are located, the name Cuba sandstone lentil aptly applies. When this sandstone was traced eastward across the Belmont quadrangle to the Wellsville quadrangle, it was found in the latter quadrangle to consist of at least three massive, hard, buff-colored (weathered) sandstone members, figure 7, similar to Doctor Glenn's description of the Cuba sandstone. It is marked by the upper limit of range of *Spirifer* (*Delthyris*) *mesacostalis.* The sandstones are interbedded with olive-green to greenish gray shales. There is justification for calling these beds the Cuba formation (or monothem) (Caster, 1934).

The Cuba formation has a thickness of 40 feet (±) in the Wellsville quadrangle, thickening slightly to the east. The full thickness (see section 1, in pocket) is exposed at station 468 on Vandermark creek and at station 760, one mile south of Alfred. The sandstones vary in thickness, the lower ones being from two to eight feet thick and the upper one from 10 to 20 feet thick. The shales are argillaceous and fissile. The greenish brown color of similar shales in the weathered outcrops of the Machias is also present in the shales of the Cuba. The shales range in thickness from a few feet to as much as 20 feet. The bluish gray shales noticed by Glenn in the Olean quadrangle below the Cuba are exposed in a few places in the

Figure 6 Type outcrop of Cuba sandstone

Figure 7 Cuba rock section, east of Scio

Wellsville quadrangle, but are more pronounced lower in the Machias, because of thickening and coarsening of the beds to the east.

Since the type locality of the Cuba sandstone at Cuba has not been used as a rock quarry for a number of years, it has deteriorated, and the sandstone is almost completely covered by talus. Where the Cuba was relatively unfossiliferous, the first light gray or cream-colored sandstone, weathering to a buff and occurring above the last outcrop of shale that contained *Spirifer* (*Delthyris*) *mesacostalis*, was taken as the base of the Cuba formation.

The Cuba has been placed by Chadwick as the lowest division of the Conneaut (Chadwick, 1933, p. 91–107, and 1935, p. 305–41). Since in the present work *Spirifer* (*Delthyris*) *mesacostalis* was found to be an invaluable aid in marking the Cuba formation, and since it is abundant in the Machias and occurs in the Cuba, but is not found in the beds above, it is suggested that the Cuba may better be placed as the top division of the Canadaway rather than as the base of the Conneaut. Previous descriptions of the faunas of these beds by Williams (1887) and by Butts (1903, p. 990–95) do not indicate that the break should be placed below the Cuba rather than above.

Figure 8 shows the fossils common to the Cuba formation. (See Chadwick, 1935, for complete list of fossils.)

Conneaut Group (Caster, 1934)

This group name has been selected for those beds that lie between the Cuba formation below and the Cattaraugus above (Caster, 1934, and Chadwick, 1935).

To Chadwick (1933, *d* and *e*) is due the major credit for calling the attention of geologists to the need of a revision of Upper Devonian stratigraphy. While much confusion will result during the process of scrapping old established names and inserting new ones, some of which likewise must be dropped later, the ultimate result will be the clarification of the concept of Upper Devonian stratigraphy. Willard (1935, p. 495–516) has done much to clarify the stratigraphic relationship in Pennsylvania, and Caster (1934) has done the same for the beds above the Conneaut up to the Olean conglomerate in northwestern Pennsylvania and southwestern New York.

Well-defined beds with a characteristic marine fauna, when traced eastward, become lost in the great mass of beds of subaerial and shallow water deposition. Consequently there is little chance of their being given definite upper and lower boundaries. While the Con-

Figure 8

CUBA FOSSILS

A *Mytilarca* sp., from station 558, near Erie railroad station at Cuba, New York.

B Idem station 558.

C *Productella* sp., from station 558.

D *Athyris* sp., from station 558.

E *Camarotoechia* cf. *contracta* (Hall), from station 558.

F *Bradfordoceras* (?) sp., from station 558.

G *Camarotoechia contracta* (Hall), from station 558.

H *Spirifer disjunctus* Sowerby, from station 558.

I *Bradfordoceras* sp., from station 558.

J *S. disjunctus* Sowerby, from station 558.

K *Oehlertella* sp., from station 558.

L *Actinopteria* sp., from station 558.

M *Delthyris mesacostalis* (Conrad), with field stations in photograph.

N *Delthyris mesacostalis* (Conrad) and crinoid columnals, from basal Cuba sandstone. Station 468D, two miles east of Scio.

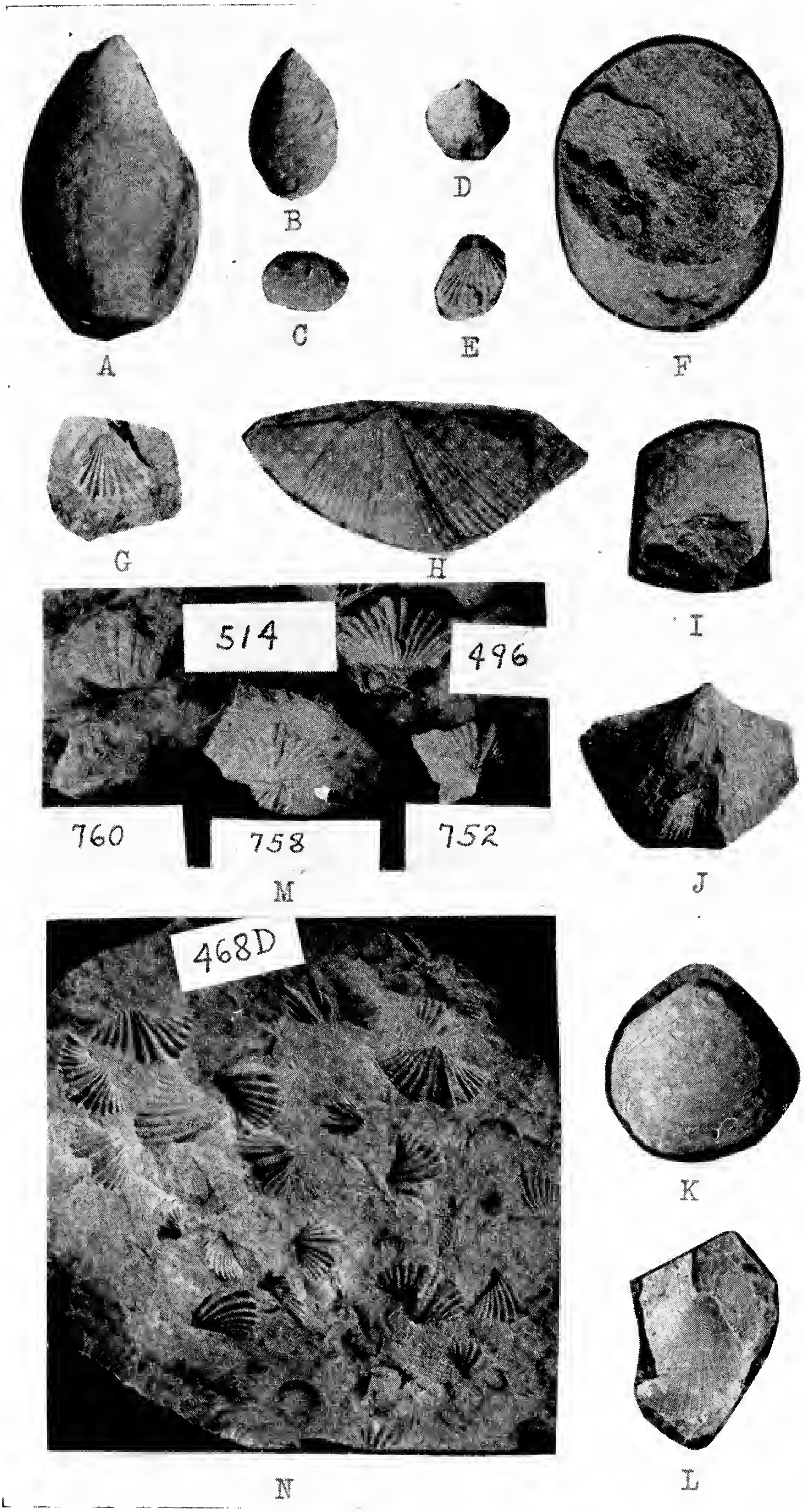


Figure 8 Cuba fossils

neaut beds of the Wellsville quadrangle correlate with the beds of the Olean quadrangle as mapped by Glenn (1903, p. 968–71) and Butts, who considered them as Upper Chemung, they may not correlate with the Upper Chemung as originally defined by Hall (1838–39) but are believed to be represented in the red beds higher in his type section at the "Narrows."

The following is quoted from Chadwick (1935, p. 326–28):

On the Ohio-Pennsylvania line, the lower Chagrin beds transected by Conneaut Creek include from the base of the Girard shale to the top of the succeeding Chadakoin beds or "Chemung" of northwest Pennsylvania. Eastward, in New York, the barren Girard becomes the fossiliferous Volusia member, and two sandstones appear in the succession, which near Olean, N. Y., consist of (*a*) Cuba sandstone, (*b*) Volusia beds, (*c*) Hinsdale sandstone, (*d*) Chadakoin beds. Already there are red interfingerings, so that the continental facies is soon entered, the upper member being mistaken at length for "Oswayo" in eastern Potter County, Pennsylvania, before being bevelled out by the Pottsville above. The fauna is particularly marked by the advent of *Camarotoechia* (?) *duplicata,* while retaining *Athyris angelica.*

The Girard, which Chadwick correlates with Volusia, and the "Chemung" are the identifications of I. C. White (1881*b,* p. 117–19). White's mistake (?) in calling the beds Chemung was a natural one because of the resemblance of the beds to the true Chemung near Elmira, and the presence of many Chemung fossils. Much light has been thrown upon the Upper Devonian problem by a host of workers since White did this work.

The writer agrees with Chadwick and others that the marine beds thicken and ascend to the east with a change of facies. As to the Chadakoin being represented by what has been called "Oswayo" in eastern Potter county, the writer disagrees so far as northeastern Potter county is concerned, where he has examined the rocks. Only the upper part of the Chadakoin has taken on the "Catskill" facies as far east as the 77° 45′ meridian or the eastern boundary of the Wellsville quadrangle. Cattaraugus beds (Conewangan fauna) have been identified by Doctor Caster northeast of Andover in conjunction with this report. The relationship of the beds is revealed in the description of the Whitesville and Germania formations and in the section on paleogeography (see p. 48–57, 58–62 and 113).

Wellsville formation. The 200 feet of rock strata included between the Cuba formation below and the Hinsdale (Chadwick, 1933*a,* p. 203) (Quarry, Glenn, 1903, p. 970), Lillibridge, (Caster, 1934, p. 63) sandstone above, zone 11 of Butts (1903, p. 990), are designated in this quadrangle as the Wellsville formation, in the lower part of the Conneaut group. The writer is inclined to follow the work of Butts and Glenn, for Butts' description of the fauna and Glenn's description of the stratigraphy of the Olean quadrangle can with little change be applied to the same interval of the Wellsville quadrangle.

The name Wellsville has been selected for this part of the section because the beds are to be seen not only near the town of Wellsville but in part in nearly every locality of the Wellsville quadrangle. The best exposures can be seen at station 560, in the lower part of Smith hollow, in Whiteman hollow and in Duffy hollow. They are present in the lower part of many ravines in the quadrangle, where running water has cut through the weathered covering and glacial debris of the area.

The beds are somewhat similar to the Machias beds below, in having an abundance of thin sandstones or siltstones, one-half inch to three inches thick, interbedded with shales, for the greater part argillaceous but sometimes arenaceous. The colors are generally olive-green and gray. The weathered outcrops usually have a greenish brown or brownish gray color. There is some indication of approaching "Catskill" deposition, as a few of the beds in the upper part have a chocolate-brown to a dull red color, but there is no evidence of the bright red of the "Catskill" time which, when it makes an appearance, becomes the predominating color of the section. Other writers (Glenn, 1903, p. 973 and Caster, 1934, p. 63) have noted the distinction in shades of red of Upper Devonian beds. The thin flags and shales do not make up so high a proportion of Wellsville beds as they do of the Machias. Grays predominate over green in the upper part of the section.

Beds of high calcium carbonate content appear frequently in the section. They vary from a calcareous shale to a shaly limestone and from a calcareous siltstone or sandstone to a nearly pure limestone. One locally persistent limestone was used for stratigraphic elevation checking in Ward and Amity townships. It is a cross-bedded, crystalline limestone containing many fossils of a variety of *Spirifer disjunctus*. Much of the calcium carbonate is in the form of calcite and the bed gives a sparkling reflection of light from crystal faces. The cross-bedding is quite unusual for a bed of this composition in the Wellsville quadrangle and was interpreted as due to variable currents in a rather shallow sea. It is five feet thick and its stratigraphic position is 40 feet above the Cuba formation. It can be seen at station 735, one mile N. 60° E. of Irish Settlement in Ward township, on the southwest bank of a creek at an elevation of 1965 feet. Another and better exposure can be seen at station 512, 3.2 miles S. 85° W. from station 735, at an elevation of 1908 feet. This same stratum is well developed in the Canaseraga quadrangle and can be seen in the northeastern part of the Belmont quadrangle.

Some of the other calcareous beds are of the typical "Chemung" kind, containing a brachiopod fauna (*Spirifer disjunctus* most abundant) and weathering into a honey-combed brownish mass of casts and molds in the exposed part.

Ripple marking and mud flows are a very common feature of the Wellsville beds and can be seen at many of the stations marked on the pocketed map. Their presence at many places in the section beneath the Cattaraugus makes them of little value as horizon markers for this area. Many odd shapes and forms were taken by the mud flows. These were frequently examined on the theory that they might be usable fossils, but because of their indeterminate character they were discarded.

A few of the beds in the Wellsville formation are marked by the great abundance of some particular species of fossil. One of these is called the *Schuchertella* zone because of the great numbers of this brachiopod in comparison with other fossils. The stratum containing them is a calcareous siltstone from one to two feet thick. It was first noticed and can be easily seen in a branch of Dry creek in Amity township, near the junction of Amity, Ward and Scio townships, at an elevation of 1763 feet. This bed is about 20 feet above the Cuba formation. A calcareous sandstone with an abundance of *Schuchertella* occurs a few tens of feet (unmeasured) above the Cuba, near station 760, one mile south of Alfred.

Another very fossiliferous bed contains what is here designated as the *Productella* zone because of the abundance of this brachiopod in a thin, hard, brownish gray sandstone. It is about 110 feet above the Cuba and can be seen in the section at station 560, north of and near Wellsville.

Figure 9 shows some of the fossils common to the Wellsville, with the ones marking the zones mentioned. (See Chadwick, 1935, for complete list of fossils.)

Hinsdale sandstone.[1] The Hinsdale sandstone of Chadwick (1933*a*, p. 203) which he correlates with the "Quarry" sandstone of Glenn (1903, p. 970) and Butts (1903, p. 990, 998) and the Lillibridge sandstone of Caster (1934, p. 63) is recognized with some

[1] On the geologic map the Hinsdale sandstone is mapped in part with the Wellsville and in part with the Whitesville.

Figure 9

WELLSVILLE AND HINSDALE FOSSILS

A *Camarotoechia contracta* (Hall). Station 667(4), about one mile southeast of Whitesville. Hinsdale.

B *Orbiculoidea* sp., from station 475, three miles north of Elm Valley. Wellsville

C *Crania* sp., from station 544, two and one-half miles north of Elm Valley. Wellsville.

D *Productella* cf. *lachrymosa* (Hall), station 544. Wellsville.

E *Leptodesma* cf. *potens* (Hall), station 544. Wellsville.

F *Leptodesma* sp., station 112(L), one mile east of Andover. Wellsville.

G *Productella* sp., station 667(4). Hinsdale.

H *Spirifer disjunctus* Sowerby, from station 112(L). Wellsville.

I *Schuchertella* cf. *chemungensis* (Conrad), from station 112(L). Wellsville.

J *Spirifer disjunctus* Sowerby, station 112(L). Wellsville.

K *Aviculopecten* cf. *alternatus* (Hall), from station 81(B), about one mile north of Whitesville. Wellsville.

L *Spirifer disjunctus* Sowerby, station 544. Wellsville.

M *Productella* sp., from station 560, northwest of Wellsville. Wellsville.

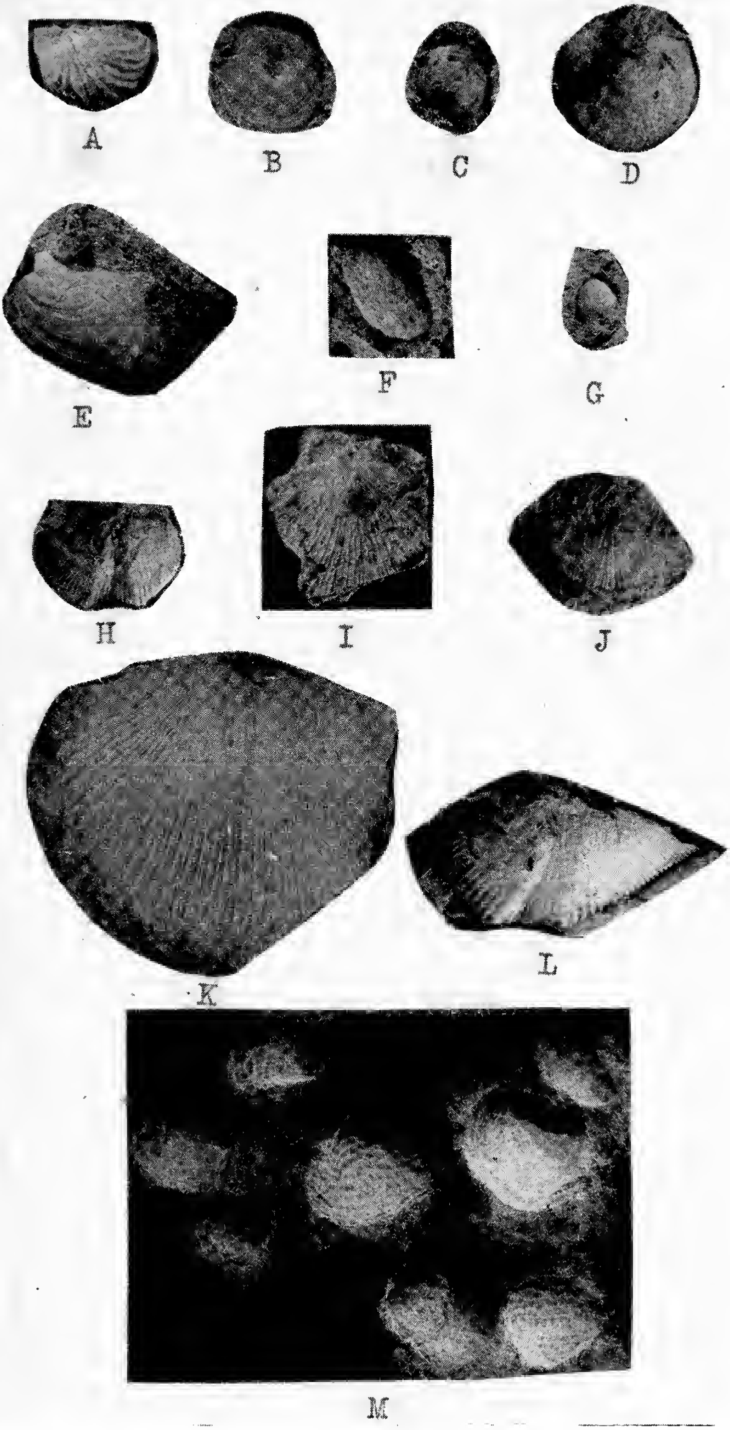


Figure 9 Wellsville and Hinsdale fossils

difficulty in the Wellsville quadrangle. Station 762, about two miles northeast of Wellsville, which was visited with Chadwick and later with Caster, is considered one of the best exposures of the Hinsdale in this quadrangle. The thickness of this bed is about 15 feet. Here it is a hard, fine-grained sandstone, gray to grayish brown near the base, becoming more of a chocolate near the top, with an increase in its iron oxide content. Near the top there are a few small quartz pebbles distributed at irregular intervals. Where it outcrops on the side of the road near-by it has a scaly surface. It may be seen at station 572, two and one-fourth miles N. 35° E. from Andover in a road cut at an elevation of 1955 feet and at station 718, on the state highway, one-eighth of a mile from the southern boundary of the quadrangle. The two last mentioned localities were the only Hinsdale outcrops at which sponges were found during the progress of this work.

A thin section made from a sample taken from the Hinsdale at station 762 shows it to be a fine-grained sandstone. The quartz grains are subangular and estimated to be 60 per cent of the material present. The next most abundant minerals are muscovite and biotite. The muscovite is in long strips, parallel to each other and to the bedding of the stratum. Clay, limonite and chlorite are common constituents and smaller quantities of plagioclase (oligoclase and albite), microcline, sericite, leucoxene, hematite, tourmaline, zircon and apatite are present. The slight difference between the Hinsdale and the Germania is discussed under Petrography on page 68.

Another good outcrop of the Hinsdale may be seen one-half mile west of Stannard school near road level, or at about 1633 feet elevation. A few fossils were collected from the Hinsdale and some are pictured in figure 10. (See Eller, 1935, and Chadwick, 1935.)

Whitesville formation. The Whitesville formation is the lower 300 feet of what has been called by Chadwick (1924, p. 154) the Chadakoin formation. The Chadakoin is correlated with that part of the section of Glenn (1903, p. 970–71) and Butts (1903, p. 990) which lies between the "Quarry" sandstone and the Cattaraugus formation. At least the lower part of the Whitesville can be correlated with the Dexterville, named by Caster (1934, p. 62–66).

The Chadakoin as represented in the Wellsville quadrangle is divided into two distinct mappable units. The Whitesville lies upon the Hinsdale and is overlain by about 70 feet of strata, the Germania formation which is described on page 47.

Figure 10

HINSDALE SPONGES

A *Prismodictya* cf. *conradi* (Hall), from station 572, two and one-half miles northeast of Andover.

B *Prismodictya* cf. *conradi* (Hall), from station 718, one and one-half miles S. 30° E. of Shongo.

C *Prismodictya* cf. *conradi* (Hall), from station 718.

D *Prismodictya* cf. *allegania* (Hall), from station 572.

E *Prismodictya* cf. *conradi* (Hall), from station 718.

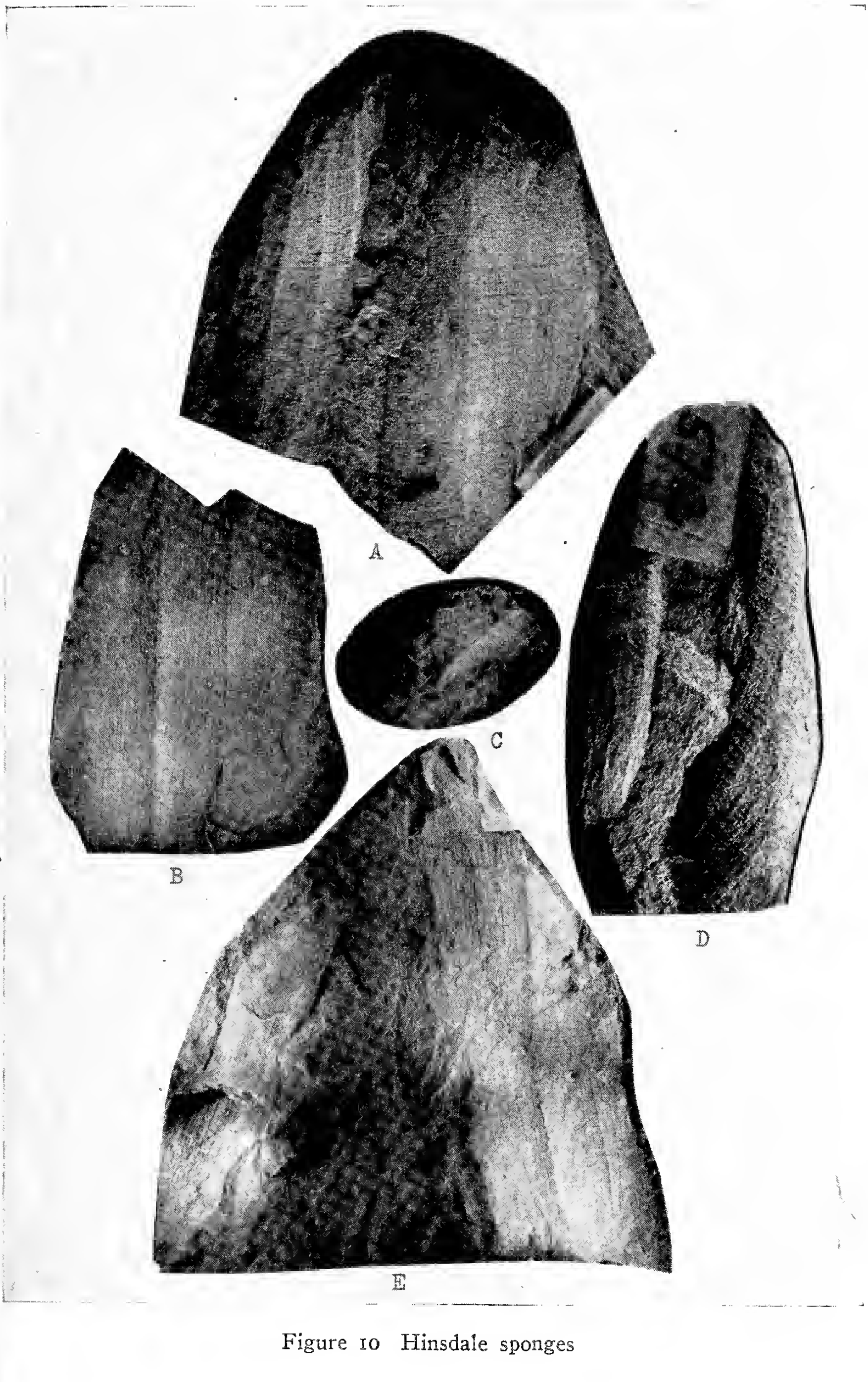


Figure 10 Hinsdale sponges

The name Whitesville is used because of the excellent exposure of these beds near the little village of Whitesville in the southeastern part of the Wellsville quadrangle. Outcrops of it can be seen on all of the tributaries which flow into Cryder creek from the north.

The Whitesville beds are of a twofold character: (1) those of marine deposition, and (2) those of the "Catskill" type of deposition. Because of the synchronous nature of beds (1) and (2), they must, although varying greatly in character and in sedimentation, be considered as a unit. Nearly horizontal beds with marine fossils are found near Whitesville, but the beds deposited at the same time, 10 to 15 miles north, are thinly laminated, cross-bedded green sandstones, bearing few or no marine fossils. Whereas there are abundant evidences of a restless sea with everchanging shore lines throughout all the Upper Devonian time, it was near that shore line that the changing conditions of sedimentation were most striking. The Wellsville quadrangle is an area where the evidence of such changes is present. The "Upper Devonian Delta" (Barrell, 1913, 1914) did not reach the Wellsville area until near the close of Chautauquan time or near the middle of the Whitesville formation. This invasion was not accomplished by the retreat of the sea to the westward on a smooth front but by a delta of very irregular front. The masses of sediments were shifted from one distributary to another, wiping out the marine life on first one front of the delta and then another. In a few instances the small marine forms would reinvade the area later to be forced westward to return no more.

Whereas there are frequent lateral gradations of beds of one type into beds of another in the Machias and Wellsville formations, such a relationship in the Whitesville beds of the Wellsville quadrangle becomes so common that it is more nearly a rule than an exception. In the lower part, in all localities, and throughout the full thickness of the Whitesville, in the Elm Valley locality, the beds are unquestionably marine. For the most part they consist of fine and medium-grained sandstones and shales. The predominating color is gray; dull red or chocolate-brown occurs in many of the beds; olive-green is not uncommon. The red color is generally found in shaly sandstones. The shales are in general much more arenaceous than those of succeeding formations in the area.

While most of the section of Whitesville beds is marine, with almost horizontal and parallel bedding planes showing good stratification and a few marine fossils, there is evidence of a neighboring and encroaching shore line. The upper 100 feet of beds frequently carry as many as five conglomeratic layers of sandstone and true conglomerates, varying from very thin beds up to those nearly two feet thick. The pebbles in the conglomerate beds are of quartz and jasper, similar to the thick flat pebbles so characteristic of the Wolf Creek and other sub-Olean conglomerates. They seldom exceed an inch in their greatest dimension and generally are less than one-half inch. Some of the beds are composed almost entirely of fragments the size and shape of a grain of wheat. The conglomerates are dull green, brown or gray in color, varying with the locality. Fish plates of gunmetal blue color and fragments of bluish white fish spines are abundant in the conglomerate beds. One spine from two miles southeast of Hallsport, near the top of the Whitesville, was tentatively identified by Doctor Caster as *Ctenacanthus*. Some specimens of *Camarotoechia* sp. and fragments of other marine invertebrates were found but were considered indeterminable.

A few calcareous siltstones which carry a *Spirifer disjunctus* fauna are present in the lower half of these beds; but they are found at less frequent intervals than in older formations. One such bed, four or five feet thick, was found north of Honeoye creek. It is probably of local development.

The lower beds of the Whitesville, with the exception of some chocolate-colored beds containing many pelecypods, contain distinctly brachiopod faunas. Those in the upper part of the Whitesville and in younger beds are distinctly pelecypod faunas, of the supposedly marine types. One brachiopod, (*Camarotoechia*) lived on persistently, however, in this area. Fossils are much less abundant in the "upper" beds. Does this change of fauna represent a shallow water environment? Does it mean that fresh waters were the medium of deposition? The waters, whatever their nature, were teeming with small fish. The increase of iron compounds in solution does not seem to be a cause for this change, for many of the red beds contain faunas (Caster, 1934, p. 70–75).

Some of the Whitesville strata are shown in figure 11 and some of the fossils common to it are shown in figure 12. (See Chadwick, 1935.)

"Catskill" type of sedimentation. A brief discussion of what is meant by "Catskill" type of sedimentation will perhaps help the reader to grasp more easily the subsequent description.

The practice of using a geographic name to represent a type (Caster, 1934, p. 19–36) of sedimentation may not be desirable, but the name "Catskill" is so firmly entrenched in the literature of North American geology that it is apt to have a continued use or misuse.

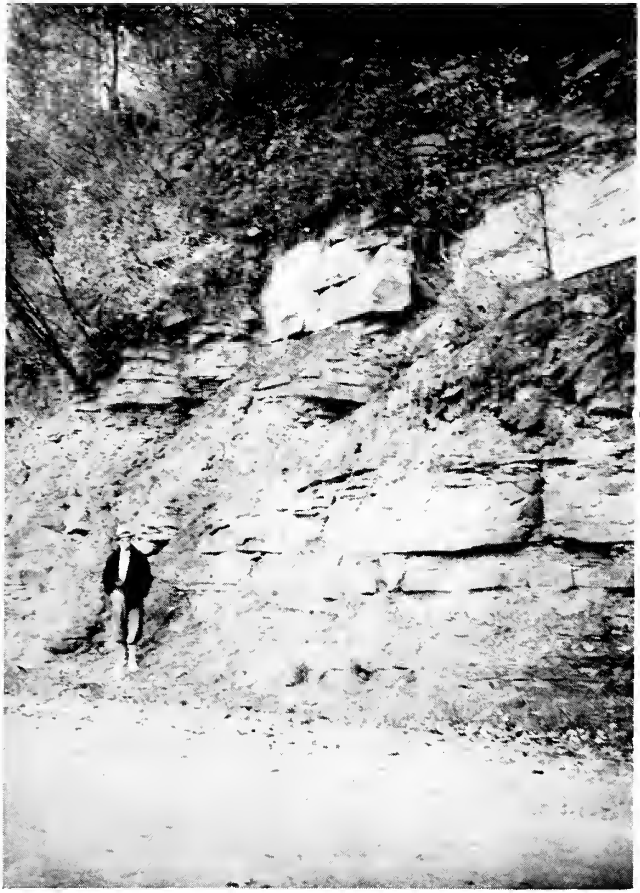


Figure 11 Lower Whitesville rock section

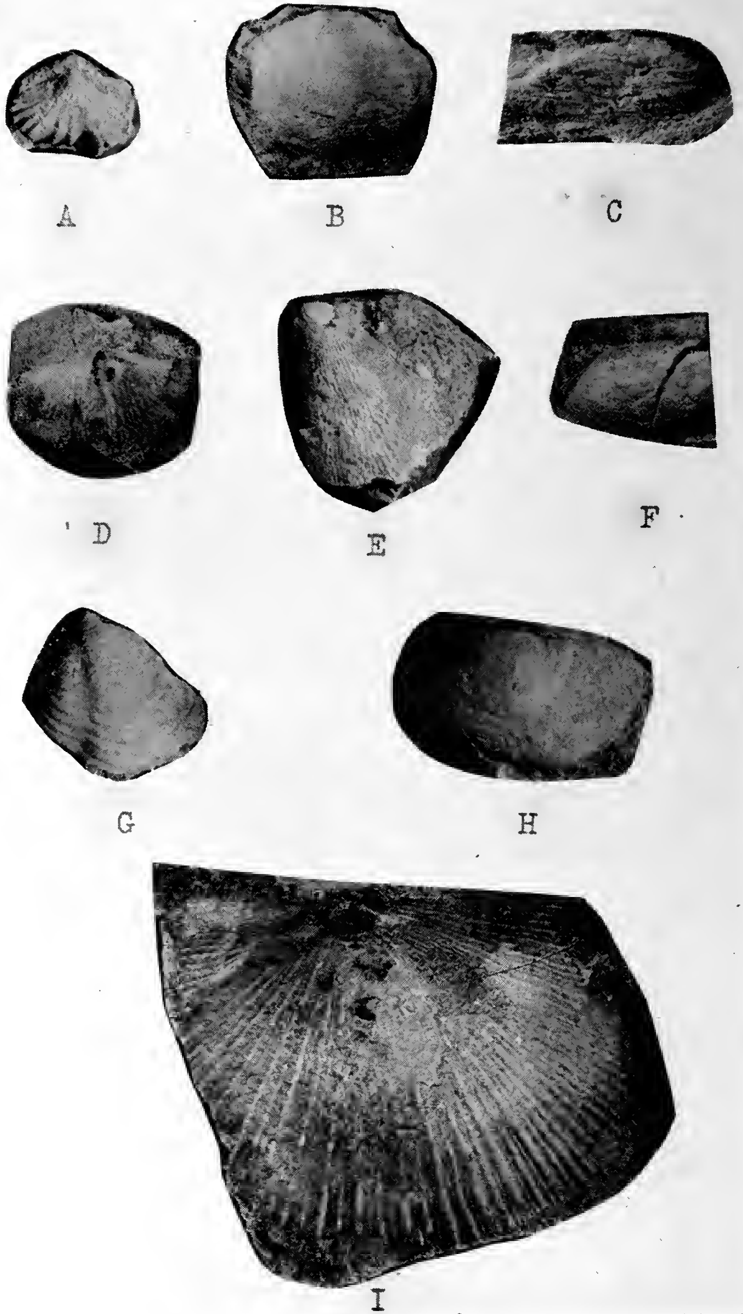


Figure 12 Whitesville and Germania fossils

Figure 12

WHITESVILLE AND GERMANIA FOSSILS

A *Camarotoechia* cf. *duplicata* (Hall), from station 577, one and one-half miles northeast of Round Top. Germania.

B *Paracyclas* sp., from station 551B, one and one-half miles northwest of Andover. Whitesville.

C *Sphenotus* sp., from station 551A, one and one-half miles northwest of Andover. Whitesville.

D *Spirifer disjunctus*, brachial view, from station 551B.

E *Oleanella* cf. *expansa* (Hall), from station 577. Germania.

F *Sphenotus* sp., from station 551B. Whitesville.

G *Grammysia* cf. *elliptica* (Hall), from station 577. Germania.

H *Leptodesma* sp., from station 577. Germania.

I *Pterinopecten* sp., from station 551B. Whitesville.

What is the "Catskill" type of sedimentation? To some it means a series of red shales and red and green sandstones and conglomerates, nearly or quite barren of animal remains except those of fish, and with an abundant flora, difficult to correlate with the flora of regions other than the Appalachian geosynclinal area. The red shales are quite similar in appearance to the Vernon beds of New York State. Some of the sandstones and conglomerates are not so unusual. The beds which typify "Catskill," as here used, are the thinly laminated, cross-bedded sandstones so well described by I. C. White (1881, p. 60). He writes:

The sandstone beds vary in thickness from 2 feet to 10 feet and are characteristically false or current-bedded. The lamination, as exhibited in the cliffs, is very curious. Each of the horizontal beds is crossed obliquely by lines an inch or two apart, weathered into furrows. The slope of the furrows in one bed will be in one direction; that of the beds above and below in the opposite direction. The ends of the furrows meet along the horizontal lines of stratification at an acute angle. Consequently, when a considerable number of these sandstone beds, lying upon one another, are exposed to view, the whole face of the cliff is sculptured in zigzags from top to bottom.

This false bedding sometimes shows regularly straight and parallel lines; at other times the lining is curved and the laminae overlap each other at the bottom; but at the top they are cut off square.

Barrell (1913, p. 443), in describing the same type of beds, states:

The sandstones give rise to ledges, the weathered surfaces revealing oblique bedding of most of the strata and the whole etching into outcrops which have been likened to piles of boards.

In the Wellsville area the "Catskill" type of sandstone is to a large measure the reason for the high hills retaining their elevation. Some of the hills capped by these beds have a nearly flat top, with the surface of the ground taking the slope of the underlying rock strata and with escarpments of from five to 15 feet bounding them a few feet below the crests. On long exposure these escarpments assume the appearance of a wall of loosely piled thin boards. The color of the weathered surface ranges from a reddish brown to a brownish gray, but the freshly broken surfaces, where protected from weathering, show a greenish gray or an olive-green color. They are always underlain by shale which offers little resistance to erosion. Consequently the sandstone is soon undermined and breaks off in large blocks. These blocks are several feet in dimensions and for the most part remain near the outcrop in a jumbled mass. In time they become nearly covered by the soil and, except for their odd positions, might be thought to be in place. Such outcrops are frequently to be seen where the secondary roads ascend to the tops of some of the higher hills. They are of little use in interpreting structure and stratigraphy in the Wellsville quadrangle for they range from well down in the Whitesville to well up in the Cattaraugus and show no recognizable fauna. No red shales were seen near the beds of this type in the Whitesville, but they are found above in the Germania and in the Cattaraugus.

This sandstone is a thinly laminated, cross-bedded, micaceous sandstone. The laminae are fractions of an inch in thickness, being generally about one-half inch. The cross-bedding is usually at angles less than five degrees, occasionally at greater angles. The surfaces of the laminae show an abundance of mica flakes (largely muscovite) which may suggest the reason for the outcrops assuming so frequently the appearance of a "pile of loose boards." The size-grade of the particles is usually fine-grained.

One phenomenon which may be of value in picturing the environment during the deposition of the "Catskill" beds of the Whitesville formation is the occurrence of conglomeratic beds, a fraction of an inch or a few inches thick, which lie unconformably upon them. In the conglomeratic beds were found many fish scales and plates and occasionally a *Camarotoechia.* The discontinuous nature of the outcrops and the patchiness of their distribution in the area did not offer opportunity for exact correlation of the "Catskill" beds with the coeval, unquestionably marine beds of the Whitesville formation. The writer suggests an irregular, flat, advancing, wave-swept delta as part of the environment during the formation of these beds. The spasmodic westward advance of the "Great Catskill Delta" does not complete the picture to his satisfaction. There must have been a northern shore line which played its part in the unusual distribution of the beds found here. Further evidence must be sought.

"Catskill" type of sedimentation may be seen in the Whitesville formation on all of the highest hills in the northern part of the Wellsville quadrangle and in many places at lower elevations in the southern part. A small hill just one-half mile S. 20° E. from Stannard Corners, in a synclinal area, shows the extension of the "Catskill" type of sedimentation well down into the Whitesville. The long ridges between Marsh creek and Railroad brook northeast of Andover also show beds of this type well down in the Whitesville.

Germania formation. The name Germania is offered as appropriate for the beds of a very distinctive character, which can be traced over most of the Wellsville quadrangle and make this formation a usable key horizon for structure in the southern two-thirds of the area. They represent the "Upper" Chadakoin beds but are distinct from Chadakoin beds previously described.

It is named for the little town of Germania, Abbott township, Potter county, Pennsylvania, because at a point one-half mile south of this town it was freshly exposed by the removal of the soil and mantle rock by a thunder shower in 1929 or 1930. Over a hundred feet of a vertical section were laid bare at that time. This section with a brief description of the beds is given in figure 13 (copied from old field notes by the courtesy of the New York State Natural Gas Corporation). First seen by the writer while employed as a geologist for the Lycoming Natural Gas Corporation (now the New York State Natural Gas Corporation) in the summer of 1931, it was found to be of help in mapping the structural geology of Potter county.

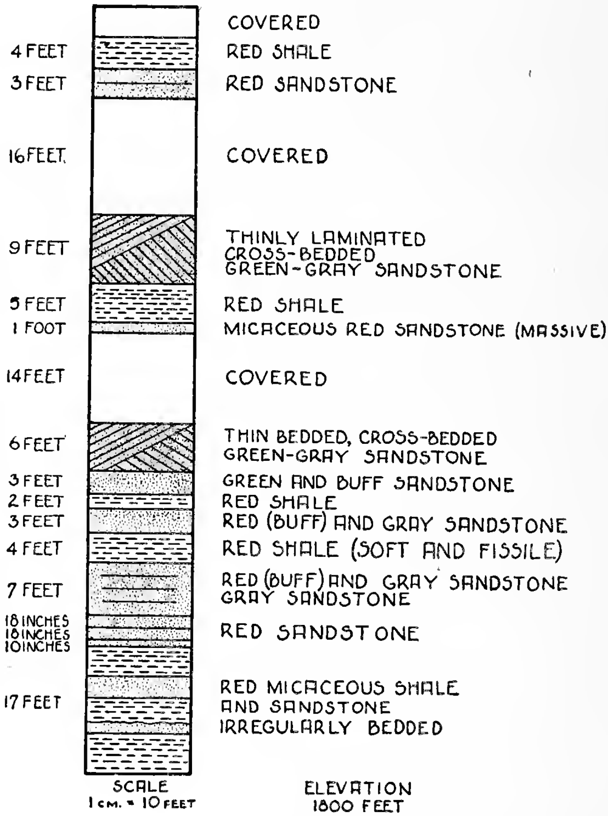


Figure 13 Section of Germania

It is equivalent to the upper 70 feet of the Chadakoin or the 70 feet of beds immediately underlying the lowest conglomerate bed of the Cattaraugus in the Wellsville area. The Germania formation consists of thin green sandstones interbedded with red shales, with the "Catskill" cross-bedded sandstone and conglomerate beds at different horizons, varying with the locality. Usually the base of the formation was easily recognized by the red color of the soil marking the earliest appearance of the "real" reds of the "Catskill." The complete section does not appear at any one locality on the Wellsville quadrangle, but on Dyke creek near Elm Valley only a small part of the upper beds was covered.

The sandstone members, which at most of the outcrops are from eight to 12 inches thick, but which may vary slightly above and below these limits, are interbedded with a few feet (five to 15) of bright red shales. The shales break down rapidly and are seen only where running water has recently cut into the beds. The unweathered shale is slightly darker than when weathered. The sandstones are fine to medium grained and when freshly broken have a green color. They are massive in structure and the top and bottom generally show irregular surfaces. At many places the sandstones show vertical worm borings which pass through the entire stratum. Some of these borings have a red color, indicating that the borings were probably made before diagenesis had occurred. One of the sandstone layers of the Germania is shown in figure 14.

The most striking feature of the sandstone layers is their green and buff appearance after being exposed to weathering. The rock breaks from the outcrop in angular blocks, from a few inches to a foot or two in dimensions, and the drift of this nature was noticed and remarked upon long before it was seen in outcrop. From a macroscopic examination it was called a glauconitic green and buff sandstone but several thin sections of these sandstones were made and glauconite was not found in any of them.

Microscopic examination of the thin section showed the sandstone to be fine-grained with an estimated composition of 70 to 75 per cent of subangular quartz. The green color is due to the abundance of chlorite and sericite present as interstitial with the quartz and other mineral grains. The buff or red color is due to the stain given the sandstone by the overlying and underlying red shales.

Unfortunately, the 70 feet of the Germania apparently does not contain a fauna which is distinguishable from the Whitesville fauna below or from the Cattaraugus (Conewangan) fauna above, except by the absence of characteristic forms. The thin conglomerate beds occurring in and near the base of the Germania in places carry a rather abundant pelecypod fauna which is more suggestive of the Conewangan than of the Chautauqua fauna (personal communication from Dr K. E. Caster). The conglomerate beds where present are not unlike those described for the Whitesville, both faunally and lithologically, but they are in some places not unlike the Cattaraugus conglomerates in lithology. These beds might have been placed as transitional beds, for they are transitional in character. However, the sandstones are distinctive. Locally, at least, their character justifies their being designated by a name.

The base of the Germania formation is 1980 feet (barometer) in elevation at its type outcrop on the south flank of the Marshfield anticline of Potter county, Pennsylvania. It is at an elevation of 2115 feet (barometer) near Hector, Pa., on the north flank of the Sabinsville anticline, and at an elevation of 2225 feet (barometer) two miles east of North Bingham, Pa., on the north flank of the Harrison anticline. In the Wellsville quadrangle its elevation ranges from about 1900 feet in the syncline to about 2300 feet where the Smethport (Watkins) anticline leaves the quadrangle on the eastern border. Its lower beds are present on most of the highest hills bordering the Dyke Creek valley on the north.

Conewangan Series

From his rather complete and extensive stratigraphic work, and from his review of the preceding works and the correlations, Caster (1934) reached the conclusion that the beds extending from the base of the Cattaraugus (Venango) to the Knapp beds should be considered as constituting the Conewangan series of rock. In northwestern Pennsylvania, the upper boundary occurs within the Riceville shales (Caster, 1934, p. 94). In the Olean, N. Y., region, the series includes the Cattaraugus and Oswayo. Glenn (1903, p. 985–86) places the Cattaraugus beds provisionally in the Devonian and considers that the Oswayo and Knapp beds belong to the Carboniferous (Mississippian). Butts (1903, p. 993–94) classifies the Cattaraugus formation as Devono-Carboniferous and the Oswayo as Subcarboniferous (Mississippian). Fuller (1903), in mapping the Gaines quadrangle, Pennsylvania, which touches the Wellsville quadrangle on the southeast corner, classifies the Cattaraugus and Oswayo as Devono-Carboniferous formations. His columnar section shows the Cattaraugus and the lower part of the Oswayo as of Devonian age, and he questions how far down into the Oswayo the

Figure 14 Typical sandstone member of Germania

Mississippian extends. Fuller's arrangement agrees in general with Glenn and Butts. The geologic map of the Olean quadrangle, published by the New York State Museum, places the base of the Paleo-Carboniferous (Mississippian) at the base of the Cattaraugus (Wolf Creek conglomerate). The printing of this map was supervised by Clarke (1903, p. 996–99) and he gives the reasons for this change from Glenn's ideas of the time relationship.

The Wolf Creek (Panama?) conglomerate at the base of the Cattaraugus marks the appearance of many new forms of life and the disappearance of many of the Devonian forms. The conglomerates indicate a renewed source of material, perhaps caused by diastrophic movements better recorded in other localities than in the Appalachian geosyncline, with a distinctive change in sedimentary conditions. Should this be the base of the Mississippian? There are many instances of Devonian forms carrying over or recurring in beds of Mississippian age (Williams, 1895, p. 94–101). This may be one.

Cattaraugus formation. The Cattaraugus beds in the Wellsville area are very poorly exposed, with no outcrop showing more than 10 feet of rock. A thickness of 440 feet was computed from the first definitely red-colored shale, 150 feet below the Olean conglomerate, to the base of the lowest definitely red shale near the Alma Hill section. The thickness of the Germania formation (70 feet ±) was subtracted from the total thickness of red shale beds leaving a thickness of 370 feet ± for the Cattaraugus.

There are three outstanding types of rock included in the Cattaraugus beds: (1) the flat pebble conglomerates of Upper Devonian age, which have received a great deal of attention in southwestern New York, northwestern Pennsylvania and elsewhere in the Appalachian region, the many correlations (Pennsylvania Survey Reports) of which are rather confusing; (2) the cross-bedded, thinly laminated green sandstones which have been described in the discussion of the Whitesville formation; (3) the red shale, also previously described, which gives the distinctive red color to the soils in a large part of the southern half of the Wellsville quadrangle. The description of these beds could be given briefly by saying that they represent the "Catskill" type of sedimentation.

The marine fauna of the Cattaraugus in the Wellsville quadrangle is conspicuous by the small number of species to be found. Only a few forms of the life that existed at the time of their deposition were found and these were limited to the conglomerate beds. Fortunately, to support the contention of the writer as to the Cattaraugus age of the beds, the fauna has a decidedly Venango stamp, and it is with some assurance that they are mapped as such.

The conglomerates which it had been hoped could be definitely correlated with those of other sections must be described as merely members of the Cattaraugus formation, with names tentatively used. From their stratigraphic position, considering them on the basis of extensive continuity of strata, if this can be depended upon, they may well be called the Wolf Creek (Panama?) and the Salamanca, since the interval between them was 175 feet ±, about the same as that found in the Olean quadrangle. J. P. Lesley (1892, p. 1524), in writing of the relationship of the upper "Chemung" beds encroached upon by "Catskill" sedimentation remarks:

. . . there is no such thing as a valid generalized section; there are nothing true but local sections, single individual specimen sections.

This gives one some idea of the nature of the Upper Devonian beds but the viewpoint has perhaps been carried to extremes. The generalized sections can be and are used, but their interpretation must be made with insight into their true nature. Since the thicknesses of the beds of the Wellsville quadrangle were found to be quite similar to those of the Olean for the same strata, with local differences as great as the regional one, the theory of continuity of strata can be used at least to the extent of correlation. Because of lack of interpretable faunas in some of the upper beds, the correlations are difficult.

Wolf Creek conglomerate member. The conglomerate which is the lowest bed carrying a Conewangan fauna has been tentatively called the Wolf Creek. See figure 15. This is the terminology of Williams (1887) and Glenn (1903). There are red beds occurring about 70 feet below this conglomerate horizon in the Wellsville quadrangle. Although none of the typical "Catskill" red shales occur below the Wolf Creek in the Olean area, this is the normal course of succession as we go eastward until we reach the Catskill mountain front, facing the Hudson River valley, where the "Catskill" red beds are found well down in the Hamilton (Cooper, 1933, p. 200–1). Willard (1933, p. 495–516 and 1934, p. 897–908) has helped to clear up the relationship of "Catskill" deposition in the Upper Devonian of Pennsylvania. The concept of an advancing delta is due to the works of many men.

While geologists in general accept the correlation of the Wolf Creek (Williams, 1887) with the Panama (Carll, 1873) (see figure 16) and the Le Boeuf (I. C. White, 1897), and while it is so listed in

Figure 15 Type outcrop of Wolf Creek conglomerate

Figure 16 Type outcrop of Panama conglomerate

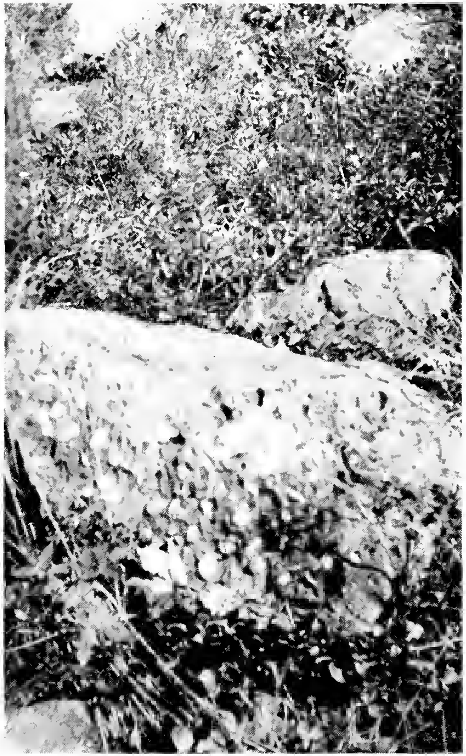


Figure 17 A close-up of Wolf Creek conglomerate

Figure 18 Blocks of Wolf Creek near outcrop

Guidebook 4, XVI International Geological Congress (1933), the writer wishes tentatively to correlate the lowest conglomerate in the Wellsville area with the Wolf Creek and let correlations that may be made between the Wolf Creek and other flat pebble conglomerates remain as a problem outside the province of this paper.

It is reasonably established in the present work that the lowest conglomerate represents the Wolf Creek. It was traced across the Belmont quadrangle on two or three separate occasions. The last time, with Doctor Caster, particular attention was given to the fauna of the beds. The Wolf Creek was not found as a well-developed conglomerate but as a conglomeratic sandstone carrying a Conewangan fauna.

On the Wellsville quadrangle conditions were favorable for the development of the conglomerate phase of the Wolf Creek. This conglomerate has a maximum thickness of about five feet but is frequently seen with a thickness of three or four feet. The freshly broken blocks are white but many of the long-exposed blocks have red stains of varying shades from iron oxide, pink being the most common. The flatness of the pebbles is the most striking feature of this conglomerate; this is true of all those conglomeratic beds found below the Olean conglomerate, at least as low as the Rushford sandstone in southwestern New York. This flat pebble character was first described in detail by Carll (1881, chapter 6). Most of the pebbles are quartz, of the colorless and pink varieties; a few are of jasper, and the surfaces of some are coated with an iron oxide stain. They have a flat discoidal shape, the periphery having a thickness nearly as great as the central portion, and they are generally less than one-half inch in their greatest dimension. Many measured more than an inch across and one taken from the outcrop northwest of Andover measured nearly two inches. Their flat sides are almost invariably parallel with the bedding of the strata, and they are arranged in greatest abundance along horizontal planes. See figure 17.

The matrix is sand, granule and small pebble size, largely quartz. A thin section (see table page 69) showed the minerals clay, biotite, leucoxene, hematite and ilmenite, with a larger amount of sericite and rock fragments of quartzite and schist. The angular and subangular fragments of rock indicate an interval of short duration between the derivation and deposition of the sediments, but the rounded corners and edges of some of the material suggest a long period of transportation. Many of the smaller fragments of quartz have preserved a portion of their original crystal faces or are authigenic.

Figure 19

CATTARAUGUS AND OSWAYO FOSSILS

A *Mytilops* cf. *praecedens* (Hall), left valve. From type outcrop of Wolf Creek conglomerate. Cattaraugus.

B *Mytilops* sp., left valve. From station 768, three miles north of Ceres, New York.

C *Ptychopteria* sp., left valve. From three miles east of Andover. Cattaraugus. An index fossil.

D *Mytilops* (?) sp. in Cattaraugus sandstone. Station 769. Two miles southwest of Sawyer.

E *Straparollus* (?) sp.; internal molds. From one mile northeast of Little Genesee "Rock City." Salamanca (?) conglomerate.

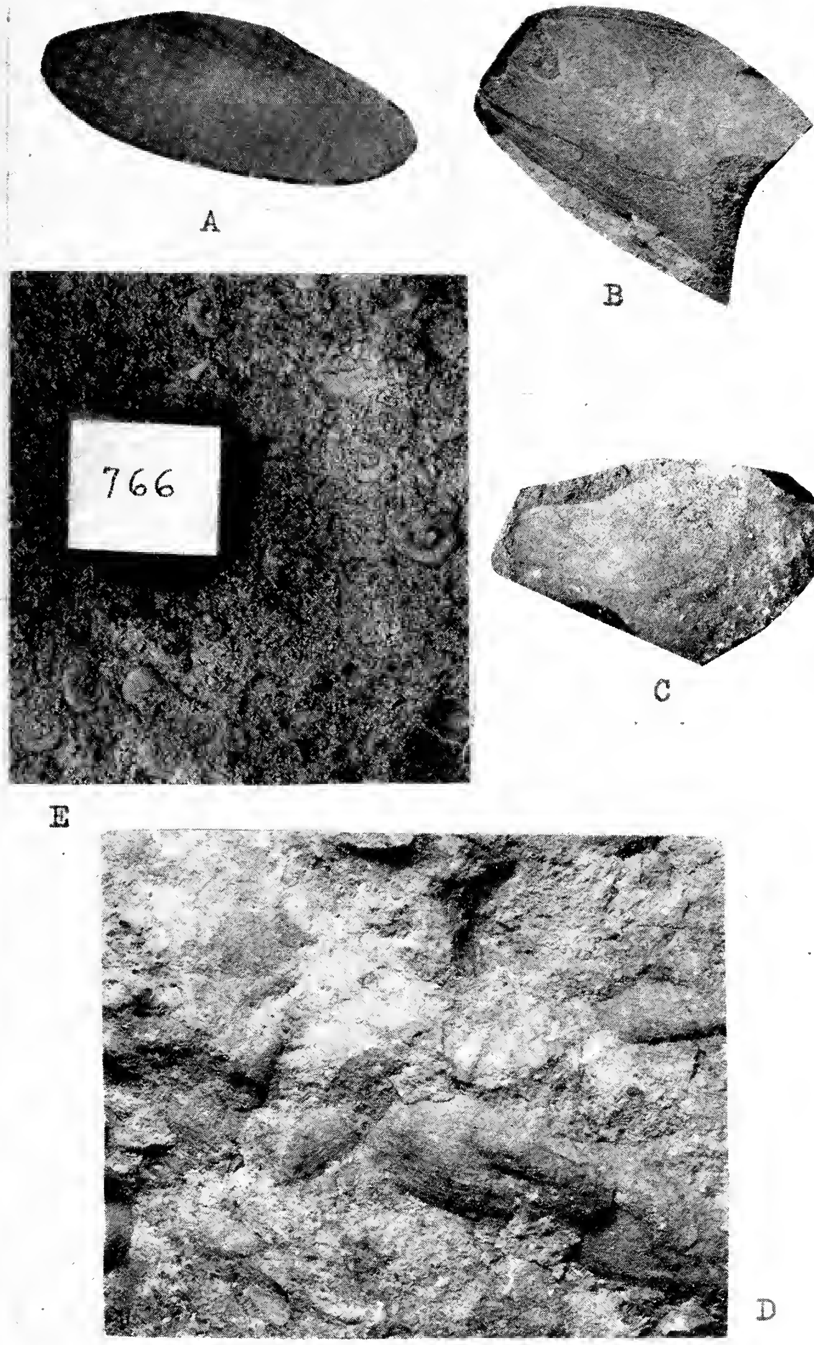


Figure 19 Cattaraugus and Oswayo fossils

Figure 19A Cattaraugus and Oswayo fossils

Figure 19A

CATTARAUGUS AND OSWAYO FOSSILS

A *Camarotoechia allegania* (Williams). From near Little Genesee "Rock City." Index fossil of Oswayo.

B *Camarotoechia allegania* (Williams). Idem.

C *Barinophyton citrulliforme* Arnold, x ¾. From quarry near Olean "Rock City." Cattaraugus.

At no place in the Wellsville quadrangle were the beds immediately underlying the Wolf Creek conglomerate seen in place, weathering having concealed these less resistant materials long ago. The Wolf Creek may be seen at places where there can be no disagreement about it resting at the site of its outcrop. It may be seen crowning the hill two miles N. 55° W. of Andover, at an elevation of 2240 feet above mean sea level. See figure 18. It also occurs three and one-fourth miles east of Andover, a little less than one mile from the eastern border of the Wellsville quadrangle, one mile west of West Greenwood, on the north side of the road at an elevation of 2250 feet. The former locality is on the northwest side of a syncline and the latter on the southeast side of the same structure. It may also be seen on the side of a hill one mile S. 60° W. from School 2 at Stannard in Willing township and blocks of it may be seen at many places in the synclinal area between Dyke creek on the north and Chenunda creek on the south. They are usually two or three feet thick, and always less than 10, generally less than five feet in their other dimensions and have irregular surfaces.

Hall (1840, p. 389–456) saw this conglomerate nearly 100 years ago. There are a few large blocks of it along the state highway, about one mile south of Stannard Corners. Lesley (1892, p. 1477, footnote) states:

(Mr. Sherwood notes that he has seen such a conglomerate *in place* on the Genesee river between the N. Y. state line and Wellsville, N. Y., and therefore Chemung, G_3, 52.)

Quoting reference G_3 52.

Mr Sherwood reports that he has seen the same kind of rock on the Genesee river, between the State line and Wellsville (in the State of New York), and exactly on the prolongation of this same Sharon anticlinal.

An *inference* was made by Lesley that the rocks were *in place*. Hall describes the blocks of conglomerate he saw, and they are believed to be the same as those seen by Sherwood, now plainly visible in the locality previously mentioned. The lower Cattaraugus conglomerate may be seen on the north side of the Honeoye-Marsh Creek divide at an elevation between 1900 and 2000 feet. In a ravine south of Whitesville the numerous blocks of the Wolf Creek were traced upstream in the hope of finding an outcrop in place. The blocks ceased at an elevation of 1950 feet, and here the formation boundary line was drawn. Such a procedure was followed in a few localities where no definitely recognizable key beds were to be found but where detrital material could be used as a clue.

The fossils of the Wolf Creek in this area were limited to a few marine pelecypods (including *Ptychopteria* sp.), numerous fish plates and spines and plant remains. Some of these are shown in figures 19 and 19a. (See Butts, 1903, Chadwick, 1935, and Williams, 1887 and 1895, for list of Wolf Creek and Oswayo fossils.)

Salamanca conglomerate member. Whereas the Wolf Creek conglomerate was seen in only a few places where it was thought to be an outcrop, the Salamanca in the region was even less frequently seen. It can be seen at an elevation of about 2280 feet, near the base of the conical-shaped hill known as Round Top, in the southwestern part of Andover township. Residual blocks of it may also be seen on the tops of the highest hills to the west and southwest in a previously mentioned synclinal area. Although it undoubtedly covers the large area of high land in southwestern Wellsville township and in eastern Alma township, it was not seen there but is probably present as an unfossiliferous sandstone. The same condition probably holds true for the synclinal area south of Whitesville, for the tops of these hills are not far below the Olean horizon, which is, in turn, only 350 feet ± above the Salamanca. The character of the Salamanca is so like that of the Wolf Creek that, in the absence of any evidence from fossils, it must be distinguished by the stratigraphic position.

Oswayo formation (or monothem). The topmost red bed is taken to represent the top of the Cattaraugus, and the 150 feet± of beds in the interval between it and the base of the Olean conglomerate is tentatively called Oswayo. The base of this bed is 200 feet ± above the Salamanca conglomerate. This thickness was measured on the east side of Alma hill, one-half mile west of the Wellsville quadrangle in the Belmont quadrangle. Two and one-half miles west of this place, on the east side of White hill, the interval estimated was 100 feet± between the topmost red beds and the base of the Olean conglomerate. The Oswayo formation in the Olean quadrangle was considered to be from 160 to 250 feet thick, with an average thickness, according to Glenn (1903, p. 978), nearer the latter figure. Figure 20 is a picture of the contact between the Cattaraugus and Oswayo formations south of the Olean quadrangle.

At Little Genesee "Rock City," about two and one-half miles northwest of the town of Little Genesee, at an elevation of about 2330 feet, there are blocks of Olean conglomerate tens of feet in dimensions. This was called the "rock city" by Williams (1887) during his reconnaissance survey of this region. Blocks of rock containing the best index fossils of the Oswayo formation were found some 100 feet below the Olean. This fossil, *Camarotoechia allegania,* is described by Williams (1887).

The conditions of sedimentation during Oswayo time were so different to the east that in the Wellsville quadrangle no distinctive fossils were found and the only ones recorded were a *Camarotoechia* sp. and a pelecypod (unidentified). Glenn (1903, p. 979) describes an impure limestone which he says is so filled with badly broken marine shells that "it might almost be termed a shell conglomerate." This apparently is the equivalent of the Roystone Coquinite zone described by Caster (1934, p. 97), seen in company with him near Olean "Rock City," south of Olean. While beds carrying marine fossils in abundance are to be found to the west of the Wellsville quadrangle, the fossiliferous beds do not appear here and beds of the same age here are nearly barren.

The Oswayo in the Wellsville quadrangle appears as drift on the highest hills in the southeast and southwest sections of the area. It is made up of yellowish brown soil and light gray and yellowish brown blocks of sandstone. Most of the blocks are from an inch to four inches thick, with generally a flat mica-covered surface and irregular edges. The sands composing them are usually of medium grain size-grade. Plant impressions are the most abundant fossils but are not always present.

In placing these beds in the Oswayo the writer is not unmindful that it is contended that rocks of similar lithology can be seen in much older beds to the east and represent what has been described as the "Pocono" (Chadwick, 1932, p. 273) landward facies which seems to have followed the "Catskill" phase of deposition westward or northwestward across the Appalachian region. Likewise, it can easily be seen that the regional dip of the beds to the west of south, even though less than one-half degree, must cause the planes of those beds which are found on the surface in southwestern New York to be above the tops of the highest hills as we go eastward a few tens of miles. It must also be kept in mind that their disappearance is delayed by the deeper synclines which are encountered in going east and southeast. The factor of the thickening of the beds must also be kept in mind. The 4000 feet or more of beds on the Catskill front represent only the lower part of the 2000 feet of Upper and Middle Devonian beds on Lake Erie, and some 9000 feet of beds to the southeast near Harrisburg, Pa. According to Dr Willard of the Pennsylvania Survey, the thickness of the red Catskill should be only 4500 to 5000 feet near Harris-

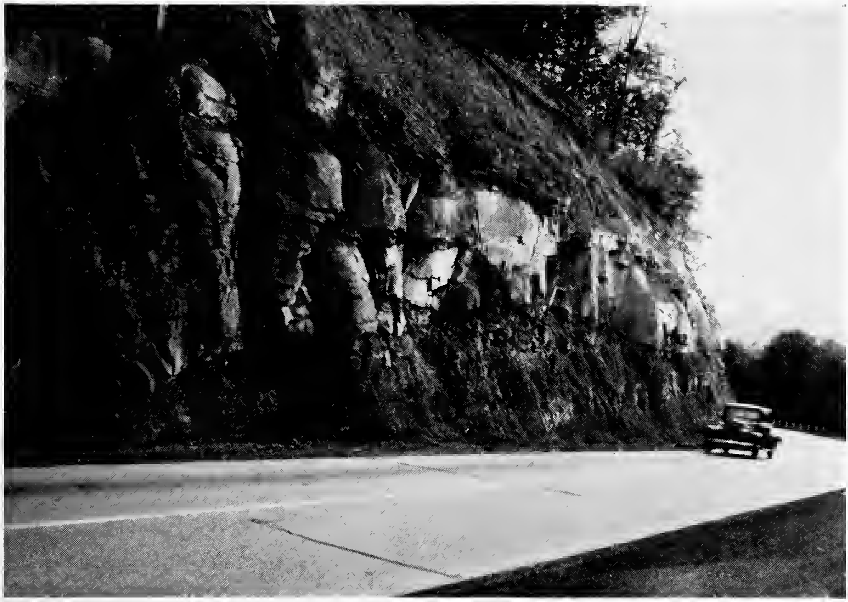


Figure 20 Unconformable Cattaraugus-Oswayo contact

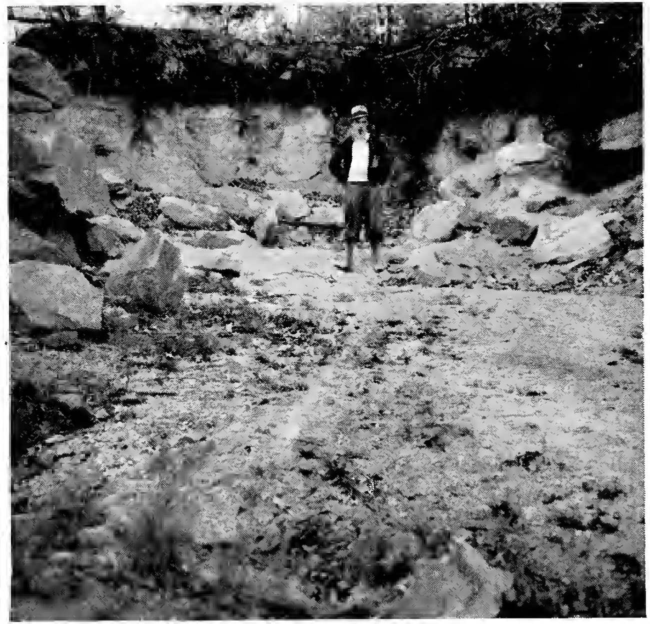


Figure 21 Olean conglomerate on Alma hill

Figure 22 Block of Olean conglomerate, Little Genesee "Rock City"

burg, Pa. This thickening is not constant, but rather variable, being greatest in the eastern part of the geosyncline near the source of most of the sediments and diminishing as the distance from the shore line to the source of material increases. To the west of the Wellsville quadrangle there is a thickness of definitely marine Oswayo in excess of 100 feet, and mapped as about 160 feet, which leads the writer to consider the beds of "Pocono" facies occurring in this quadrangle as at least in large part Oswayo. Lacking the presence of a definitely identifiable fauna in the Wellsville area, only an arbitrary boundary line can be drawn between the Cattaraugus and the Oswayo.

MISSISSIPPIAN

No definite proof was found in the Wellsville quadrangle to indicate that any rocks of Mississippian age have been preserved there. It is quite possible that a part or all of the beds called Oswayo may be of Mississippian age. Evidence advanced by Caster (1934) in his work with marine beds which are believed to be of the same age as the Oswayo beds of the Wellsville quadrangle leads the writer to believe that little or none of the rocks in the Wellsville quadrangle are of Mississippian age. The only fossil animals found had a close relationship to the Devonian forms of the same genera. It is possible that Mississippian sediments were deposited here but have since been so completely removed as to leave no evidence. If such was the case, they were very thin as the Olean conglomerate is only a few feet above the beds present. Many hours were unsuccessfully spent in searching for fossils in the beds immediately underlying the Olean conglomerate, in the area just west of the Wellsville quadrangle. The Mississippian beds were never present or have long been removed by erosion preceding the deposition of the beds of Pennsylvanian age.

PENNSYLVANIAN

Olean conglomerate. The Olean conglomerate, which is Pottsville in age, does not occur in this quadrangle but occurs just one-half mile to the west at an elevation of 2500 feet and has been found useful in working out the relationship of the beds in the Wellsville quadrangle. The fact that the red beds on White hill are only 100 feet± below the Olean and are 160 feet± below it on Alma hill is suggestive of an unconformity. The fact that the interval is greater to the east may suggest the steady rise of the red beds westward. Despite this local contradictory evidence the writer is inclined to the viewpoint of his associates in the field that the Olean rests on successively older beds in general toward the east and southeast for this particular region. See figures 21 and 22.

PETROGRAPHY OF SOME UPPER DEVONIAN ROCKS

Since some of the Upper Devonian beds lack a definite fauna, it was thought that it might be possible to make correlations on the basis of their mineral constituents. It was also believed that petrographic examination of thin sections might indicate the source of the material forming these beds. Eleven samples were taken from the Germania sandstone and eight samples from other beds to be used for comparison. The identifications of the minerals were verified by Professor Walter F. Hunt of the University of Michigan. The results of the investigation are given in the table on page 69.

The slide numbers are the same as the field stations from which the samples were taken. Most of these can be located by referring to the pocketed map. The table shows the kinds and relative abundance of the minerals occurring in each sample.

Most of the samples from the Germania were taken from the lowest sandstone stratum from widely separated points in the Wellsville area and, at intervals of a few miles, south as far as the type outcrop, station 635, near Germania, Potter county, Pennsylvania. This gave an opportunity to study the paleogeographic range of the mineral constituents.

Of the 15 or more minerals present in each of the thin sections from the Germania, nine are common to all of them. These are quartz, muscovite, leucoxene, plagioclase feldspars, hematite, zircon, tourmaline, ilmenite and chert. Microcline is absent from slide 313, sericite from slide 690 and apatite from slide B. Clay, biotite, chlorite and rutile are absent from two of the 11 Germania thin sections but no two of them from the same slide. Considering the possibility of missing minor quantities of minerals present, the last seven minerals can be considered common to the Germania. The minerals are surprisingly constant for the same beds over an area in excess of 100 square miles.

Reference to the table shows that most of these minerals are also common to the Hinsdale and Whitesville beds, about 300 feet below the Germania, and indicates a rather constant source of sediments. Rutile is conspicuously absent from the thin section taken from the lower beds. Chert, common to the Germania, is found only in minor quantities in slide 667 (4). Limonite, common to the lower beds, is in small quantities in only two of the Germania slides.

While the petrographic evidence obtained is not sufficient to warrant a conclusion, it is an advance in our knowledge of the composition of the various types of rocks in this area. Further study with more thin sections is needed and it is hoped that this further data may shed more light on the source of the Upper Devonian sediments.

To supplement the work heavy and light mineral separations have been made of some of the samples. The results are not ready for publication.

Minerals Present

SLIDE NUMBER	TOWNSHIP LOCATION	QUARTZ	CLAY	LIMONITE	SERICITE	BIOTITE	MUSCOVITE	CHLORITE	LEUCOXENE	PLAGIOCLASE	MICROCLINE	HEMATITE	ZIRCON	TOURMALINE	APATITE	ORTHOCLASE	RUTILE	ILMENITE	CALCITE	CHERT	TITANITE	OTHER MINERALS AND ROCK FRAGMENTS
	Cattaraugus Conglomerate																					
654	(Independence).....	A	P		C	P			P			P						P				Quartzite and Schist
	Germania Sandstone																					
172	(Andover)..........	A	C		C	C	P		C	C	P	P	C	P	C	P	P	P		P		Magnetite
313	(Andover)..........	A	C		C	P	C	C	P	P		P	C	P	P	P		P		C		Magnetite
79	(Independence).....	A	P	P	P		P	C	C	P	P	P	C	P	P	P	P	P		C		
87	(Independence).....	A			C	P	P	P	P	C	C	P	P	P	P	P	P	P		C	P	Quartzite and Schist
500	(Independence).....	A				P	C	P	C	C	C	C	C	C	C	P	P	P		C		
647	(Independence)......	A	P		P	C	C	C	P	C	P	P	P	P	C			P		C	P	Quartzite and Schist
89(658)	(Independence).....	A	C		C	C	P	P	C	C	P	P	C	P	C		P	P		C		
635	(Abbott, Pa.).......	A	C		C		P	P	C	P	C	P	P	P	C		P	P		C		
636	(Hector, Pa.).......	A	P		P	P	P	C	C	P	P	P	C	C	C		P	P		C		
637	(Harrison, Pa.)......		C	P	C	P	P	P	C	P	P	P	C	P	P		P	C		C		Magnetite
B	(Hebron, Pa.).......	A	C		C	C	C		P	P	P	P	P	P		P	P	P		P		Magnetite and Schist
	Germania Conglomeratic Sandstone																					
A	(Hebron)...........	A	C	P	P	C	P	P	P	C	P	P	C	P	P		P	P		P		
	Hinsdale (Quarry) Sandstone and "Lower" Whitesville																					
762	(Wellsville).........	A	C	C	P	A	A	C	P	P	P	P	P	P	P							
667(4)	(Greenwood Qd.)....	A	P	C	C		C	C	P	P	P	P	P	P	P	P		P		P		Magnetite
667(7)	(Greenwood Qd.)....	A	C	C	P	P	C	C	P	C	P	P	P	P	C	P		C				
667(9)	(Greenwood Qd.)....	A	C	C	P	P	C	P	P	P	P	P	P	P	P							
	Machias (Crinoidal Layer)																					
468A	(Scio)..............	C	P	P	P	P	P	P	P			P	P						A			Pyrite
	Rushford Sandstone																					
554	(Canaseraga).......	A	P		P	P			P	P	P	C	P	P	P	P		C		P		

A = Abundant.
C = Common.
P = Present (less than 1 per cent of composition).

STRUCTURAL GEOLOGY

The Wellsville quadrangle, being a part of the northwest extension of the Allegheny plateau, would be expected to have the type of structure characterized by Willis (1892, p. 213–81) and others for that region. The Appalachian mountains have many parallel sharp folds and thrust faults. The dips on the limbs of the folds increase and faults occur more frequently toward the southern part of the Appalachians. As one goes northwest from the highly folded area in southern and southeastern Pennsylvania, the folding is much more gentle and faulting becomes uncommon. Along the boundary line between Pennsylvania and New York, as far west as Allegany county, New York, there are many gently folded anticlines and accompanying synclines.

The anticlines are generally a few tens of miles in length and from five to 15 miles in width. The gently curved forms of the anticlines have their axes varying from northeast-southwest to near east-west and take their position from, and in general are parallel to, the greater folding of the Appalachians. In cross section the crests of the anticlines are a few hundred feet higher than the synclines, with the syncline adjacent on the southeast usually from 100 to 300 feet lower than the one adjoining on the northwest. As a rule, the anticlines plunge gently to the southwest, the exception being the few closures which have been mapped during the recent gas developments of this region. The amount of closure seldom exceeds 200 feet and generally is less than 100 feet. A general concept of the positions occupied by the anticlines and synclines of New York can be had by reference to the work of Wedel (1932) and to the Pennsylvania Survey reports (Cathcart, 1934*a*).

REGIONAL DIP

The geological maps of New York State lead to the impression that all the strata in central and western New York have a more or less regular south and southwest dip. This is true only in a very general way. The variable directions of dip due to the gentle anticlines become of increasing importance as the southern boundary of the State is approached. The northward dip of rock in New York State was first noted by Hall (1839, p. 323) as follows:

> . . . the rocks rising southward from Horseheads to the Chemung river.

Later Williams called attention to the series of nearly parallel folds in central and south-central New York. His statement, "The dips to the northwest are shorter and steeper than those in the opposite direction" (Williams, 1892, p. 412), should be slightly modified. The writer agrees with Kindle (1904, p. 281–89), who has observed that the steep flanks of the folds are on the south or southeast sides. The height of the fold, in all those observed, must be obtained by ascertaining the difference in feet of the crest of the fold and the syncline adjacent on the northwest. The region of folding on its distal border to the northwest is shown, surficially at least, by anticlinal noses. Obtaining a regional dip on beds having the complexities of structure of the Wellsville area is somewhat difficult.

The regional dip for central and western New York has been given by various authorities as south or to the west of south, from 20 to 60 feet a mile. Nevin states in his recent book (1931, p. 32):

> In all of central and western New York, the regional dip is to the south at about forty feet to the mile.

That is a good general statement. Barrell, in pointing out the relationship of the series of beds in south-central and southwestern New York, says:

> In the higher strata, however (the basal Mississippian), the regional dips are to the southwest at an average of about 20 feet to the mile. In the Middle Devonian the dips average in direction 20 to 30 degrees nearer south and at average inclinations of from 30 to 50 feet per mile (Barrell 1914, p. 233).

The form taken by the deposits in the Appalachian geosyncline was similar to a roughly shaped wedge, with the thin edge in the western and northwestern part of the basin. Now, consider this wedge as tilted toward the south by an uplift on its northern side. The result is that the uppermost beds must necessarily have more of a westerly dip than the lower or older beds. The distribution of the lithologic facies show that the *original* dip must have been to the west, or slightly north of west, for the region considered as a whole. The *initial* dip of the lower beds in the warping trough of deposition was at least more nearly in a horizontal plane. If the plane of horizontality be considered as near the base of the Hamilton, then it is readily seen that the upper beds of the wedge of deposition would have a more westerly dip than the beds below.

The regional dip, estimated from outcrops of the Cuba formation, is from 35–40 feet per mile in a direction S. 35°–40° W. The structural contours drawn on the base of the Cuba most nearly show the regional dip in the northern third of the quadrangle. The dip of the Oriskany sandstone, estimated from the few deep well records, is between 50 and 65 feet a mile to the south.

STRUCTURAL MAP

The structure map is contoured with an interval of 50 feet. The contours show the elevation of the top of the Cuba formation above mean sea level. The Cuba was selected as the key bed because (1) it has a distinctive faunal and lithologic character, (2) its thinness (40 feet±) makes possible the use of a smaller contour interval than could have otherwise been used, (3) it maintains its distinctive character over a larger geographic area than most of the formations exposed, and (4) it is the formation which is perhaps best known to geologists who have worked in the area.

Except for the area near Shongo, where the Genesee river cuts through a well-developed anticline, the outcrops of the Cuba sandstones are limited to the northern part of the Wellsville quadrangle. It was not found *in place* near Shongo, but some Machias beds, carrying *Spirifer mesacostalis,* may be seen just east of the village, along a secondary road.

The contouring of the southern half of the quadrangle is made possible by using the Germania formation. The base of the Germania is 500 feet± above the top of the Cuba, and where it was found in outcrop, 500 feet were subtracted to get the elevation of the Cuba. A slight allowance was made for the increase of this interval to the southeast. The distinctive lithologic character, structure and red shale associated with it make the Germania usable with even greater facility than the Cuba. The description of the Germania formation is given in a discussion of the stratigraphy.

Where the contour lines are broken upon the map, the information on which they are based was not considered sufficiently definite to place the elevation of the key bed more than tentatively.

The forms outlined by the curving contour lines are to a considerable extent based upon the strike readings taken at the outcrops. Although a few hundred dips and strikes were taken in the quadrangle, only a few were considered of sufficient value to warrant their use in the preparation of the structural map. The dips were classified as good, fair or poor. Those considered good and a few classed as fair were used. The highly undulating character of the strata of all horizons makes the use of dips rather hazardous. The strikes are considered reliable, however, to at least within a few degrees of their recorded direction. A correction for the magnetic deflection was made in the dip and strike readings. The mean declination for the area was 7½° west of north in 1924 and was considered to be 8° to 8¼° west when the field work was done in the years 1931–34 (Lahee, plate 1, p. 398).

The structural contours purport to represent the structure of the surficial rock only. The crestal axes of the anticlines are drawn with heavier lines than the structural contours and are continuous for each anticline whether it is plunging or is a closed structure. The synclinal axes are drawn as heavy broken lines. There are two anticlinal and three synclinal areas shown on this map. Each of these areas will be briefly described.

The names applied to the major anticlines and synclines in the Wellsville quadrangle are those used by Kindle and Wedel or the Pennsylvania Topographic and Geologic Survey or new names introduced by the writer when there has been no substantiating evidence of correlation with earlier named structures. For the convenience of some of the readers, the earlier used names are placed in parentheses to indicate a possible correlation.

Most of the anticlines and synclines of southern New York were first named by Kindle. Wedel has traced these structures through a large part of southern New York and as far west as the western edge of the Wellsville quadrangle. While the present paper does not agree in detail with Wedel's work, the structures are rather similar. The writer did not find a syncline in the northwest part of the quadrangle, mapped by Wedel as part of the Glenora syncline. When the old names are used it indicates that these structures have been traced a sufficient distance beyond the Wellsville quadrangle to warrant their use. The Pennsylvania Survey names are used where the structures are known to be a continuation of the structures mapped by the Pennsylvania Survey.

Oswayo (Cayuta) Syncline

This syncline is the northeastward extension of the Oswayo syncline of the Pennsylvania Survey (Cathcart, 1934*a*, figure 2). Its axis extends across the southeast corner of the Wellsville quadrangle, passing to the south of Whitesville. On the southeast it is bordered by the Harrison anticline, and on the northwest by the steep flank of the Smethport (Watkins) anticline (Cathcart, 1934*a*, figure 2). There is some doubt in the writer's mind as to the details of structure in this small area. Further mention is made of this area under a discussion of faulting.

Smethport (Watkins) Anticline

The most significant structural feature in the quadrangle, both for its magnitude and its potential economic importance, is the Smethport anticline. It is a continuation of the Smethport (Sharon) anticline of Potter county, Pennsylvania, and enters the Wellsville area about two miles from the southwest corner. Its crestal axis is a gently curving line, which extends more than 14 miles across the quadrangle in a direction varying from N. 40° E. to N. 60° E., passing through Shongo, and to the south of Independence. Near the latter point it swings to the north as it approaches the Greenwood quadrangle. Its height varies between 200 and 400 feet, being greatest in its southwestern part. The steepest part of the southeast flank has a dip of from 200 to nearly 300 feet a mile toward the Oswayo syncline. On the northwest flank the greatest dip is nearly as great in the southwest section. The other part of the northwest flank dips more gently and in varying directions into the irregular Wellsville syncline. From the Oswayo syncline on the southeast to the Wellsville syncline on the northwest the distance is from seven to nine miles.

In the northeastern part of this anticlinal area is an anticlinal nose plunging to the west. The axes of this nose and the Smethport anticline converge to the E. N. E. in the Wellsville area and probably join a short distance beyond in that direction. The nose is a continuation of the plunging anticline which is located two to two and one-half miles northwest of Greenwood. The east-central part of the Wellsville quadrangle and the west-central part of the Greenwood quadrangle were subjected to an unusual strain during the folding of the region. A fault occurring in the area and the great change in the direction of the anticlinal axes are evidences of this.

The Smethport anticline has two of the few closures to be seen on the anticlines of this region. These closures are on the southwest half of the structure and show an excellent possibility of a supply of natural gas. While it was definitely determined by the outcrops of known horizons that there is closure, the exact amount and dimensions of the elongated dome or domes were not definitely determined. The map shows the interpretation made in this work. The estimated amount of closure was between 50 and a little more than 100 feet, with the probability of two points, as shown on the map, being slightly higher than the rest of the surrounding area.

Wellsville (Corbett Point) Syncline

Little need be said about this irregular-shaped area covering nearly one-third of the quadrangle. The rock slopes gently as the bottom of this structural low is approached, reaching its lowest position in the west-central part of the southwest section. About one-half mile west of the Wellsville quadrangle the Olean conglomerate is found in place. The location and extent of the syncline may be seen on the accompanying map.

Alfred (Fir Tree) Anticline

The so-called Alfred anticline, as here interpreted, is more correctly classified as a plunging anticlinal nose with its height measured in tens of feet. Its south flank is fairly steep, but to the north it merges into the regional dip with only a slightly synclinal area intervening. In its southwestern part it is little more than a terrace. Its axis extends across the quadrangle from a point southwest of Scio to the south side of the village of Alfred in the northeast, following a course about N. 60° E.

TOPOGRAPHY AND STRUCTURE

As in many other regions of stratified rock, the structure of the rock is reflected in the topography of the Wellsville quadrangle. The Smethport anticline can in a general way be recognized by the cliffs along Honeoye and Cryder creeks. On Honeoye, the steeper side of the valley is to the northwest, but on Cryder creek it is to the southeast, facts indicative of the northwest and southeast dip of the strata. The west side of the Genesee river, except where modified by glacial drift, shows the same phenomenon. A glance at the tributaries in the northwestern part of the quadrangle reveals the position of the rock strata for that area and shows the steeper side of the valleys to be to the southwest.

JOINTING

Jointing in the rocks of the Wellsville quadrangle is poorly developed, or at least poorly shown at the outcrops. This is readily understood, since great numbers of the rock are thin layers of interbedded shales and sandstones. Jointing is best developed in rocks of homogeneous character. It was originally planned to make a careful study of the joints in this area in their relation to the other structures. The poor quality and infrequency of the occurrence of the joint planes caused abandonment of this plan.

There are a few good examples of dip joints. Those measured are on the southeast side of the Smethport and Alfred anticlines. Their direction of strike varies from N. 20° W. to N. 30° W. parallel or at a small angle to the dip of the rock. The hade of these joints is only one or two degrees. The development of the joints is far from the striking feature displayed in the Finger Lakes region (Sheldon, 1912). The best example of well-developed joints in this quadrangle, where they control the direction of and are exposed by a tributary stream, is one-fourth mile northwest of station 415, about one mile west of Tip Top, in Alfred township. The strike of the joint planes is N. 30° W., being parallel to the strike of the rock locally but also nearly at right angles to the direction of the axis of the Alfred anticline. A photograph of this jointing is shown in figure 23.

FAULTING

No major faults could be traced in the Wellsville quadrangle, and in only one place was there indisputable evidence of faulting. A block of flat-pebble conglomerate with slickensides was found near station 721, one-half mile southeast of Paynesville. A photograph of this block is shown in figure 24. This rock was found near the elevation where it would be expected to be in place as the stratigraphic throw of the fault was small. This is in the Oswayo syncline.

Slate Creek Fault

Five miles east of the northeast section of the Wellsville quadrangle, on a tributary flowing into Slate creek (Greenwood quadrangle) from the north, there is a clearly marked fault. The fault plane or surface is well exposed at a point three-fourths of a mile above the mouth of the tributary, in the east bank of the stream, at an elevation of 1300 feet. The strike of the fault here is about S. 65° W., and Canadaway beds are exposed on either side of it in a nearly vertical position. The exact amount of the throw could not be determined but was estimated to be in excess of 100 feet, perhaps as much as 300 feet. An effort to trace this fault into the Wellsville area revealed it again at a point on Slate creek one and one-half miles to the S. 60° W. of the place just described. Here the beds were also found to be on edge for several feet in the bed of the stream and in its south bank. The strata in the stream one-fourth mile to the northwest of the latter place have a dip of 18° to the northwest, a fact which suggests that the fault

Figure 23 Stream erosion between joint planes

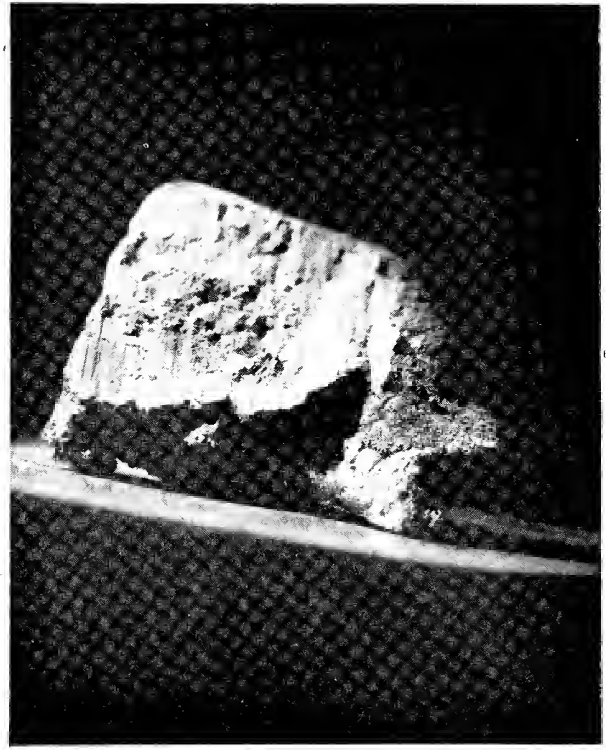


Figure 24 Slickensided block of Wolf Creek conglomerate

Figure 25 A small anticlinal fold

Figure 26 Outcrop, showing faulting and folding

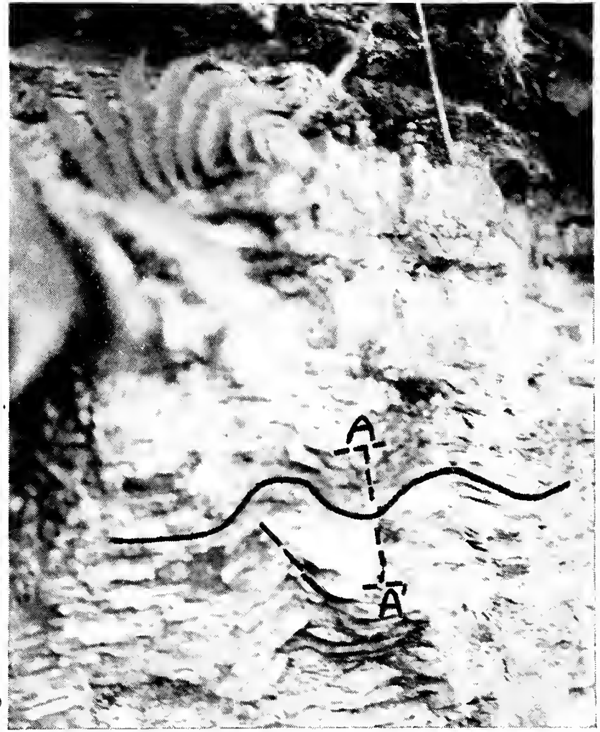


Figure 27 A close-up of small fault and folds

has a considerable throw. At a point on Slate creek, about one-half mile southeast of the line of faulting, are beds with a dip of 17° west, indicative of a branch fault with a north-south strike. The fault could not be definitely traced south of the Slate Creek valley. The strike projected would join the Wellsville quadrangle east of Andover, but the outcrops in Dyke creek, east of the town, have a dip of only a few feet a mile to the west.

A few cases of local dips, abnormally high, were carefully investigated, but no further evidence of faulting was found. It is believed that, with the possible exception of the small area southeast of Cryder creek, any surface faulting discovered in the future in the Wellsville quadrangle will be of minor character. Even in this area the position of the strata can be accounted for by flexures, but the slickensided conglomerate block is very definite evidence of faulting.

MINOR STRUCTURES

Minor folds are common throughout central and western New York, and they range in size from small undulations to well-marked anticlines. A good description of some minor structures is given by Decker (1920). The most striking folds are revealed by arched beds found where the creeks have carved out steep-sided channels. An example of the arching beds is pictured in figure 25.

Such structures are believed to be due to local relief of pressure and do not extend far below the bed of the stream. It is important to recognize the character of the folds lest they be used in error to interpret a major structure. Where there is an outcrop showing in only one bank of the stream an abnormally high dip into the bank may be recorded.

Small Folds and Faults in Incompetent Beds

One striking example of faulting and folding in incompetent shale beds between the more competent sandstone layers may be seen on the west bank of the Genesee river, one-fourth mile north of the Pennsylvania line. This outcrop is on the steep southeast flank of the Smethport anticline, about one and one-half to two miles from its axis. The strike of the folds is S. 87° W. and the height of each of them is less than two inches. The distance of the camera in figures 26 and 27 from the outcrop was four feet and the direction of the outcrop from the camera formed acute angles on the northwest and southeast sides of the axis of folding.

Some unusual features of the structures shown in the shale beds were noted as follows: (1) The steep flanks of the small folds were on the southeast side. (2) There were small thrust faults showing a low-angle dip (37°) to the north. One fault is marked at B in the photograph, figure 27. It shows a displacement of only a fraction of an inch and soon dies out below and above. (3) Jointing, which is confined to the shale bed and extends only a few inches, is shown by AA′, figure 27. A descriptive plan of the beds is shown in figure 28. The shale bed thins on the face of the outcrop to the northwest.

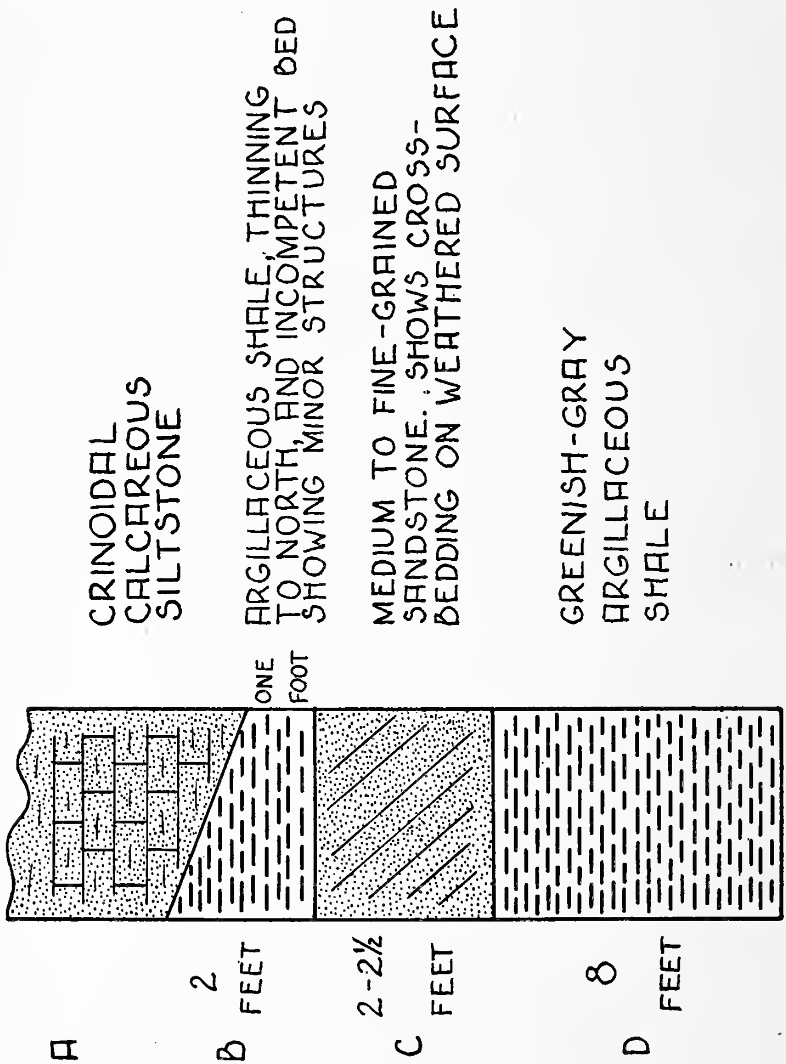


Figure 28 Section of beds shown in figures 26 and 27

The shale in bed D, near river-level shows jointing in a direction N. 67° W. The sandstone bed C shows jointing in two directions, N. 48° W. and N. 50° W. The variation of joint direction in beds C and D, a sandstone and a shale respectively, is perhaps because of their unlike character. The jointing in the shale bed B indicates that it was developed after the folding in that bed.

While it has been a custom of geologists to follow the time-honored works of Van Hise (1894–95) and Leith (1923) in their explanation of folding in beds of variable character, the theory must conform with the field facts. The folding here seems to be an unusual exception. Figure 27, page 79, shows the steep side of the drag folds to be in the opposite direction from the one which should have developed if the Smethport anticline was formed entirely by a direct compressional stress from the southeast. The additional evidence of the low-angle fault dipping to the north indicates that the stress was applied from that direction if it is an overthrust.

DEFORMING STRESSES IN THE WELLSVILLE AREA

It is generally accepted that the original irregularities of the floor upon which sediments are deposited exert a strong influence on the forms taken by those sediments when subjected to stresses. What irregularities were on the Precambrian floor of this area have not been disclosed.

The Wellsville quadrangle as a part of the Appalachian geosyncline has its structural history closely bound up with that great structural feature. The significance of the relation of geosynclines of deposition to structure is explained by Schuchert (1923), and geology was much enriched by the recognition by Hall (1883, p. 83) that great folded and faulted mountains represented geosynclinal areas of deposition. Schuchert (1923, p. 174–75) tells us that more than 40,000 feet of strata were deposited in southern Pennsylvania and in Maryland and that the basement has gone down some 35,000 feet. Price (1931, map, p. 40), following these ideas, shows the close relationship between the "Appalachian Structural Front" and the depositional basin from the base of the Silurian to the top of the Pottsville. His diagrammatic sections contrast the extreme folding of the region of the "Structural Front" with the more gently folded region to the west and northwest. While the greater thickness of the competent beds in some parts of the Appalachian geosyncline has had more influence upon the final form taken by the structures there than in the areas where they are not so thick, the difference is considered to have been small in comparison with the greater bending downward of the synclinal areas at the places of greater load, but not necessarily because of the load.

Although the distribution of size-grade of the sediments of Devonian time clearly indicates that the original or primary dip must have been to the northwest, the bowing down of the trough of deposition to accommodate the great thicknesses of succeeding beds of shallow water deposition must have been great enough to have reversed this dip for the western part of the trough. The lower beds in that part of the trough would then have an initial (Nevin, 1931, p. 30) dip to the southeast. Is it conceivable that such a great downward flexure could have occurred without deformation of the beds involved? Induration had, for some of these beds at least, not reached a very advanced stage. It would seem that the ever-present force of gravity would take advantage of this situation and that the place of greater disturbance would be near the axis of the syncline. Flowage folding as discussed by Bain (1931), De Terra (1931) and others should perhaps be given more consideration.

Some field facts are: (1) In the area near the axis of the Appalachian syncline of deposition there was close folding. As one follows along the axes to the southwest, there is an increase of overturning and thrust faulting to the northwest. (2) The steep limbs of the anticlines in this highly folded region are the northwest ones. (3) Further from the geosyncline to the northwest, including the area studied for this paper, the southeast limb is the steeper for a majority of the anticlines; only a few have a steeper northwest flank. (4) The folds in the Allegheny plateau, though differing in symmetry from those near the geosynclinal axis, conform with them in the trend of their axes.

The close conformity of the trend of the folds indicates a close genetic relationship. The difference in their symmetry, or, more correctly, their asymmetry, indicates a stress difference. Sherrill (1934) has shown by his study of the "Foreland Folds" of the Appalachians that the south and east flanks of these folds are from 1.2 to 1.3 times as steep as their north and west flanks. This degree of asymmetry resulted after deducting the effects of regional tilting. The folds are basically asymmetrical.

The writer is inclined to consider two major directions of stress responsible for the structures described in the Wellsville quadrangle. The first was a direct compressional stress from the southeast, reaching its maximum in Late Paleozoic time but present since Precambrian time. This stress was generated by Appalachia, or through the agencies which caused the changes in that land mass. Propagated largely through the basement complex and the older competent beds of the Paleozoic, it has given the form to the present folds. Contemporaneously and later another direct compressional force developed from the northwest, perhaps more nearly from north-northwest. The first stress had a large tangential component acting upwards; the later stress from the northwest had a large downward component. This second stress was presumably caused by a renewed uplift of the Canadian Shield, during the late Paleozoic, and by gravity pulling the masses of sediments toward the axis of the Appalachian geosyncline.

THE UPPER DEVONIAN PROBLEM

The work of geologists in attempting to give a clear concept of Upper Devonian sedimentation and stratigraphy is somewhat analogous to the history of the "Great Catskill Delta" which by its complex nature has so effectively given a problem worthy of attention. Starting in Hamilton or Marcellus time, building continuously to and into the Carboniferous, the process of formation is marked by spasmodic and rapid advances, with intervening recessions of its shore line, as though it were mustering its forces for the next advance; reaching ever further toward the west and northwest in the Appalachian geosyncline until brought to a close by the retreat of the seas. Doctor Willard (1933) of the Pennsylvania Geological Survey gives an excellent review of the advances made in the study of the Upper Devonian and his paper has a good bibliography. Professor Chadwick (1933*a*), as a result of years of study, gives a comprehensive review and correction of errors of correlation. The Upper Devonian problem of the Wellsville area is similar to the Upper and Middle Devonian problem on the eastern front, but the Middle Devonian has been acceptably distinguished by Cooper (1933) in New York State.

Mather's (1840) original definition of the Catskill Mountain group is as follows:

The CATSKILL MOUNTAIN group terminates the series of indurated rocks in the First District. This group consists of white, gray and red conglomerates, with gray, red, olive and black grits, slates and shales. Some of the strata in the lower half of this group abound with the impressions and casts of fossil shells, while those of the upper half contain the impressions and casts of numerous plants, some of which are similar to those of the coal beds of Carbondale.

Whereas this was originally used to designate a group of beds of definite age and character, later work, described in the papers referred to above, proves that the Catskill Mountain group is only the landward phase or facies of many formations of Middle and Upper Devonian time.

Williams (1884*b*) more than 50 years ago understood the time concept of the relationship of the faunas in the different zones of sedimentation in the Appalachian geosyncline. As the zone of shallow water, with its deposition of coarse clastic material, was pushed westward, the fauna favoring that environment moved westward with it, rising higher in the geologic time scale with a few changes. This is illustrated by Chadwick (1933*a*) and by Caster (1934). Prosser (1891) substantiates Williams' concept of Upper Devonian deposition. Darton (1893) in a clear, analytical fashion describes and illustrates the relationship to marine beds of the "Catskill" in the "lower" Portage of eastern-central New York, showing the thickening of the Oneonta in its eastward extension. Barrell (1913, 1914) in his classical papers on "The Upper Devonian Delta" reviews the ideas of the environment of Upper Devonian sedimentation, introduces the modern geological concept of the contemporaneity of subareal and subaqueous deposition and in a broad general way describes the advance of the "great delta" northwestward in the Appalachian geosyncline. Willard (1934, p. 897, 908) gives a definite boundary to the shore line of this delta in early Chemung time in Pennsylvania.

The concept now is of an Upper Devonian sea, occupying in part the Appalachian trough of deposition. This trough extended a little to the east and southeast of the present Catskill escarpment, southwest across Pennsylvania and Maryland with irregular extensions to the northwest, south into Virginia, Kentucky and Tennessee and west into Ohio. Its northern extension must remain questionable because erosion has removed the beds in that direction. That the sediments deposited on the margin of and in this sea represent different types of coeval deposition is shown by the papers of Chadwick, Caster, Willard and others previously mentioned. The zones of deposition in general are parallel to the shore line, and the width varies from one locality to another and from time to time. Extending northwestward toward the distal part of the delta there are the following successive zones: (1) the light gray and yellowish gray (leached appearing) sandstones; (2) the conglomerates, cross-bedded sandstones and red beds, reds and greens predominating, indicating subareal, fresh-water and marine deposition near shore;

(3) the coarse clastic marine beds; (4) the marine, fine sands and silts; (5) argillaceous beds, greens and grays [limestones found interbedded with (4) and (5)]; and (6) the black shales. The oscillating character of the sea did not allow these zones to have well-defined boundaries but left an interfingering of beds of great complexity. One of the objects of this paper is to show the conditions of the deposition for the beds occurring in the Wellsville quadrangle or the role taken by them as a part of the "Upper Devonian Delta."

GEOLOGICAL HISTORY AND PALEOGEOGRAPHY

GENERAL

Geological history implies the recording of the events that transpired in this area from the beginning of geological time to the present. Since only the Upper Devonian strata are exposed in the Wellsville quadrangle and even the deepest wells have not penetrated the Silurian and older rocks below, the discussion is here limited to the conditions existing when the Devonian beds were forming. The reader can refer to any good text on historical geology for a general account of what the conditions were during the other divisions of geological time.

The sedimentary beds of Paleozoic age in the Wellsville quadrangle are about two miles thick. About half of this thickness is Devonian. This inference is based upon (1) the thickness of the older Paleozoic beds outcropping to the north, (2) a deep well drilled to the Cambrian, near Camillus, about 150 miles northeast of Wellsville, and (3) deep wells which penetrate the Silurian, drilled in near-by areas to the west, south and southeast.

The Wellsville quadrangle was part of the region which was uplifted towards the close of the Paleozoic era and erosion has since been more or less continuously at work shaping the land. A brief discussion of the effects of erosion is given under Peneplanation, page 94 and the unconformable Cenozoic deposits under Pleistocene, page 97.

SOURCE OF UPPER DEVONIAN SEDIMENTS OF WESTERN NEW YORK

It has long been an accepted fact that the sediments of Upper Devonian time were derived from the ancient land mass to the east and southeast, Appalachia. Since Barrell's papers (1913, 1914) those working in Upper Devonian of New York and Pennsylvania have been content to accept his conclusion as correct. Whereas the evidence is irrefutable that the sediments of Upper Devonian times were largely from the east, there are data which make a source of sediments from the north at least worthy of consideration.

As early as 1881, H. S. Williams (1881*a*, p. 318–20) found evidence suggesting that all of the sediments were not derived from an eastern source, although he did not so interpret its significance. He describes channel-fillings distributed through about 20 feet of fine shales in transitional beds from the Portage to the Chemung, near Ithaca. His description reads:

The shale is well characterized by its fauna. Its termination is distinctly marked above by coarse arenaceous shales and sandstone, well-known in the Chemung group, but these peculiar sandstone channel-fillings are not known to occur above or below this particular horizon. Whenever, in the neighborhood the outcrop of the shales, with its characteristic fauna was discovered, careful search brought to light also the channel-fillings, everywhere running in a *uniform direction*, and varying in thickness from nine to eighteen inches, and in width from five and one-half to eight or nine feet.

Describing the direction of a channel-filling which appeared on opposite sides of a ravine he says:

The mass has its longitudinal axis in a line lying about 15° E. of N. and 15° W. of S.

In a description of some ripple marks on sandstone from one of these channel-fillings he says that the steep side of the ripple mark clearly indicated movement from north to south. Fine threadlike lines crossing the rocks of the channel-fillings in a general east-west direction he attributed to tide or current, carrying seaweeds. If we accept Willard's (1934, p. 903,906) determination of the direction of ocean currents (clockwise, from west to east and deflected to the southwest), these lines would tend to confirm his theory. Williams postulates channels scoured out by icebergs moving southward, with the east-west current filling the channels with the coarser material. The fact that the 20-foot layer of shales containing the channel-fillings is overlain by the coarser material of the Chemung sandstones would perhaps better indicate an advancing delta and that the channel-fillings were made by bottom currents flowing into this area from a little to the east of north. It is unfortunate that some of the evidence to the north has long since been removed by erosion. The positions of the long axes of these channel-fillings are very awkward to account for by a delta advancing from the southeast or east, even though distributaries may form a large angle with the main stream. Unfortunately the time relations of the deposits in a north-south direction have not been so carefully worked out as in the east-west direction.

James Hall (1839, p. 319), in describing features of a rock stratum in the Ithaca group, near Jefferson, Tompkins county, writes:

> . . . . the surface of a layer worn smooth and grooved, as if by a current, transporting some hard body over it.

With reference to the scratches he says they

> . . . . appear to have been made before the rock was entirely indurated. In this instance I have not been able to ascertain the direction of the current, though it was probably from the north, ...

J. F. Carll (1883, p. 197–99), in his report on Warren county, Pennsylvania, states:

> The great difficulty in keeping hold of the Panama rock is, that it so soon fines down and disappears when traced as far as it can be traced on the surface in a *southerly* direction. The Rock city at Panama is a massive conglomeritic stratum 69′ thick. At Eureka well three miles south, the rock is thinner, more flaggy and contains fewer pebbles.

Carll believed the Panama to be present at Lottsville, Pa., a few miles farther south, as a "thin band of irregular bedded sandstone, greenish-yellow in color, coarse grained in spots and sometimes attaining a thickness of one foot."

Further (Carll, 1883, p. 200) he states:

> From Panama toward Lottsville (however imperfect our observation may have been) it is evident that the rock decreases in thickness and radically changes in lithology and structure.

Carll (1883, p. 184–95) suggests the hypothesis that the materials of the flat pebble conglomerate were long exposed to wave action, having been brought slowly down toward the center of the basin from older shore deposits lying to the north. This reworked shore material was ultimately exhausted in the basin-filling as submergence of the region proceeded. In the western and southwestern parts of Warren county, Pennsylvania, the sub-Olean is a medium-grained iron-stained sandstone, and in the northeastern part, it is a conglomerate, 30 to 40 feet thick, with many pebbles.

L. C. Glenn (1903, p. 974), speaking of the Salamanca conglomerate lentil, says:

> It thins out and disappears to the eastward, not being known to occur on the Olean quadrangle to the northeast of the Allegheny river and Oswayo creek. South and west of this line it occurs in the Olean area as a hard gray sandstone 10 to 15 feet thick, which becomes coarser and thicker westward and passes into a massive conglomerate on the Salamanca quadrangle.

Glenn (1903, p. 975) raises another question for consideration, slightly different from Carll's conclusion as to the source of the flat pebbles. He says:

As the presence of the occasional jasper pebbles among the flattened quartz ones in all of the conglomerate beds in the region below the Olean or round pebble conglomerate gives sufficient grounds for concluding, it is believed by the writer that the coarse materials of these lower, or flat pebble conglomerates, were derived from the Lake Superior region and were transported eastward along the shore by the waves and long shore currents of the Devonic and Carbonic seas, the flattened or discoid form so characteristic of the pebbles of these lower conglomerates being produced by their to and fro motion along the beach during this long eastward journey.

The evidence, opinions and hypotheses offered by the authors quoted and the further evidence of the universal coarseness of the conglomerates in their northern extent (frequently less coarse to the south in southwestern New York and northwestern Pennsylvania) lend probability to a northern source for at least a part of the material found in the flat pebble conglomerates.

One must view with admiration the results of Willard's work (1934) in locating the ancient shore line of Early Chemung time in Pennsylvania. His postulated shore currents causing the deflection of former delta lobes to the southwest should perhaps be further considered. If the source of the flat pebbles found in the conglomeratic beds was in the southeast and the long shore currents postulated by Willard flowed to the southwest (Willard, 1934, p. 903, 906), how was the great quantity of the large pebbles (some one-half inch in diameter) transported in excess of 100 miles to the northwest from the shore line? One of the Rushford sandstone members containing many large, flat quartz pebbles was seen by the writer near East Rushford in a roadcut near the western end of the Rushford reservoir. The Rushford sandstone is stratigraphically about 500 feet below the base of the Cuba formation. This conglomerate bed is believed to be later in age than the delta lobes described by Willard. There are many flat pebble conglomerate beds in the stratigraphic interval between the Rushford formation and the Panama conglomerate above. The pebbles were probably not from the west where black muds were then being deposited. The likely alternative seems to be that these pebbles had as their source the beaches to the north, extending from Lake Erie to the Adirondacks or farther, upon which they had been washed to and fro for a long time.

CONDITIONS DURING UPPER DEVONIAN DEPOSITION

The lowest beds outcropping on the surface in the Wellsville quadrangle were deposited a few tens of miles distant from the shore lines in a quiet shallow sea which probably did not exceed 50 fathoms in depth. Muds and fine sands were the chief sediments of the time and the large number of brachiopods shows that this type of bottom was well suited for that form of life. Bryozoans were abundant and crinoids and pelecypods were present. The waters of the sea were rather rich in calcium acid carbonate, not only supplying the building material for the shells of the invertebrate forms of life present but also making calcium carbonate a common constituent in the shales and sandstones and giving rise to a few thin limestone layers, distributed at irregular intervals in the section. The limestones are due partly to the extraction of calcium carbonate from the waters by organisms and perhaps partly to the increase of supply, cyclic changes of climate or some other factor favoring precipitation. Their formation was repeated often during "Chemung" time, nearly to the Conewangan time of the Cattaraugus beds.

The many alternations of the green and gray shales and sandstones are due perhaps as much, if not more, to the change in the character of the load transported by the rivers as they are to a changing level of the sea. That the sea was shallow is attested by the many layers of the ripple-marked sandstones, which show that its bottom was at least not below the depth of wave action. Some of the many rounded ridges and grooves found on the rocks indicate the dragging of objects, living or inanimate, over the surface of the unindurated beds. Some of the rocks composed of fine-grained sand and silt have, covering their surfaces, many small irregularities, deceptively like fossils, but probably inorganic in origin. The beds of sandstone were rapidly covered, for the individual grains are for the most part subangular and angular, indicating that they were not rolled about on the sea bottom for any long period of time.

The hinterland between the distal part of the delta and the uplifted area of old Appalachia, the source of much of the sediment, was low and flat, extending over a hundred miles. This must necessarily have been true for "Chemung" time and demands no argument to convince even the most exacting critics. Yet some of the sandstones formed at this time are conglomeratic, carrying pebbles in excess of one-half inch in diameter. Their deposition may have been made possible by a rejuvenated vigor of erosion and transportation, or they may represent material contemporaneously brought in from the north.

The repetition of alternating beds of shale and thin sandstones continued from the time of deposition of the Machias beds until the deposition of the Hinsdale sandstone, with a gradual increase in the proportion of sand over the muds. At only one time, during the formation of the Cuba sandstones, did the area seem to possess uniform deposition over a large area.

The Hinsdale sandstone and the Whitesville beds were deposited only a short distance in front of the approaching delta. While the presence of ferrous iron compounds is common in the green shales of the lower beds, in the sediments of the Hinsdale and higher beds they have had opportunity to oxidize, and brown colors are frequently seen. The environment had become unsuited for the preceding brachiopod fauna and pelecypods predominated. A few of the hardier brachiopods, such as *Camarotoechia* and *Spirifer disjunctus,* continued to meet the changing conditions of ocean bottom. Sponges seem to have profited from the change in conditions, as they were found in the Hinsdale chocolate-colored ferruginous beds. ***Prismodictya,*** the sponges found in these strata, according to Dr G. M. Ehlers (personal communication), are best suited to sandy bottoms.

Conglomerates and conglomeratic sandstones become more frequent in their occurrence in the Whitesville and the marine fossils, in association with myriads of fish scales, indicate that these beds are of marine deposition. The fish may have been fresh-water fish living in the waters of the rivers flowing across the delta. The plant remains found were carried to the waters in front of the delta. The pebbles making the conglomerate layers were transported by swiftly moving streams or by near-shore currents.

The cross-bedded, thinly laminated green sandstones of the "Upper" Whitesville and higher beds represent periods of rapid deposition and, even though barren, except where conglomeratic material is deposited on them, they are believed to be of water deposition. The reasons for this belief are the thinness and regularity of the bedding planes and the low angles at which they lie adjacent to each other. They are considered as a part of the delta structure.

"Catskill" Time in the Wellsville Quadrangle

The "Catskill" sedimentation or "Delta" deposition reached its full development in the Wellsville area at the time of deposition of the Germania formation which includes some 70 feet of strata below the Cattaraugus, with the first appearance of the characteristic red beds. The "Catskill" cross-bedded sandstones, more than 100 feet lower in the section in the Whitesville formation, herald the approach of the delta environment.

The beds in the Germania formation are largely alternating layers of red muds and green sandstones. The exception is the occurrence of conglomeratic beds in and close above its base. The widespread continuity of the green sandstones suggests a short-time invasion of the delta by marine waters at frequent intervals before the final westward retreat of the sea. The thin conglomeratic layers often contain *Camarotoechia* sp., suggesting that they likewise were of marine deposition.

Cattaraugus Time

The "Catskill" sedimentation continued throughout Cattaraugus time, the only break in the monotony of deposition being invasions of the sea over the delta, which left the Wolf Creek and higher conglomerates. From the character and distribution of the conglomerates, and from the marine fossils which they contain, they are considered as representing embayments of the Conewangan sea extending over a part of the delta material.

Oswayo (?) Time

Deposited upon the red bed strata, unconformably according to Glenn (1903, p. 978-80) are the light gray and yellowish or brownish gray sandstones of the Oswayo. The evidence in the Wellsville quadrangle gives reason neither to refute nor to support the idea of an unconformity. The rock appears to have been exposed to the leaching action of solutions for a long time, and the lapse of time since the uplift of the region points to the truth of such a conclusion.

Perhaps the nearly barren Oswayo (?) represents fresh-water or subaerial deposition on the landward part of the delta. If so, it would tend to complete the logical sequence of events.

The Oswayo represents the youngest indurated sedimentary rock in the Wellsville quadrangle. Hundreds of feet of beds have been eroded away. How much of these beds was deposited conformably and unconformably upon the Oswayo, now found at the top of the highest hills, is a matter of speculation. Fuller (1903) says that the Sharon (Olean) conglomerate represents the late Pottsville and was deposited after many hundreds of feet of sediments had been laid down in earlier Pottsville time in eastern Pennsylvania. In southwestern New York there is evidence that the Olean conglomerate in its eastward extension overlaps successively older formations. Following this evidence the writer assumes that the Wellsville area was subjected to uplift and erosion in late Mississippian time. The Pennsylvanian strata have been entirely removed by subsequent erosion.

The Appalachian revolution resulted in this region's being again elevated far above sea level, where it has remained, subject to many minor and a few major fluctuations of level.

EVIDENCES OF PENEPLANATION

The Wellsville region beautifully illustrates a former peneplanation in that all sections except the west-central one (the Genesee river cuts diagonally across it) have hills rising concordantly to a height in excess of 2300 feet and showing a slope of this summit near-level of 10 feet a mile to the north. Its slope from Alma hill, one-half mile west of the southwest section of this quadrangle, to the hill one mile southwest of Whitesville is between three and four feet a mile. Due east from the last-mentioned hilltop the slope of the summits is about 27 feet a mile across the Greenwood quadrangle. Across the Woodhull quadrangle the slope is approximately 18.5 feet a mile. The east-west line of the Corning quadrangle is essentially horizontal, the Tioga river dividing it into nearly equal east and west portions.

In determining this summit slope the highest points in the southern third of each quadrangle were selected for the east-west slope. The points were taken as nearly in an east-west line as practicable.

From Alma hill, the highest point in the New York part of this region, the hill summits slope gently westward at the rate of a little more than 3.5 feet a mile to a point four miles from the western border of the Salamanca quadrangle, there being a slight reversal to the east in this quadrangle. The slope of hill crests across the Randolf quadrangle is to the west approximately 25 feet a mile, and is comparable to the eastern slope in the Greenwood and Woodhull quadrangles. The slope across the Jamestown quadrangle is 37 feet a mile to the west. The Chautauqua quadrangle has a reversed slope of about 10 feet a mile to the east. The hill crests are essentially on a level across the Clymer quadrangle, near the same level as the western part of the Jamestown quadrangle or about 1860 feet above mean sea level.

In the Genesee quadrangle, Pennsylvania, some seven or eight miles south of the Wellsville quadrangle, many of the hills reach an elevation in excess of 2500 feet, with some over 2560 feet, or about 20 feet higher than Alma hill. The slope to the north from these hills to the highest point in the Wellsville quadrangle is six feet a mile. The slope continues to the north across the Wellsville quadrangle at 10 feet a mile and thence across the Canaseraga quadrangle at a rate of

19 feet a mile. It increases to a rate of 40 feet a mile across the Nunda quadrangle.

The east-west and north-south profiles of high points show the relation of the topography of the Wellsville quadrangle to a former peneplain. This quadrangle is near the crest in the northern part of the plain. These profiles are shown in figures 29 and 30.

Through the use of an advance sheet of the topography of the Genesee quadrangle, Pennsylvania, it was possible to get the topographic relation of the Wellsville quadrangle to the area south of it. This sheet is of interest to physiographers for it shows not only the divide between the three great river systems, the Genesee, the Susquehanna and the Allegheny, but also the probable crest of the oldest peneplain now evident in the southwestern New York and northwestern Pennsylvania part of the Allegheny Plateau region.

The summits of the highest hills are accepted by von Engeln (1932, p. 52) and others as being part of the Kittatinny (Cretaceous) peneplain. A part of the oldest peneplain, they are apparent to the eye in the field and appear plainly upon the topographic maps, whether we correlate them with the Fall Zone (Johnson, 1931), Kittatinny, Schooley, Harrisburg or some one of the many minor recognized peneplains.

Campbell (1903, p. 281-82) recognizes another peneplain in this area. He says:

From this evidence it seemed to the writer probable that the Jura-Cretaceous peneplain may be represented by the synclinal ridges, which in this region rise to altitudes ranging from 2200 to 2500 feet, and that the Chemung hilltops, which vary from 1600 to 2200 feet, may represent a peneplain of early Tertiary age.

Similar conclusions were arrived at independently by L. C. Glenn in the study of the Olean and Salamanca quadrangles of southern New York. Campbell further says:

Mr Glenn is disposed to regard the 2100 foot contour as marking approximately the position of a Tertiary peneplain surface, . . .

In one of the few comprehensive studies of topographic forms of this area, Fridley (1929) also recognizes two peneplains, the Kittatinny, represented by the highest points in the area, and the Schooley, represented in his Woodhull-Belmont profile by an elevation 400 to 500 feet lower or at altitudes of 2300 feet and 1800–1900 feet respectively.

There is a steepening of slope to about 50 feet a mile in the eastern part of the Greenwood quadrangle and in the western part of the

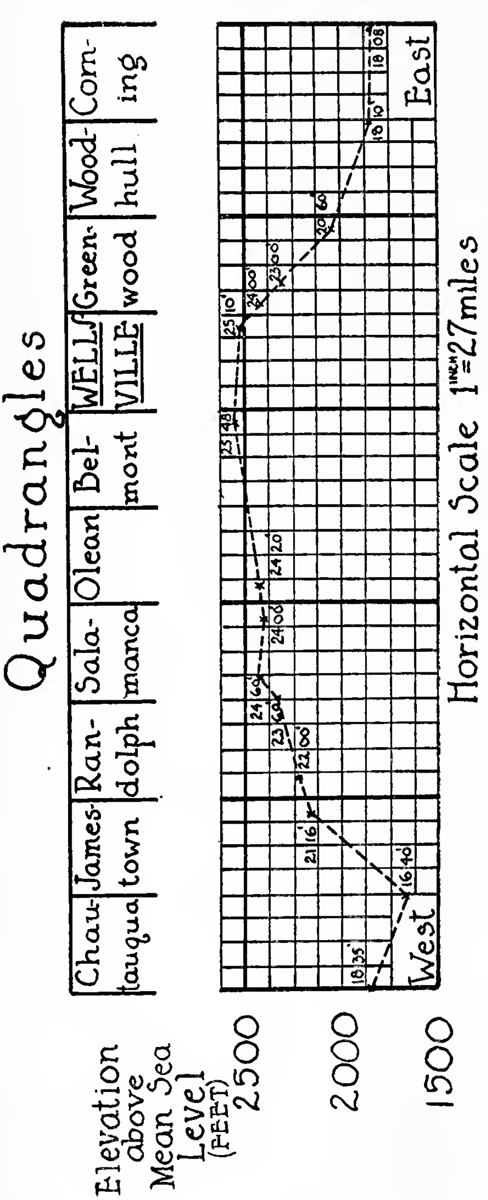


Figure 29 East-west profile of the Wellsville region

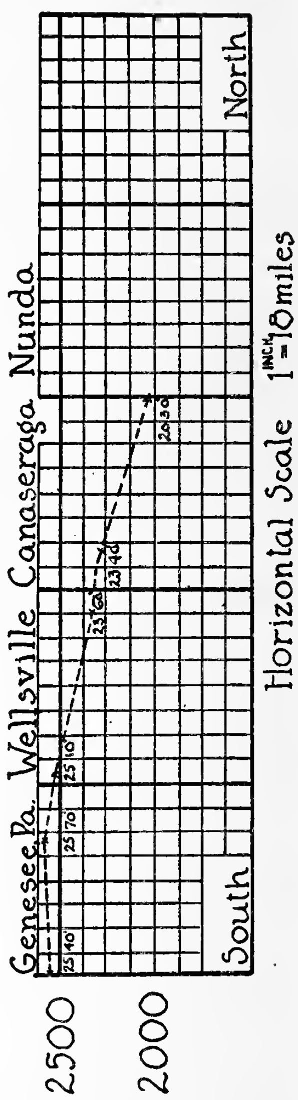


Figure 30 North-south profile of the Wellsville region

Woodhull quadrangle. The more gently sloping area may represent a peneplain, or it may show differential erosion, since the Whitesville and Cattaraugus (Venango) conglomerates and sandstones cap most of the higher elevations to the west, with the lower Conneaut and Canadaway beds of a less resistant character capping the lower hills to the east. As we go still farther east, the lower beds have a coarse, clastic character and the plain again rises. The profile of the peneplain or peneplains is suggestive of Hogarth's line of beauty (Hobbs, 1931) and is believed to be characteristic of denudation by running water.

There are many more or less flat-topped hills in the Wellsville quadrangle rising to elevations of 2100–2340 feet. The summits of a large majority of them slope gently to the south and west in the direction of the regional dip of the rock, suggesting that their character is dependent upon rock structure, the higher ones being capped generally by the more resistant rock.

Perhaps there has been comparatively recent regional warping such as is illustrated by Campbell (1903, p. 279) and Fridley (1929, p. 130) in figures 31 and 32.

PLEISTOCENE

Figure 33 shows the position of the Wellsville quadrangle with relation to the ice invasion of the Pleistocene. While the whole quadrangle was undoubtedly covered by at least one ice sheet, as is evidenced by the finding of glacial cobbles and boulders on the highest hills, the debris of that origin is not found in great abundance at the higher elevations. This is thought to be because the ice did not long remain at the higher elevations or because the finer material was subsequently removed. A few boulders of igneous rock were noticed at elevations in excess of 2200 feet in this quadrangle.

By far the greater amount of glacial material found in this quadrangle is along the sides of the main valleys and is of glaciofluvial deposition. Practically all of this is classified as deltas and lateral terraces. Such deposits are to be found (1) near the junction of Cryder creek with the Genesee river, (2) on the east side of the Genesee valley between York Corners and Stannard Corners, (3) on both sides of the Genesee valley near Scio, (4) near Elm Valley, south of Dyke creek, and (5) in the area east of Alfred. At Alfred Station near locality (5) there is a large sand and gravel plant. Some of the other localities have been a source of local supply of sand and gravel for building roads.

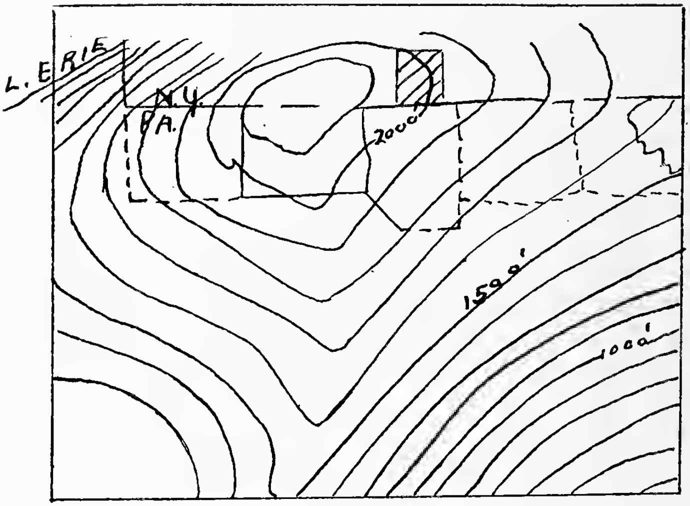


Figure 31 Warped surface of Harrisburg peneplain

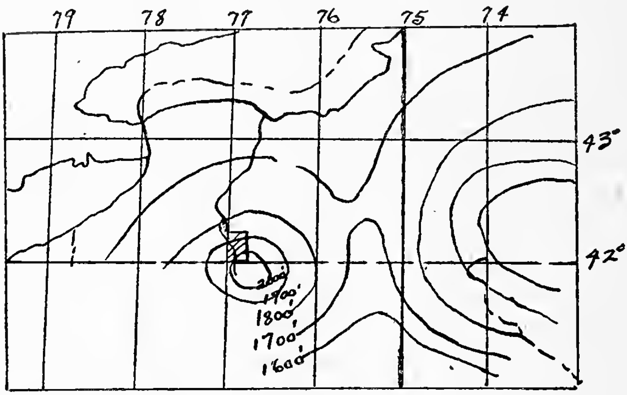


Figure 32 Warped surface of Schooley peneplain

The relatively low, flat-bottomed, steep-sided, swamp-covered character of the divides in Railroad brook (north of Andover), Cryder creek and Honeoye creek indicates that these channels were the sites of much more potent streams in glacial times. The great chasm in which the Honeoye and Marsh creeks have their divide in the southwest section is less than 100 feet higher than the channel through which Leverett (1901, p. 201–9) shows Lake Maumee to have been drained by the Allegheny river. The drainage from this lake was over the low divide near Cuba lake, between the towns of Belfast and Olean. Before the retreat of the ice had uncovered the mouth of this valley at Belfast, the Allegheny river received the waters from the Wellsville area through the Honeoye channel.

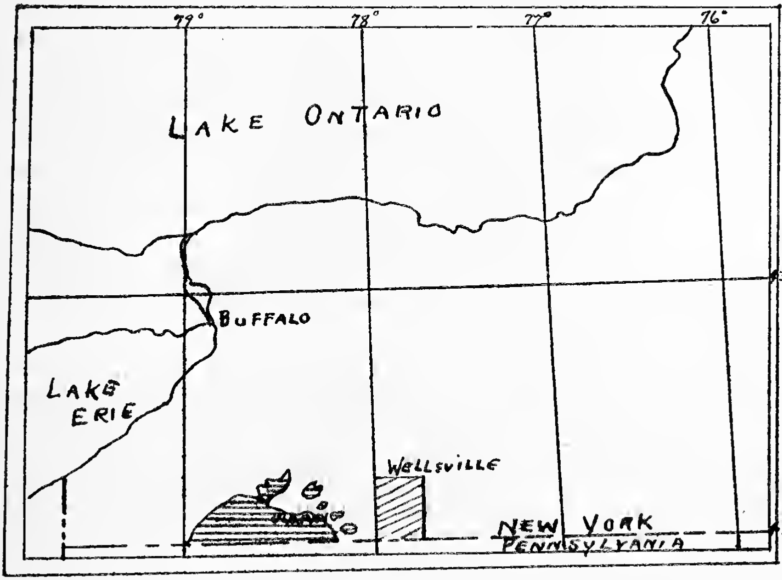


Figure 33 Unglaciated area in New York State (after Leverett)

There is also evidence that the Allegheny river, through Honeoye creek carried much more water from this quadrangle than is carried by the Genesee. The direction of alignment of the tributary streams and topographic evidence of water gaps in this and in the Belmont quadrangle led the writer to the following conclusion: The area was, after its elevation following peneplanation, drained to the southwest; the Genesee river at some much later time captured the drainage of this area.

The Pleistocene geology and the former drainage of the region have not been studied intimately in the preparation of this report, but these few important facts should not pass unmentioned.

ECONOMIC GEOLOGY

GENERAL

This section of the paper is primarily intended for the lay reader who is interested in the natural resources of the Wellsville area. It was originally planned to treat only of the stratigraphy and structure of the Wellsville quadrangle, but since some data of economic interest have been collected in pursuit of the original plan, it is thought that the presentation of these data may be of some value. A few historical facts are also included.

CLAYS AND SHALES

Common clays used in the making of brick, tile and similar products have been produced in the Wellsville quadrangle and although there are still sufficient deposits in the Genesee River valley and the tributary valleys for the making of clay products, they are of only mediocre quality and are not quarried today. Except for a small amount in the northern part of the quadrangle, the shales are either too sandy or do not occur in beds thick enough to warrant their being worked.

The shales of the Gowanda or Lower Canadaway beds, which outcrop to the north of the Wellsville quadrangle, are of better quality for making brick and tile than the shales of this quadrangle. According to J. Nelson Norwood, president of Alfred University (a personal communication):

> There were two terra cotta tile companies, one at Alfred, formerly called Alfred Center, where the university is, known as the Celadon Terra Cotta Company (later the Ludowici-Celadon Company); another concern at Alfred Station two miles away ran for quite a number of years and was known as the Alfred Clay Company. About 1898 or 1899 the Alfred plant was burned and rebuilt. It burned again about 1909 and was never rebuilt. . . .

One of the Alfred University athletic fields is the site where the Alfred terra cotta plant was located.

According to C. A. Hartnagel, State Geologist, the Celadon Terra Cotta Ltd. produced terra cotta and roofing tile as early as 1894. In 1905 the Terra Cotta Company had ceased making terra cotta and the name was changed to the Celadon Roofing Tile Company. The Alfred Clay Company was located at Alfred Station and they manufactured building brick and building tile. The writer was informed by local residents that the plants have not been in operation for 15 years or more. Shales were formerly obtained near Alfred Station, a little more than a mile north of the Wellsville quadrangle but in later years they were shipped in from other regions.

Part of the town of Alfred is in the northeast part of the Wellsville quadrangle.

Although there is not a single brick plant or kiln in the Wellsville quadrangle today, clay manufacture had an important part in the building of the towns in this area in the past. The bricks for many of the older buildings were manufactured locally. Wellsville has had three brickyards which have long been dismantled and are now only a memory for the older inhabitants of the town. According to George W. Frederick of Wellsville, all of these brick plants made brick from the clay deposits of the Genesee valley. The first plant to be operated was owned by a Mr Whitcombe and was located in the lot now occupied by the City Ball Park. The second and largest was located on Chamberlin street and was owned by William Signor. A third plant was located on property now occupied by the Wellsville Golf Club.

According to Birney M. Wilson of Whitesville, a brick kiln was operated more than 50 years ago just southwest of Whitesville. The clay for making the brick was taken from the Cryder Creek valley.

SAND AND GRAVEL

Like most of the other quadrangles of New York that have been covered by the ice of the Pleistocene, the Wellsville has large quantities of sand and gravel. There are many deposits of these materials in the valleys of the major streams in the quadrangle. An examination of several of the fluvioglacial deposits proved that they are composed of a great variety of clastic pieces derived from the more resistant rocks outcropping to the north. They are not unlike the many other glaciofluvial deposits left in the many river valleys of central and southern New York. As was expected, the more resistant local rocks are in greatest abundance. The less distant sedimentary rock of the north is much more abundant than the igneous rock transported farther from Canada. The granites, gneisses, quartzites and other igneous and metamorphic rocks are estimated to make up less than five per cent of the total deposit.

There are no gravel pits in the Wellsville quadrangle that are being worked on a commercial scale with the exception of a very small area in the extreme northeastern part which has furnished some sand and gravel in the operations of the Alfred-Atlas Gravel and Sand Corporation. J. R. Evans, superintendent of the company, told the writer that the gravel business there was started by Leonard Claire. When the present operating company was organized in 1928, a new plant was constructed which, according to Mr Evans, is capable of washing over 2000 tons of gravel and sand in 24 hours. The yearly production is said to be about 100,000 tons with about 50 per cent of each.

There are numerous small gravel pits, opened for local use, in the Wellsville quadrangle. Most of the gravel has been used on the secondary roads and the best known of the local pits is the one owned by W. D. Goodridge. It is located near the southern boundary of the quadrangle, just north of the junction of Cryder creek with the Genesee river. This pit has been open for over 50 years and the gravel has been used for covering roads, building concrete bridges and other construction. One other pit, figure 34, which may deserve mentioning is located about one-half mile south of Elm Valley and can be seen from the highway. The gravel has been removed from an area of about 150 feet in diameter and to a depth of about 40 feet. It is of good quality and ranges in size from a boulder of about five feet in diameter down to sand. There are many places along the Genesee River valley where sand and gravel are available should there be a demand for their use.

BUILDING STONES

Although there are no building stones in the Wellsville quadrangle which can quite compare with the Bedford limestone of Indiana, used in the construction of the new Wellsville library, there are excellent stones to be had for building purposes. The building stones of this area fall in the general classification of "flags" or flagstones. They are siltstones and fine-grained sandstones which may be found in all of the geological formations in the Wellsville quadrangle from the Machias below to the Cattaraugus above. They have been used in many of the towns in the area as foundation stones and as paving blocks. Many of the business houses of Wellsville have foundations of local stone. After being exposed to the weather for a few years the stones become brownish in color due to the oxidizing of their iron compounds. Some of them split rather easily, perhaps due to the abundance of small flakes of mica present. Although flags may be quarried in almost any part of the quadrangle, they vary in quality from place to place in an unpredictable manner. The stone in a stratum does not remain constant in character over a very large area.

The only quarry in operation in the Wellsville quadrangle in 1936 was owned and operated by R. Danielsen. This quarry is on Vandermark creek about one-half mile southeast of Scio. According to Mr Danielson, the roughly sized stones are sent to Buffalo to be used as a veneer on the outside walls of buildings. The stones bring a price

Figure 34 Gravel pit near Elm Valley

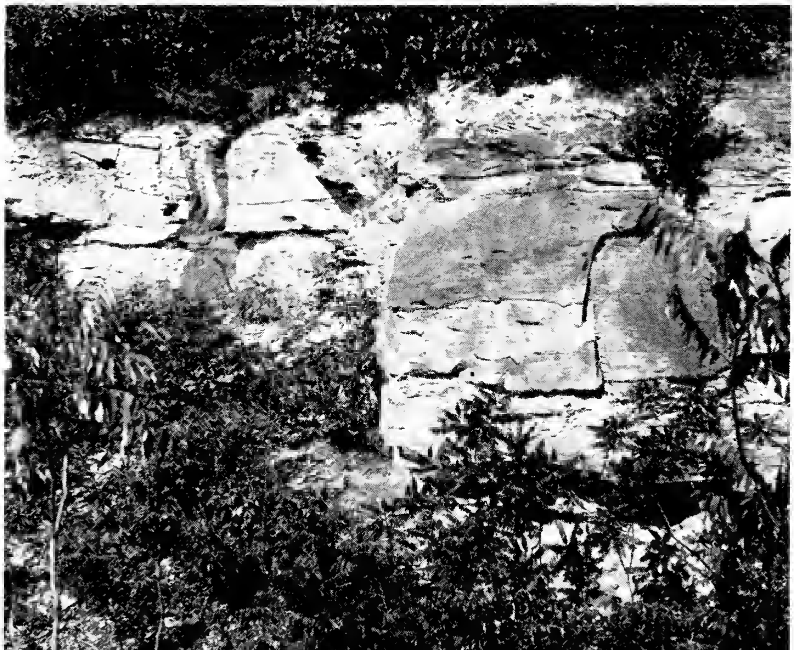


Figure 35 The "Old Hurd Quarry"

of three dollars a ton. The quarrying is done on a small scale in seasonable weather. The stones are taken from the bed and banks of Vandermark creek. When first quarried the stones can be shaped rather easily into rough flags of the desired size (nearly all are small), but after being exposed to the air for a few days they can not be shaped so easily. Most of the stones are a light bluish gray when freshly exposed. This quarry is located in the "Upper" Machias formation.

Wellsville Quarries

Much of the information given here concerning the old buildings and quarries in and near Wellsville has come from Mr Frederick, a near-octogenarian.

One of the first quarries used to obtain building stones for construction in Wellsville was the Theobold quarry opened more than 60 years ago in the side of the hill about one-half mile southeast of the village. The foundation stones for the "old opera house," State and Main streets, which was torn down in 1936, the Rauber Furniture Company and the Fuller Block buildings were obtained from this quarry. Most of the stones in these buildings have a brownish color but were no doubt gray when they were taken from the quarry.

Another of the older quarries, which has been in operation much more recently, is the Hurd quarry on the Lorenzo Hurd farm about one mile northeast of Wellsville. It is on the southeast side of the hill, near the top, at an elevation of 2050 feet and is in the Whitesville formation. This is believed to be the largest quarry opened in the Wellsville quadrangle. It has not been used for some 15 or 20 years as can be seen from the photograph, figure 35, but some stone taken from it is in the base of the Wellsville City Hall and in the Methodist Church on Madison street. About the beginning of the last quarter of the last century most of the improved walks of Wellsville were made of wood. They were gradually replaced by flagstones taken from the stone quarries near the city. A large part of these were taken from the Hurd quarry. Mr Frederick recalls some of the "flags" taken from the Hurd quarry for walks as being 16 feet long. Because of its importance in the early building of Wellsville, this quarry was visited and is described below.

It was found to be almost concealed by the growth of small trees and brush, and the base of the quarry was covered with the waste rock from quarrying. It extended some 250 feet along the face of the hill and had been cut back about 75 feet into the hill at its deepest point. About 25 feet of the face of the quarry were exposed. See figure 35. The top layers were badly weathered and the rock in many places had split along the bedding planes of the cross-bedded sandstones. Some of the bedding planes made angles in excess of 20 degrees with the horizontal. Some of the beds about 10 feet below the top were horizontally bedded and looked much better than the top beds for quarrying. They were gray, micaceous, medium-grained sandstones. Other sandstones in the quarry had shale pebbles and clastic particles of sandstone included in them. About an hour spent in a search for fossils was rewarded by finding only a few impressions of plant stems.

Other quarries of minor importance near Wellsville were the Vaughan quarry, a little over a mile north of the village; the Tadder Hill quarry, back of the Catholic Church; and the Mike Murphy quarry on South hill. The flagstones in front of the new library were obtained from a quarry at Oswayo, Pa.

Whitesville Quarries

The editor of the Whitesville paper, Glenn J. Robbins, pointed out to the writer some green and red mottled sandstone used in the foundation of one of the Whitesville stores. This was immediately recognized as Germania sandstone. It had been brought from near Whites Corners, Pa., but similar stone might just as easily have been taken from some of the hills to the north and west of Whitesville. It had been thought in the course of the field work that the Germania, because of its attractive appearance and its facility in breaking into nicely shaped and sized blocks, would make an excellent stone for foundations and here it proved so.

There is one other quarry worthy of mention. It is located on the southeast side of the hill, at an elevation of 2000 feet, about three-fourths of a mile west of Paynesville, on the farm of James Kenyon and was opened about 20 years ago. When it was visited in 1934, it looked as though it had been in recent use and the quality of the stone appeared good.

PETROLEUM AND NATURAL GAS

The production of petroleum began early and is of leading importance among the natural resources in the Wellsville area. Oil and gas production has been an important factor in the lives of the inhabitants of the southern half of Allegany county for more than 50 years. Since the drilling of the Triangle No. 1 well in 1878–79, four and one-half miles southwest of Wellsville by O. P. Taylor, there have been thousands of wells drilled in this part of New York and about one thousand wells in the Wellsville quadrangle. Nearly all of the wells have been drilled to the "shallow sands," varying in depth from about 300 to about 1500 feet, depending upon the location and elevation at which the well is started. A majority of them were drilled for oil but a considerable number were drilled for natural gas. Most of the shallow gas areas are controlled by the Empire Gas and Fuel Company but many of the small oil pools are owned by individuals and by smaller companies. During the years 1931–36 there were more than 25 wells drilled to a depth of 3500–5000 feet in search of gas in the richly productive Oriskany sandstone. (There were more than 40 in June 1938.) Many of these have resulted in some of the best producing natural gas wells in New York State. The descriptions of the "shallow" and "deep" producing sands of the Wellsville quadrangle are treated separately.

"Shallow" Oil and Gas Pools

The shallow oil and gas pools of this section have been described by Hartnagle and Russell (1929) and also by Newland and Hartnagle (1932), but some facts are reviewed and new observations added for the completeness of this paper. There are several small pools of oil and gas that have been producing for 30 to 50 years. Subdivisions of some of them have been given separate names but for convenience only one name will be used in the description of each pool. The local name for each producing sand is used and a discussion as to their correlation is given on pages 107–12.

Scio pool. The Scio pool is in the northeastern part of Scio township near the village of Scio, and in the Dry Creek area of Ward and Amity townships. The pool is divided into two parts, one on either side of the Alfred (Fir Tree) anticline which is here little more than a terrace, the southern part of the pool being one-half to one mile south and slightly east of Scio and the northern part being one to two miles northeast of Scio.

The southern part of the pool was the first opened with the initial well drilled on the John Wright farm about three-fourths of a mile east-southeast of Scio. Most of the wells drilled here are in the valley and reach the pay sand at a little less than 400 feet. According to Charles P. Johnson of Wellsville, some of the wells in the Scio field had an initial production of 50 barrels of oil a day, with an average initial production of about 10 barrels for all of the producing wells. The wells in the northern part of the Scio pool are at varying elevations and most of them strike the pay sand at depths of from 700–900 feet.

The producing sand is called the Scio. It is usually 30–60 feet thick and seems to be continuous for the area. There are between 175 and 200 wells in this field and they have proved to be of long life. The production had dropped to about one-sixth of a barrel a well but with the recent introduction of flooding, many thousands of barrels of oil will be recovered. There has been very little gas found in the Scio field.

Madison Hill pool. The Madison Hill, or Buena Vista, pool joins the southern division of the Scio pool on the east and southeast and extends to within about two miles of Wellsville. This pool produces from the "Scio" sand. The average depth of the wells is about 1000 feet. The reason for the greater depth to the "Scio" sand here is the high elevations at which most of the wells are started. There is also a gentle slope of the producing sand from the Scio to the Buena Vista pool.

According to Mr Johnson, there were 61 producing wells in this pool in 1935. About 14 wells were drilled in 1936, most or all of which were to be used for flooding. Some of the larger wells had an initial production of about 60 barrels a day. Before flooding was introduced the average production of a well had dropped to about one-sixth of a barrel a day. The producing sand is reported to have a thickness of 25 to 45 feet.

The Madison Hill pool, according to Hartnagel was opened in 1913, some years after the Scio pool, the first well being drilled on the Smith farm. The gas production in this pool is light.

Ford Brook pool. The Ford Brook pool is located in the northwestern part of Willing township and the northeastern part of Alma township, on and between the north and south branches of Ford brook. Besides the major part of the pool, the north and east part, owned and operated by Lewis H. Thornton, there are two smaller subdivisions. They are the 106 pool, owned and operated by Fred Jones, and the Big Basin pool, owned by Mr Frederick. Pool 106 is sometimes considered as a separate pool from the Ford Brook pool.

According to Mr Thornton there are between 500 and 600 acres of production in the Ford Brook pool. The first well was drilled about 1885 by James Thornton on the Fassett farm. This old well, abandoned for some time, was reopened in 1896 and may be considered the beginning of production in the Ford Brook pool. There are now about 125 wells in the pool, 30 to 40 of which were drilled within the past few years or since the flooding method of oil recovery was introduced in this section.

Some of the best producing wells had an initial production of about 75 barrels of oil a day, but the initial production of the wells near the edge of the pool was nearer 15 barrels a well a day. The average production of the wells dropped to between one-twelfth and one-eighth of a barrel a day.

Four productive sands have been reported in this pool. The first two give little production. The third is considered by oil men to be the equivalent of the Richburg and it has an average thickness of about 30 feet in this pool. It is probably contiguous with the Richburg, for its stratigraphic position and its elevation make that possibility seem likely. The fourth sand, averaging about 25 feet in thickness, is also a good producing sand in some of the wells. The fourth sand is about 85 feet below the top of the "Richburg" sand. The depth of most of the wells in the Ford Brook pool is between 1000 and 1350 feet, depending upon the elevation at which the well is started. The top of the sands is nearly flat with a gentle slope to the southwest. The pool is synclinal in its structural position.

Fulmer Valley pool. The Fulmer Valley pool is located about five miles east-southeast of Wellsville in Fulmer valley. The production is largely confined to oil but the producing sands are gas-bearing to the north, east and south of this pool. It occupies a relatively low position in the Wellsville (Corbett point) syncline, being similar in structure to the Ford Brook pool. The pool has been in operation for many years and the production is now limited to a fraction of a barrel a well a day.

The producing sands are found at depths varying from 800 to about 1300 feet, depending upon the elevation at which the well is located. In the valley the shallow sands are less than 1000 feet below the surface of the ground. There are four producing sands in an interval of about 100 feet of strata. The first three are thin and the fourth is seldom more than 30 feet thick. The first sand in places contains a small quantity of gas and the other three are oil-bearing. The fourth, called locally the Fulmer Valley sand, is present throughout the field, and is likely the same sand as in some of the other shallow pools.

Potter or Mervine pool. The Potter or Mervine pool, also called locally the Heselton pool, occupies an area of about one square mile in Independence township, about one and one-half to two and one-half miles a little east of north from Whitesville. According to Mr Wilson, who for several years has operated a lease in this pool, the first well was drilled in 1890. Moses Mervine drilled the first producing well and most of the stock in the project was owned by some of the citizens of Whitesville. Another account is that the first producing well was drilled by A. J. Johnson in cooperation with Fred Phillips, Frank Phillips, R. C. Elsworth, Elmer J. Johnson and Charles P. Johnson and was pumped for local use. The writer does not venture to say which is the correct account, but the field has been producing for a considerable number of years and had some production in 1936.

There are at least three producing sands and four were reported for some of the wells. The top sand, a light brown in color, is called the Penny sand. The lower sands, a much darker shade of brown, are believed to be an extension of the Fulmer Valley sand. There are about 12 to 15 feet of sands which are individually very thin and interbedded with shales. Based on the surface geology, the sands in the Heselton pool are at the same stratigraphic level as the sands in the Fulmer Valley pool. A discussion of the "shallow" sands is given on pages 112–15 in this paper. Most of the production is obtained at depths of 950 to 1250 feet and the wells are started at elevations of 2000 to 2300 feet.

There is some gas in this pool but the drilling was primarily for oil. The initial production was from 10 to 30 barrels a well a day. The average production dropped to about one-eighth barrel a well a day. Flooding had not been used in this pool, but it was not expected to be long before this method of oil recovery would be adopted. The thinness of the sands no doubt caused the delay in its introduction. There were about 100 wells in this pool.

Cryder Creek pool. The Cryder Creek pool, located in Cryder Creek valley, is about two miles S. 60° W. of Whitesville. This pool is so small that the use of the name pool is hardly justified, but in as much as it is a separate producing unit in this area the name is useful. According to Sheridan Austin, the operator of the principal lease, the first well was drilled about 1900 by the Harris Brothers for M. Mervine. Actual production was begun in 1922 and since then 34 wells were drilled, 24 of which were producers.

The producing sand, from light to dark brown in color, and locally called the "Penny," varies from zero to 12 feet in thickness, averaging about eight feet in the producing wells. It is lenslike in structure, thinning rapidly to the south to zero thickness. There is little variation in thickness in the east-west direction in the limited area that has been drilled. The valley floor is from 1630–660 feet above sea level and the sand is struck at a depth of 500 to 550 feet. The initial production was from five to 20 barrels of oil a well a day. Production dropped to about one-tenth of a barrel of oil a well a day. The small yield is somewhat compensated by the shallow depths of the wells. In the Wellsville quadrangle, only the Scio pool surpasses it in this economic advantage.

Independence natural gas field. Whereas the oil pools in the "shallow" sands in the Wellsville quadrangle are seldom more than a square mile in extent in any one pool, the natural gas production covers many square miles in one continuous field. The Independence gas field covers a small portion of the eastern part of Wellsville and Willing townships, the southeastern part of Andover township and the northern half of Independence township. The gas wells, spaced a few hundred feet apart, may be seen in a large part of this area. The production of gas is largely controlled by the Empire Gas and Fuel Company which has hundreds of wells in the Wellsville quadrangle. The productive sands are in the same stratigraphic position as the sands of the oil pools which in many instances are adjacent to the gas field, and producing from the same sand. Much of the oil is found in synclinal areas, but the gas is generally found well upon the anticlines. The structural highs and lows can be visualized by noting the distribution of the oil and gas wells. The position of the wells here illustrates one of the well-known principles of water, oil and gas accumulation in reservoir beds in that the substance having the least specific gravity will occupy the highest structural position. The Independence gas field is located on the Smethport (Watkins) anticline. (See map of the structural geology.) The gas wells are located at fairly high elevations and the depths to the producing sands generally vary from 800–1800 feet. The thicknesses of the sands are comparable to those mentioned in the discussion of the oil pools. For further details, consult the table of "shallow" oil and gas wells given on pages 113 and 114.

Alfred natural gas field. The Alfred gas field is located on the Alfred (Fir Tree) anticline, in Alfred township, extending from near Alfred, to the south and southwest, to within a mile of the Andover township boundary. This field is much smaller than the Independence field but it is also commercially important. The producing sand, called locally the "Alfred" sand, is thinner than most of the "shallow" producing sands, but they occupy the same stratigraphic position. The depth to the sand in well No. 413 (see map), located in the valley, about one-half mile southwest of Tip Top, is 475 feet. The wells on the hills to the north and west of well No. 413 are from 800–900 feet deep.

Alma pool. Through the courtesy of Mr Hartnagel, information about two small oil pools which extend into the edge of the Wellsville quadrangle is given below:

Directly south of the Ford Brook oil pool, an eastern spur of the Alma pool extends into the Wellsville quadrangle. The Alma pool has a direct connection with the large Richburg pool. That portion of the Alma pool that extends into the Wellsville quadrangle is also known to producers as the 106 pool. Lot 106 is near the north edge of the pool. The productive sand in the Alma pool is from 15 to 30 feet thick, and the depths of the wells vary from 1000 to 1300 feet.

Andover oil pool. The Andover oil pool was discovered in 1888 and lies east and southeast of Andover, partly in Allegany and partly in Steuben county. Two sands are present, the upper known as the "Penny" and the lower as the "Fulmer Valley" sand. Most of the oil is produced from the lower sand. Both of the sands produce gas. In depth the wells range from about 700 to 1100 feet.

The "shallow" sands. The "shallow" oil and gas producing sands in the Wellsville area and in much of the area to the south and west of it have for a long time been recognized as a part of the "Chemung" of Upper Devonian age. It is the opinion of the writer that the productive sands are members of the Rushford formation, a part of the "old" Chemung. The Rushford (Williams 1887) is divided into the Shumla and Laona sandstone members (named by Luther in 1903) which are separated by the Westfield shales. They are a part of the Canadaway group which was first named by Chadwick. The Rushford beds are roughly about 500 feet above the top of the Chemung as recently redefined by Chadwick (1933*a*, a personal copy corrected by the author). The Rushford is overlain by the Machias shales and thin sandstones and siltstones and is underlain by the fine argillaceous shales of the Caneadea (Gowanda) formation. Its position favors it as a natural reservoir for the accumulation of oil and gas formed in the bituminous shales.

The Rushford formation is below the surface of the ground at all points in the Wellsville quadrangle, but an excellent outcrop of it may be seen about 10 miles north of this area. It is four-tenths of a mile N. 30° W. of School 4, Almond township, in the Canaseraga quadrangle. The elevation of the outcrop is about 2050 feet above sea level and is only a few tens of feet south of a secondary road.

"Shallow" Oil and Gas Wells of the Wellsville Quadrangle

STATION NO.	TOWNSHIP	LOCATION	ELEVATION, FEET ABOVE SEA LEVEL	DEPTH TO PRODUCING SANDS — RESULTS	THICKNESS OF SANDS
58	Willing	2 Mi. S, 20° W, Stone Dam	2050	Gas	....
327	Alma	2.7 Mi. SW of Stone Dam	2000 Ap.	1300′ Ap. Gas	....
344	Alma	1.6 Mi. S, 78° W, Stannard Sch.	2011	(3) 1168′, (4) 1252′	28′, 25′
136	Willing	.5 Mi. SE, Stone Dam	1738	Gas	....
62	Willing	2 Mi. S, 73° E, Stannard Cor.	1658	(1) 790′, (2) 806′, (4) 891′. Gas and Oil	....
63	Willing	2 Mi. S, 73° E, Stannard Cor.	1649	(1) 761′, (2) 822′(?), (4) 895′. Gas and Oil	....
65	Willing	.6 Mi. S, 15° E, No. 62	1788	(1) 778′(?), (2) 904′, 1135′(?). Gas	....
264	Willing	1 Mi. NW of Hallsport	1737	787′, 828′, 865′ (Bot). Gas	....
70	Willing	.4 Mi. N, 70° E, Sch. No. 5	2252	1300–1400′ Ap. (?) Gas	....
72	Willing	.9 Mi. E, Sch. No. 5	2224	Gas	....
73	Willing	1.1 Mi. N, 80° E, Sch. No. 5	2230	Gas	....
240	Willing	1.5 Mi. N, 5° W, Paynesville	2085	1755′. Gas	25′
241	Independence	1.1 Mi. N, 10° E, Paynesville	2010	1675′. Gas	....
80	Independence	2.5 Mi. W, Whitesville	2035	1150′(?) Ap. Gas	....
78	Independence	.4 Mi. N, 35° W, No. 80	2113	Gas	....
110	Independence	1 Mi. SE, Hallsport	2042	Gas	....
84	Independence	1.5 Mi. N, Whitesville	2097	1074′. Oil	....
86	Independence	2 Mi. N, Whitesville	2272	(1) 950′ (Penny), (2) 1120′, (3) 1202′, (4) 1250′. Gas and Oil	....
88	Independence	.35 Mi. N, 30° E, No. 86	2290	(1) 933′ (Penny), (2) 1085′, (3) 1170′, (4) 1220′. Gas and Oil	....
90	Independence	.4 Mi. S, 85° E, No. 88	2240	1184′, 1210′. Oil	....
106	Independence	.6 Mi. S, Independence	2191	1150′ Ap. Gas	....
107	Independence	.8 Mi. S, Independence	2075	1065′. Gas	....
101	Independence	1 Mi. N, Independence	2305	1200′ Ap. Gas	....
166	Andover	1.2 Mi. N, Independence	2240	1145′. Gas and Oil 1231′ (Bot)	....

" Shallow " Oil and Gas Wells of the Wellsville Quadrangle — (*concluded*)

STATION NO.	TOWNSHIP	LOCATION	ELEVATION, FEET ABOVE SEA LEVEL	DEPTH TO PRODUCING SANDS — RESULTS	THICKNESS OF SANDS
167....	Andover......	1.5 Mi. N, Independence	2190	1123', 1168', 1206' (Bot). Gas and Oil	....
168....	Andover......	.2 Mi. S, 70° W, No. 167	2105	843' (Penny?), 1063', Gas and Oil, 1075', 1116' (Bot)	....
170....	Andover......	.7 Mi. N, 25° W, No. 168	2235	946' (Penny?). Gas and Oil in deeper sands	....
171....	Andover......	.6 Mi. N, 80° W, No. 170	2230	1068', 1276' (F.V.?).......	....
306....	Andover......	.8 Mi. SE, Round Top	2220 Ap.	1300' Ap. Oil...........	....
124....	Andover......	.7 Mi. NW, Fulmer Valley	1955	1025' (gas), 1070' (oil), 1089' (Bot)	....
114....	Wellsville.....	1.8 Mi. N, 72° E, Stannard Cor.	1821	1003', 1043', 1256' (Bot). Gas and Oil	34', 18'
118....	Wellsville.....	1 Mi. N, 65° E, No. 114	2083	1235' (gas), 1340' (oil).....	28'
119....	Wellsville.....	2 Mi. S, 70° W, Fulmer Valley	1826	935' (gas), 985' (oil).......	23'
123....	Wellsville.....	1.1 Mi. S, 72° W, Fulmer Valley	1747	952', 963'. Oil...........	....
161....	Wellsville.....	.7 Mi. S, 75° W, Fulmer Valley	1827	872' 899' 957' (994' FV). Oil	....
162....	Wellsville.....	400' W of 161	1812	846' (gas), 936' (oil), 972' (Fulmer Valley Sand)	....
163....	Wellsville.....	.5 Mi. S, 80° W, No. 162	1752	819' (gas), 851', 954' (FV sand)	....
262....	Wellsville.....	.5 Mi. NE, No. 114	2030	1158' (gas), 1212' (oil).....	57'?
324....	Alfred........	1.5 Mi. SW, Tip Top	2285 Ap.	864' (gas), 914'...........	8'
325....	Alfred........	.2 Mi. N, 10° W, No. 324	2295 Ap.	856' (gas)...............	....
326....	Alfred........	1.5 Mi. N, 85° W, Tip Top	2305 Ap.	893' (gas)...............	....
405....	Alfred........	.2 Mi. SE, No. 324	2190 Ap.	800' Ap. Oil and Salt water.	....
406....	Alfred........	.4 Mi. N, 5° W, No. 406	2282	875' (gas)...............	....
413....	Alfred........	.6 Mi. SW, Tip Top	1820	475' (gas)...............	....
424....	Alfred........	1 Mi. SW, Alfred.	2245	800' Ap. (gas)............	....

The depths given are to the oil or gas bearing sands. Much of the information was collected from persons who were often uncertain as to its accuracy. Some of this is designated by a question mark(?) and by the abbreviation Ap., meaning approximately correct. Most of the figures are presented as they were given to the author of this bulletin.

The station numbers refer to the location of the wells on the included map of the economic geology. Many other oil and gas wells have been accurately placed on the map to give the reader a general idea of their distribution in this region. Only a few score of the one thousand or more wells drilled in the Wellsville quadrangle are shown.

The outcrop in Almond township is a massive, light gray, medium-grained sandstone, about 20 feet thick and abundantly fossiliferous. The mineralogical composition of the sandstone is given in the table on page 69.

It may also be seen near the Rushford dam where the type section is exposed. Whereas the Rushford formation is represented by the Shumla and Laona sandstones in the surface outcrops to the north of the Wellsville quadrangle, to the south and east from the outcrops there is an increase in the number of sandstones at the same stratigraphic position. This is the common rule of change in the Upper Devonian in this region. Some of the sands are lenses of small extent, while others, such as the producing sand in the Independence gas field, are widespread. After tracing the Rushford sandstones and the overlying formations into and across the Wellsville quadrangle and into Potter county, Pennsylvania, by well records, the writer feels justified in saying that most of the "shallow" sand production in this quadrangle at least is from the Rushford formation. The varying depths at which the producing sands are found are due to the different elevations at which the wells are started and to their structural position.

Oriskany or "Deep" Gas Production

Since 1930 the exploration for natural gas has been considerably stimulated in New York State. The discovery of natural gas in the Oriskany sandstone near Wayne and Dundee, N. Y., and near Tioga, Pa., resulted in the leasing of many hundreds of thousands of acres of land and the drilling of hundreds of "deep" test wells in southern New York and northern Pennsylvania. The result of this activity was the discovery of three "fields" of natural gas of great potentiality. The three "fields" discovered are the Tioga and the Hebron fields of Pennsylvania and the State Line field of New York, which has also been referred to as the Wellsville field.

The State Line field is likely to become the greatest producer per unit area that has ever been discovered in New York. The discovery well of this "field" was located (location moved south by operators) by the author of this paper in 1932, and was drilled in the latter part of that year and the early part of 1933, by the Cunningham Natural Gas Corporation of Bradford, Pa. It is located in Pennsylvania a few hundreds yards south of the New York State boundary. This well had an estimated initial flow of about 10,000,000 cubic feet a day. There was some salt water in the Oriskany sandstone in this well indicating that it was near the margin of the field. In June 1936, about 15 wells had been drilled to the Oriskany. Thirteen of these report the finding of natural gas with initial open flow varying from 5,000,000 to 50,000,000 cubic feet a day a well.

The State Line field in 1936 did not cover more than three square miles but its full extent had not been determined. It is located on the Smethport (Watkins) anticline where that structure crosses the New York-Pennsylvania boundary line. The depths of the wells vary from 4100 to 4950 feet in this "field." The Tully limestone, which is about 50 feet thick in the State Line gas field, is a little over 600 feet above the Oriskany sandstone and the average interval between them is 615 feet, but in most of the wells the interval is between 600 and 610 feet. As determined from the well records, there is a slight thickening of this interval toward the southeast. The Onondaga limestone, which immediately overlies the Oriskany has a thickness of about 35 feet. The Oriskany sandstone was not penetrated more than three or four feet in most of the wells, but the reported thicknesses vary from four to 10 feet. It is thinner here than in the two Pennsylvania "fields" previously mentioned. Nevertheless its porosity is sufficiently high for it to contain an abundance of gas as evidenced by the excellent wells drilled.

Three "deep" test wells have been drilled in the Wellsville quadrangle outside of the producing field (1936). In none of these wells was gas found in the Oriskany. One, about one mile east of York Corners, was not well-located. The Oriskany sandstone was struck at a depth of 4668 feet or about 150 feet structurally lower than some of the producing wells on the Smethport (Watkins) anticline. The other two were drilled on the Alfred (Fir Tree) anticline in fairly good locations. The Johnson well, located about one mile southwest of Alfred, on the Randolph farm, struck the Oriskany sandstone at 4374 feet. The interval between the Tully and the Oriskany was reported as 669 feet and the Onondaga as nearly 50 feet thick. The other well drilled on the Alfred (Fir Tree) anticline is located on the Black farm, one and one-half miles east of Scio. The Oriskany sandstone was reached at a depth of 4092 feet. The Tully-Oriskany interval is 627 feet and the Onondaga limestone is 67 feet thick. The Black well is eight and four-tenths miles S. 60° W. of the Randolph well and on the same anticline. The Oriskany sandstone is 188 feet lower at the Black well than it is at the Randolph well or has an average slope between them of a little more than 22 feet a mile. The Tully-Oriskany interval increases in an opposite direction from the slope of the Oriskany at a rate of five feet a mile. From this latter fact and the data given in the description of the State Line gas field, assuming the reported figures to be correct, the Tully-Oriskany interval for the Wellsville quadrangle thickens to the east. The thickening to the south indicated in the State Line gas field is a local condition. The reader is referred to the table of "deep" well records for further information.

The Oriskany sandstone. The Oriskany sandstone is named for Oriskany township, Oneida county. It was first named and described by Vanuxem in 1839. The type outcrop is located on the east side of a hill above a limestone quarry about one mile north of Oriskany Falls. It is easily accessible and is an interesting place for observation for those persons particularly interested in seeing the type outcrop of the Oriskany sandstone. The Oriskany is one of the better known formations of North America, extending from Canada to Alabama and from New York to Missouri and Oklahoma. The characteristic fossils of the Oriskany are the large brachiopods, the *Spirifer arenosus* (Conrad), *S. murchisoni* (Castelnau), and *Hipparionyx proximus* (Vanuxem), all of which are abundant in many of the outcrops in New York State.

The sandstone is composed of medium to coarse grained quartz with about 50 per cent of the grains larger than one-half mm in diameter and a few that are more than two mm in diameter. The grains are firmly cemented with calcium carbonate when freshly exposed. Upon long exposure the cementing material leaches out so that the grains of quartz may be easily separated from the rock. Many such friable blocks of the Oriskany sandstone were left in southern New York by the Pleistocene glacier or glaciers. The freshly exposed rock is white to cream colored but soon weathers to a yellow or light brown, due to the iron compounds which it contains in small amounts. The description here applies to a few of the outcrops in central New York and in particular to the type outcrop near Oriskany Falls. In some of its outcrops it is characterized by pebbles or nodules of either chert or limestone, or phosphorite, or shale or several of these occurring together.

The thickness and character of the Oriskany are inconsistent in its outcrops in New York. Its thickness varies from zero to 15 feet. Near Oriskany Falls it is about 10 feet, but a few miles west, in the Stockbridge valley, it is absent, the Onondaga limestone resting directly upon the Helderberg limestones. Such variations in thickness are the rule in its east-west extension across central and west-

"Deep" Gas Wells in the Wellsville Quadrangle

NO.	TOWNSHIP	LOCATION	ELEVATION	DEPTH TO TULLY LS	DEPTH TO ONONDAGA LS	DEPTH TO ORISKANY SS	TOTAL DEPTH	RESULTS
423	Alfred	1 Mi. SW Alfred	2240 Feet	3705 Feet	4325 Feet	4374 Feet	....	Salt water
717	Scio	1.75 Mi. E Scio	1778 Feet	3465 Feet	4025 Feet	4092 Feet (11′)	4100 Feet	Salt water
772	Willing	.9 Mi. E Yorks Cor.	1858 Feet	4040 Feet	....	4668 Feet	4672 Feet	Salt water
773	Willing	1.4 Mi. S, 80° W, Shongo	2074 Feet	....	....	4838 Feet	4842 Feet	9 Mil. (H_2O)
774	Willing	.5 Mi. N, 30° W, No. 773	1855 Feet	3992 Feet (50)	4616 Feet	4647 Feet	4703 Feet	Salt water
775	Willing	.4 Mi. N, 75° W, No. 773	2065 Feet	4150 Feet (48)	4907 Feet	4939 Feet	4953 Feet	Salt water
776	Willing	.8 Mi. N, 65° W, No. 773	1723 Feet	3824 Feet (47)	4403 Feet	4436 Feet	4444 Feet	20 Mil.
777	Willing	1.2 Mi. W No. 773	2091 Feet	4152 Feet	....	4754 Feet	4758 Feet	33 Mil.
778	Willing	1.2 Mi. N, 80° W, No. 773	2006 Feet	4114 Feet	....	4722 Feet	4724 Feet	7.5 Mil.
779	Willing	1.2 Mi. S, 80° W, No. 773	2100 Feet	4141 Feet (55)	4718 Feet ?	4750 Feet ?	4757 Feet ?	35 Mil.
780	Willing	1.3 Mi. S, 55° W, No. 773	2186 Feet	4262 Feet	....	4886 Feet	4891 Feet	13 Mil.
781	Willing	2 Mi. S, 60° W, No. 773	2135 Feet	4205 Feet	....	4861 Feet	4865 Feet	11 Mil.
782	Alma	.9 Mi. N, 15° W, No. 781	1706 Feet	3842 Feet	....	4428 Feet	4434 Feet	35 Mil.
783	Alma	.75 Mi. N, 10° W, No. 781	1830 Feet	3920 Feet (42)	4472 Feet	4520 Feet	4524 Feet	11 Mil.
784	Alma	.4 Mi. N, 30° W, No. 781	1959 Feet	4000 Feet	....	4627 Feet	4631 Feet	20 Mil.
785	Alma	.3 Mi. N, 30° W, No. 781	2211 Feet	4327 Feet (79)?	4894 Feet	4932 Feet	4941 Feet	50 Mil.
786	Alma	.4 Mi. N, 60° W, No. 781	1954 Feet	3991 Feet	....	4609 Feet	4614 Feet	25 Mil.
787	Alma	.75 Mi. N, 55° W, No. 781	2110 Feet	4180 Feet (59)	4754 Feet	4781 Feet	4792 Feet	25 Mil.

The records given above include all of the "deep" drilling in the Wellsville quadrangle to June 1936. Most of the figures were obtained through the courtesy of the North Penn Gas Company, Port Allegany, Pa., and Dr John R. Reeves of Coudersport, Pa. Some were obtained through the courtesy of the drillers. The figures in parentheses show the thickness of that particular bed.

ern New York. The pebbles or nodules mentioned are most likely to be present when the formation is very thin, with only a few pebbles representing it in some outcrops. The Oriskany thickens to the south and in the Tioga gas field in Pennsylvania an average thickness of 45 feet is reported, (Cathcart 1934*b*, p. 21). The known records of the "deep" wells indicate a thinning of the sandstone toward the west with a thickness of 10 feet in northern Potter county, just south of the Wellsville quadrangle.

The elevation of the type outcrop near Oriskany Falls is about **1160 feet above** sea level. The elevation of the Oriskany sandstone in the State Line gas field is 2600 to 2800 feet below sea level, or a drop of nearly 4000 feet from the type outcrop. The State Line field is about 145 miles S. 64° W. from Oriskany Falls, which shows the Oriskany to have an average slope of 26 feet a mile in that direction. (The true direction of dip, or the direction of maximum dip of the Oriskany is to the south and in the Wellsville quadrangle it is in excess of 50 feet a mile.) It slopes from the Black and Randolph wells on the Alfred (Fir Tree) anticline to the gas field on the Smethport (Watkins) anticline averaging 37 and 35 feet respectively. Since the anticlinal areas are elevated unequally it is believed that regional dips are best obtained from neighboring synclinal areas. (Nevin 1936, 2d Ed.)

Future possibilities for oil and gas. In the early part of the present century, wells drilled to a depth of 2000 feet in New York were considered as "deep" wells. Since more recent wells have been drilled to two and three times that depth, the earlier ones are now considered as "shallow" wells. The finding of natural gas in the Oriskany sandstone indicates excellent opportunity for a large increase in gas production in New York. Although a large number of the favorable structures (anticlines) have been explored to the Oriskany, there are still others that are as yet unexplored. Some of these will likely add to the present known supply. Wells will be drilled to the Medina and other potential gas and oil reservoirs in southern New York as soon as the present supply becomes depleted. The improved methods of recovering oil from the sands has added materially to the total production and will be extended to include all of the old oil pools of New York. Oil and natural gas will continue for several years as important natural resources of New York. Its greatest natural gas field, the State Line, was not thoroughly explored in 1936.

WATER SUPPLY

Water, one of the cheapest and at times the most precious product of nature, is bountifully supplied to the inhabitants of the Wellsville quadrangle. The region is well drained by surface slopes and yet the bedrock is sufficiently porous to hold a good supply of water in reserve. The top of the watertable (surface of the ground water) is seldom more than a few tens of feet below the surface. No one who has the industry to dig or drill a well should lack for an abundant supply of water of excellent quality. This fact is evident from the number of fine springs in the area. Some of these continue to flow through long although infrequent periods of drought.

The ground water of the Wellsville quadrangle is fairly hard. The great abundance of sandstones in the area would seem to indicate that the waters should be soft, but many of the sandstones contain calcareous cement and some of them contain almost enough calcium carbonate to justify their being classed as limestones. Traces of iron are present in practically all of the rocks and there are a few beds that can be considered as low grade iron ores. The rocks along some of the streams are sometimes stained by the hydrated iron oxides.

Water power is not utilized to any great extent in the area, but should there be a need, the Genesee river and some of its tributaries contain excellent potentialities. Many of the tributaries have narrow steep-sided valleys which could be easily dammed for commercial use.

Flood control is at present a subject of great interest to the people of southern New York and elsewhere. This interest was stimulated by the great property losses suffered through the floods of 1935 and 1936. There seems to be little danger of especially damaging floods in the Wellsville quadrangle except by extremely heavy and long-continued precipitation. The Genesee River valley is large and probably has sufficient slope to facilitate the safe conveyance of the waters out of the area under normal weather variations. The area is only a few miles from the source of the Genesee and the area of the catchment basin is relatively small. There is always the possibility of an extremely heavy flood, but the danger from this is slight as compared to some of the other localities of southern New York. There is local danger of flooding in some of the tributaries of the Genesee, such as was experienced in Vandermark creek in 1936. The small extent of the damage would hardly justify the expense of constructing dams for flood control.

INTERESTING PLACES IN THE WELLSVILLE QUADRANGLE

Fossils representing animals that lived many millions of years ago and beautiful crystals of minerals formed by nature are interesting to look at when displayed in the cases in museums. It is perhaps more exciting to the majority of persons actually to find some of these specimens in their natural rock environment. For that reason it is believed to be advisable to describe a few localities where fossils can be easily found. Map 2, Areal Geology, has been prepared so that the reader can go directly to the rock outcrops described in this bulletin. The x placed at the base of each section marks its location. The elevation of the base of the section above sea level is also given. Although there are no such striking examples of rock outcrops as can be seen at Letchworth Park, on the Genesee river, or at "Olean Rock City" near Olean, there are many interesting geological phenomena in and near the Wellsville quadrangle.

Many of the beds of rock found in the northern part of the area are very fossiliferous. The thicker layers of sandstones contain an abundance of brachiopods like the ones pictured in figure 5. The *Spirifer disjunctus* is by far the most common form of brachiopod present but other forms are quite numerous. *Athyris angelica,* another common brachiopod, is more readily found in the softer rocks, the argillaceous shales. There is a rock outcrop about one-half mile southeast of Scio which is an excellent place to collect some Machias fossils. To reach this place, take the macadam road to the east from Scio and follow Vandermark creek. Just around the first large right-hand bend of the road, the outcrop can be seen on the southwest bank of the stream, and is easy to reach except in time of high water. Another outcrop bearing Machias fossils, also easily accessible, is at Withey, where the road crosses Phillips creek in the northwest part of the northwest section of the Wellsville quadrangle. This location can best be reached by traveling the hard-surfaced road east from Belmont. Only a little more than a mile southeast of Withey the cross-bedded, crystalline limestone of the Wellsville formation may be seen in outcrop. It is on the north side of the hill, about two-thirds of the elevation from the bottom to the top of the hill. It is marked station 512 on the map and can be reached by a secondary road.

The Cuba sandstones can be seen at two places in the quadrangle: at station 468, about two miles east of Scio where the rock towers above the road on the north side of Vandermark creek, (the Cuba sandstones are near the top of the exposed rock section), and at station 760, about one mile south of Alfred, which can be reached by a dirt road joining the Alfred-Andover highway on the west side, about a mile north of Tip Top.

Some of the Wellsville formation may be seen by walking up the creek which crosses the corporation limits of Wellsville on the northwest corner. There is a very fossiliferous layer of calcareous siltstone in the creek near the city boundary. Some of the *Productella* sp., pictured in figure 9M, may be found a few hundred yards farther up the stream. They are abundant in the thin layers of hard brown sandstone.

Perhaps the most interesting fossils to be found in the Wellsville area are the sponges, pictured in figure 10, from the Hinsdale formation. The famous sponge collection of Edward Hall is well known to many of the people of Wellsville. Many of the sponges were found in the Wellsville quadrangle. In collecting material for this paper, the writer found the best sponges at station 572, two miles northeast of Andover. The outcrop is along a dirt road at an elevation of about 1975 feet above sea level or almost 300 feet above Andover. The sponges were all found in a chocolate-brown siltstone layer of the rock section. Some few sponges were found in the rock on the west side of the Wellsville, New York-Genesee, Pennsylvania highway, near the boundary line between the two states. The latter place did not prove to be prolific in sponges.

The waters of late Devonian time were apparently teeming with fish, for their scales may be seen in almost any of the conglomerate beds of the Whitesville, Germania and Cattaraugus formations. The scales, generally a gunmetal blue or a bluish white, are usually about the size of one's smaller fingernails. Pink or salmon-colored fish spines can frequently be seen in the conglomerates.

Some of the Whitesville conglomerates may be seen on the road extending to the south from Elm Valley. The better exposures are fairly near the top of the steeply ascending part of the road. There are also many excellent exposures of the Whitesville beds near the village of Whitesville.

The Germania sandstones are more characteristically marked than any other strata present in the area. They are thin (less than one foot in thickness), hard and have a green and red coloring when freshly exposed, but weather to a mottled green and buff coloring upon long exposure. They may be seen at elevations of from 2000–2300 feet in most of the southern half of the quadrangle. Samples of these sandstones may be seen on the dirt roads to the north of Cryder creek at stations 647 and 79 in the west-central part of the southeast section.

Conglomerate beds of southwestern New York and northwestern Pennsylvania have for some time been famous for their beauty in outcrop and for their importance in attempted correlations by geologists. The round quartz-pebble Olean conglomerate of Pottsville age is easily recognized. "Olean Rock City," previously mentioned, shows an excellent outcrop of this rock and is worthy of a visit. The most eastern outcrop of the Olean conglomerate in New York State may be seen on Alma hill in the Belmont quadrangle, one-half mile west of the west-central edge of the southwest section of the Wellsville quadrangle.

There is much less agreement on the age and extent of the many older flat pebble conglomerates found in this area. Because they occur only at high elevations in the Wellsville area and are underlain and overlain by shales which break down easily, it is difficult to find an outcrop of them. One of the better known of the flat pebble conglomerates, the Wolf Creek, may be seen near the top of a hill a little more than a mile northwest of Andover. Large blocks of it may also be seen on the east side of the road, about one mile south of Stannard Corners. There are a few scattered blocks of it on the north side of the hill just south of Whitesville.

Those persons who have had the happy experience of spending some time along the shore of a large body of water with a sandy bottom have no doubt noticed many simple and complex patterns made upon the surface of the sand by the moving water. Such patterns are associated with shallow water, whether they are the ones forming in the sands today or are the ones left in the sands of the seas of the geological past. There are so many outcrops in the Wellsville area that show sandstones with ripple or wave-marked surfaces that it does not seem necessary to point out any one particular locality. Any of the formations below the Germania and most of the outcrops occurring near the valley floors will be apt to show these markings.

Many persons have never seen a *fault*. Faults are the result of the forces within the crust of the earth breaking the layers of rocks and moving one side of the rock mass up, down or laterally with respect to the other side. They are awe-inspiring sights, when the imagination causes one to appreciate the tremendous strength that was required to shift the millions of tons of rocks and the probable hundreds of earthquakes that accompanied the shiftings. The best example of faulting in western New York known to the writer is only five miles east of the Wellsville quadrangle, in the Greenwood quadrangle. To reach this fault, take the Greenwood-Canisteo road to Slate creek and drive up the Slate Creek road about 1.7 miles to a north branch. There is a house on either side of the branch and rather close to it. Walk up this branch of Slate creek about three-fourths of a mile to a little beyond a left-hand fork. The shale beds in the outcrop on the east bank of the stream have their bedding planes in a vertical position. Other points on this fault may be seen. A brief description of it is given in this paper on pages 76 and 81.

OIL AND GAS WELLS

To the natives of southwestern New York, oil and gas wells are almost as uninteresting as telephone poles but to more than half of the population of New York they would be exciting objects to observe. This is particularly true if the drilling rig has not been moved from the location. It is also interesting to see how the pumps to several wells on an oil lease are all hooked to one large, centrally-located motor, for pumping the oil from them. Oil wells are considered from a practical viewpoint by those persons who have long worked near them but to the uninitiated they mean romance.

The visitor to the Wellsville area should not miss the opportunity of seeing some of the many wells located there. A few miles west of Wellsville, on Highway 17, many of the "shallow" oil wells may be seen from the road. Some are also easily seen from any of the dirt roads to the south of Wellsville. After seeing some of the wells drilled to the "shallow" sands it might be well to drive out to the "deep" or Oriskany gas field. High derricks and powerful motors are used to drill to depths of nearly a mile in the crust of the earth through the layers of hard solid rocks. To reach the "deep" gas field, travel the highway south from Wellsville to York Corners, a distance of about five miles, and turn to the west on a secondary road which crosses the Genesee river. At the road junction, nine-tenths of a mile west of York Corners, take the left or south road and follow Marsh and Honeoye creeks for about two miles. Honeoye creek is on the north side of the "gas field." Some of the wells will be seen from the road. Any of the local people will be glad to give directions to any particular well. The photographs in figure 36 give a comparison between a rig used to drill "shallow" wells and those used for "deep" drilling. The large derricks are often made of steel and generally tower a hundred feet or more above the well.

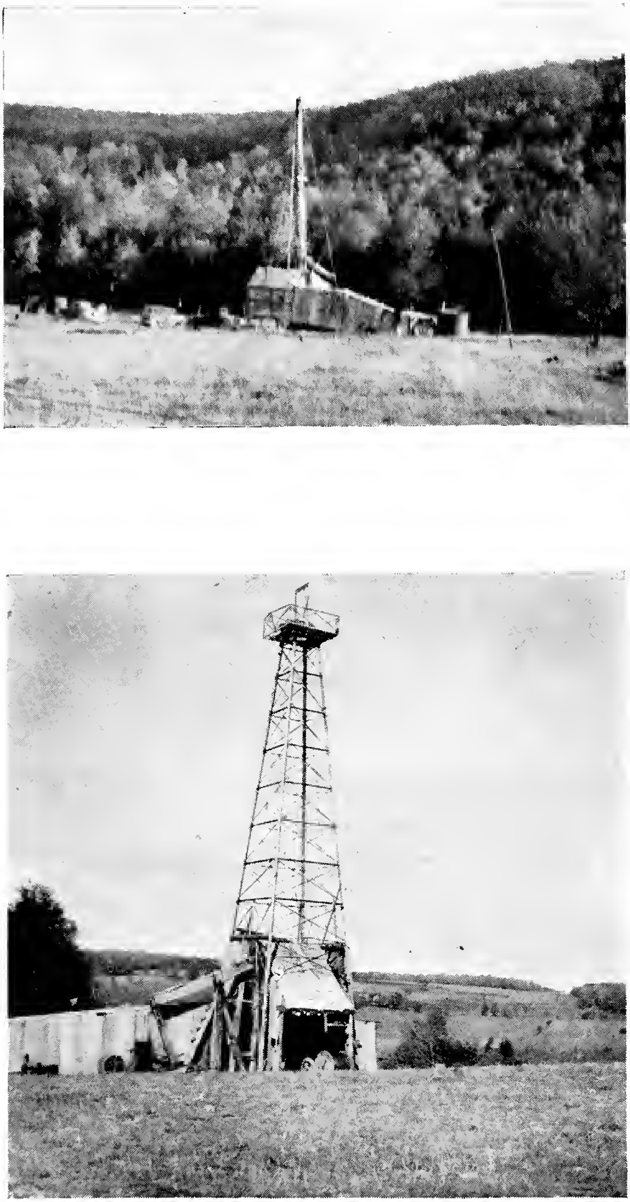


Figure 36 Oil rigs

How is Oil Formed?

Petroleum (meaning rock oil), commonly called "oil," receives its name from the fact that it is taken from rocks. But the substances composing rocks are generally inorganic whereas oil is organic. Organic substances are present in and are derived from living tissues (plants and animals). The plants and animals, from which the oil (and gas) found in the Wellsville area was formed, lived during the Devonian geological period when this area was covered by marine waters. Later they were covered by many hundreds of feet of sediments and subjected to heat and pressure. Part of the organisms were converted into the mixtures of compounds made of carbon and hydrogen (hydrocarbons) known as petroleum. Natural gas is a mixture of the lighter hydrocarbons and petroleum is a mixture of the heavier ones. The oil and gas then accumulated in the rocks which had the greatest porosity or the greatest amount of space between the constituent grains. Sandstones generally have more pore space than other rocks and become the natural reservoir in which the gas and oil collect. To be effective, the reservoir should have impervious beds of rock above and below it, thus sealing in the petroleum. Many such reservoir beds have been penetrated by the steel drills of industrious men. Many more are waiting for discovery. The treasures of oil and gas have been locked in the reservoirs for many millions of years. The oil in the Devonian rocks of the Wellsville quadrangle is estimated to be about 300 million years old.

Just exactly how the oil and gas were formed in the crust of the earth is a problem upon which scientists have spent considerable time and thought. Hundreds of pages have been written on the theories of how petroleum was formed and about the results of experiments performed in an effort to solve the problem. These can be read in the literature on geology, chemistry and physics. The nearest approach to a true solution is that small amounts of petroleum have been formed or extracted from organisms in the laboratory. Man can approach the high temperatures and great pressures present in the crust of the earth in laboratory experimentation but the factor of time (millions of years) is beyond his attainment. It is sufficient, for the purpose of this paper, to say that the petroleum was distilled from organisms (plants and animals) in a favorable environment in the crust of the earth and has accumulated in the porous beds.

BIBLIOGRAPHY

Ashburner, Charles A.

1880 The Geology of McKean County (Pa.). Pa. 2d Geol. Surv. Report R 371p.

Ashley, G. H., Cathcart, Willard & Fettke

1931 Gas in the Tioga Region (Pa.). Pa. Topog. and Geol. Surv. Bul., 102. 21p.

Bain, G. W.

1931 Flowage Folding. Amer. Jour. Sci., 22: 505–30.

Barrell, Joseph

1913 Upper Devonian Delta of the Appalachian Geosyncline. Amer. Jour. Sci., 4th Ser., 36: 429–72.

1914 Idem. 37: 87–109, 225–53.

1925 Marine and Terrestrial Conglomerates. Geol. Soc. Amer. Bul., 36: 279–342.

Butts, Charles

1903 Fossil Faunas of the Olean Quadrangle (N. Y.). N. Y. State Mus. Bul., 69: 990–95.

Campbell, M. R.

1903 Geographic Development of Northern Pennsylvania and Southern New York. Geol. Soc. Amer. Bul., 14: 277–96.

Carll, J. F.

1875 Report of Progress in the Venango County District (Pa.). Pa. 2d. Geol. Surv. Report I. 49p.

1880 The Geology of the Oil Regions of Warren, Venango, Clarion and Butler Counties (Pa.). Pa. 2d Geol. Surv. Report, I_3. 482p.

1883 Geological Report on Warren County and the Neighboring Oil Regions. Pa. 2d Geol. Surv. Report, I_4. 439p.

Caster, K. E.

1930 Higher Fossil Faunas of the Upper Allegheny (river). Amer. Pal. Bul., 15: 142–318.

1933 Stratigraphic Relations in Northwestern Pennsylvania. (Abstract) Geol. Soc. Amer. Bul., 44: 202–3.

1934 The Stratigraphy and Paleontology of Northwestern Pennsylvania. Part 1, Stratigraphy. Amer. Pal. Bul., 21, No. 71. 185p.

Cathcart, S. H.

1934*a* Gas and Oil in Potter County (Pa.). Pa. Topog. and Geol. Surv. Bul., 106. 31p.

1934*b* Geologic Structure in the Plateau Region of Northern Pennsylvania and Its Relation to the Occurrence of Gas in the Oriskany Sand. Pa. Topog. and Geol. Surv. Bul., 108. 24p.

Chadwick, G. H.

1919 Portage Stratigraphy in Western New York. (Abstract) Geol. Soc. Amer. Bul., 30: 157.

1921 Devonian Black Shales of Western New York. (Abstract) Geol. Soc. Amer. Bul., 32: 91.

1923 Chemung Stratigraphy in Western New York. (Abstract) Geol. Soc. Amer. Bul., 34: 68–69.

1924 The Stratigraphy of the Chemung group in Western New York. N. Y. State Mus. Bul., 251: 149–57.

1925 Chagrin Formation of Ohio. Geol. Soc. Amer. Bul., 36: 455–64.

Chadwick, G. H.—*continued*

1927 New Points in New York Stratigraphy. (Abstract) Geol. Soc. Amer. Bul., 38:160.

1931*a* Storm Rollers. (Abstract) Geol. Soc. Amer. Bul., 42: 242.

1931*b* Oneonta Fade-Out. (Abstract) Ibid.

1931*c* Catskill Formation. (Abstract) Ibid. p. 242–43.

1932 Pocono Problem. (Abstract) Geol. Soc. Amer. Bul., 43: 273.

1933*a* Great Catskill Delta: and Revision of Late Devonic Succession. Pan-Amer. Geol., 60: 91–107.

1933*b* Ibid. Pt. 2. Areal Refinements. p. 189–204.

1933*c* Ibid. Pt. 3. Revised Correlations. p. 275–86, 348–60.

1933*d* Hamilton Catskill. (Abstract) Geol. Soc. Amer. Bul., 44: 77.

1933*e* Ibid. Upper Devonian of the New York Region. (Abstract) p. 177.

1935 Faunal Differentiation in the Upper Devonian. Geol. Soc. Amer. Bul., 46: 305–42.

Chamberlin, T. C. & Salisbury, R. D.

1906 Geology, Earth History. v. 2. Henry Holt and Co.

Clarke, John M.

1901 Preliminary Statement of the Paleontologic Results of the Areal Survey of the Olean Quadrangle. N. Y. State Mus. 55th Annual Rep't Bul., 49: 524–28.

1903*a* Type Specimens of Paleozoic Fossils. N. Y. State Mus. Bul., 65. 847p.

1903*b* Construction of the Olean Rock Section. N. Y. State Mus. Bul., 69: 996–99.

Cooper, G. Arthur

1930 Stratigraphy of the Hamilton Group of New York. Amer. Jour. Sci., 19. Pt. 1:116–34. Pt. 2:214–36.

1933 Stratigraphy of the Hamilton Group of Eastern New York. Geol. Soc. Amer. Bul., 44:200–1. (Abstract)

Cushing, H. P.

1912 The Age of the Cleveland Shale of Ohio. Amer. Jour. Sci., 4th Ser., 33: 581–84.

Darton, N. H.

1893 The Stratigraphic Relations of the Oneonta and Chemung Formations in Eastern Central New York. Amer. Jour. Sci., 3d Ser., 45:203–9.

Decker, C. E.

1920 Studies in Minor Folds. Univ. of Chicago Press. 89p.

De Terra, H.

1931 Structural Features in Gliding Strata. Amer. Jour. Sci., 21:204–13.

Eller, E. R.

1935 Remarkable Assemblage of Paleozoic Sponges. Pan-Amer. Geol., 63:203–6.

Fridley, Harry M.

1929 Identification of Erosion Surfaces in South Central New York. Jour. Geol., 37: 113–34.

Fuller, Myron L.

1903*a* Geology of the Gaines Quadrangle (Pa.). U. S. G. S. Folio 92.

1903*b* Geology of the Elkland-Tioga Quadrangles (Pa.). U. S. G. S. Folio 93.

Glenn, L. C.

1903 Devonic and Carbonic Formations of Southwestern New York. N. Y. State Mus. Bul., 69:968–89.

Hall, James
1838–39 Third Annual Rep't of the Surv. of the Fourth Geol. Dist. of the State of New York. p. 287–347.
1840 Fourth Annual Rep't of the Surv. of the Fourth Geol. Dist. of the State of New York. p. 401–11.
1876 On the Geology of the Southern Counties of New York and adjacent parts of Pennsylvania, especially with reference to the Age and Structure of the Catskill Mountain Range. Amer. Jour. of Sci. and Arts., 3d Ser., 12:300–4.
1883 Proc. Amer. Ass'n Advancement of Sci., 31:68.

Harris, G. D.
1891 Notes on the Geology of Southwestern New York. Amer. Geol., 7: 164–78.

Hartnagel, C. A. & Russell, W. L.
1929 New York Oil Fields. Structure of Typical American Oil Fields. Amer. Ass'n Petrol. Geol., p. 269–89.

Herrick, C. L.
1891 The Cuyahoga Shale and the Problem of the Ohio Waverly. Geol. Soc. Amer. Bul., 2: 31–48.

Hobbs, W. H.
1931 Earth Features and Their Meaning. The Macmillan Co. 517p.

Jewett, E.
1862 A letter to Dr S. B. Woolworth concerning the age of the "Catskill Group." Silliman's Jour., 2d Ser., 4:418.

Johnson, Douglas
1931 Stream Sculptures of the Atlantic Slope. Columbia Univ. Press. 142p.

Kindle, E. M.
1904 A Series of Gentle Folds on the Border of the Appalachian System. Jour. Geol., 12: 281–89.
1912 The Unconformity at the Base of the Chattanooga Shale in Kentucky. Amer. Jour. Sci., 4th Ser., 33: 120–36.

——— & Williams, H. S.
1905 Contributions to Devonian Paleontology. U. S. G. S. Bul., 244. 144p.

Lahee, F. H.
1931 Field Geology. McGraw-Hill Book Co. 789p.

Leith, C. K.
1923 Structural Geology. Henry Holt and Co. 390p.

Lesley, J. P.
1892 Devonian and Silurian. Summary Final Rep't 2. Pa. Geol. Surv. 1524p.

Leverett, Frank
1901 Glacial Formations and Drainage Features of the Erie and Ohio Basins. U. S. G. S. Monograph 41. 802p.

Mather, W. W.
1840 Fourth Annual Rep't of the First Geol. Dist. of the State of New York. p. 212–34.

Merrill, Frederick J. H.
1902 Description of the State Geologic Map of 1901. N. Y. State Mus. Bul., 56. 37p.

Nevin, C. M.

1931 Principles of Structural Geology. John Wiley and Sons, Inc. 303p.

Newland, D. H. & Hartnagel, C. A.

1932 Review of the Natural Gas and Petroleum Developments in New York State. N. Y. State Mus. Bul., 295: 101–84.

1936 Recent Natural Gas Developments in New York State. N. Y. State Mus. Bul. 305:97–161.

1939 Natural Gas Developments in New York State for the Period 1935 to 1938. N. Y. State Mus. Bul. 319:109–56.

Price, Paul H.

1931 The Appalachian Structural Front. Jour. Geol., 39: 24–44.

Prosser, C. S.

1891 The Geological Position of the Catskill Group. Amer. Geol., 7:351–66.

1893 The Thickness of the Devonian and Silurian Rocks of Central New York. Geol. Soc. Amer. Bul., 4: 91–118.

Randall, F. A.

1894 Preliminary Report on the Geology of Cattaraugus and Chautauqua Counties. N. Y. State Mus., 47th Annual Rep't p. 713–21.

Schuchert, Charles

1923 Sites and Nature of the North American Geosynclines. Geol. Soc. Amer. Bul., 34: 151–230.

Sheldon, P.

1912 Some Observations and Experiments on Joint Planes. Jour. Geol., 20: 53–183.

Sherrill, R. E.

1934 Symmetry of Northern Appalachian Foreland Folds. Jour. Geol., 42: 225–47.

Sherwood, Andrew

1880 The Geology of Potter County (Pa.). Pa. 2d Geol. Surv. Rep't G_3. 121p.

Stevenson, John J.

1892 The Chemung and Catskill (Upper Devonian) on the Eastern Side of the Appalachian Basin. Amer. Geol., 9: 6–33.

Van Hise, C. R.

1894–95 Principles of North American Precambrian Geology. U. S. G. S. Sixteenth Annual Rep't p. 581–843.

Von Engeln, O. D.

1929 Interglacial Deposit in Central New York. Geol. Soc. Amer. Bul., 40: 469–80.

1932 The Finger Lake Region. Sixteenth International Geol. Congress, Guide Book 4. p. 39–69.

Wedel, A. A.

1932 Geological Structure of the Devonian Strata of South Central New York, N. Y. State Mus. Bul., 294. 74p. with Map.

White, David

1900 Relative Ages of the Kanawha and Allegheny Series as indicated by the Fossil Plants. Also remarks on this paper by H. S. Williams. Geol. Soc. Amer. Bul., 11: 594–95.

White, I. C.

1881*a* The Geology of Susquehanna and Wayne Counties, (Pa.) Pa. 2d Geol. Surv. Rep't G_6 243p.

1881*b* The Geology of Erie and Crawford Counties. Pa. 2d Geol. Surv. Rep't Q_4. 406p.

Willard, Bradford

1933 "Catskill" Sedimentation in Pennsylvania. Geol. Soc. Amer. Bul., 44:495–516.

1934 Early Chemung Shore Lines in Pennsylvania. Geol. Soc. Amer. Bul., 45:897–908.

Williams, H. S.

1881*a* Channel-fillings in Upper Devonian Shales. Amer. Jour. Sci., 3d Ser., 21:318–20.

1881*b* The Recurrence of Faunas in the Devonian Rocks of New York. Proc. Amer. Ass'n Advancement of Sci., 30:186–91.

1882 The Undulations of the Rock Masses across Central New York State. Proc. Amer. Ass'n Advancement of Sci., 31:412 (Abstract).

1884*a* On the Fossil Faunas of the Upper Devonian. U. S. G. S. Bul., 3. 36p.

1884*b* Geographical and Physical Conditions as Modifying Fossil Faunas. Proc. Amer. Ass'n Advancement of Sci., 33:422–23. (Abstract)

1885 On the Classification of the Upper Devonian. Proc. Amer. Ass'n Advancement of Sci., 34:222–34.

1887 Fossil Faunas of the Upper Devonian. U. S. G. S. Bul., 41:485–603.

1895 On the recurrence of Devonian Fossils in Strata of Carboniferous Age. Amer. Jour. Sci., 3d Ser., 49:94–101.

Willis, Bailey

1892 Mechanics of Appalachian Structure. U. S. G. S. 13th Annual Rep't, Pt. 2:213–81.

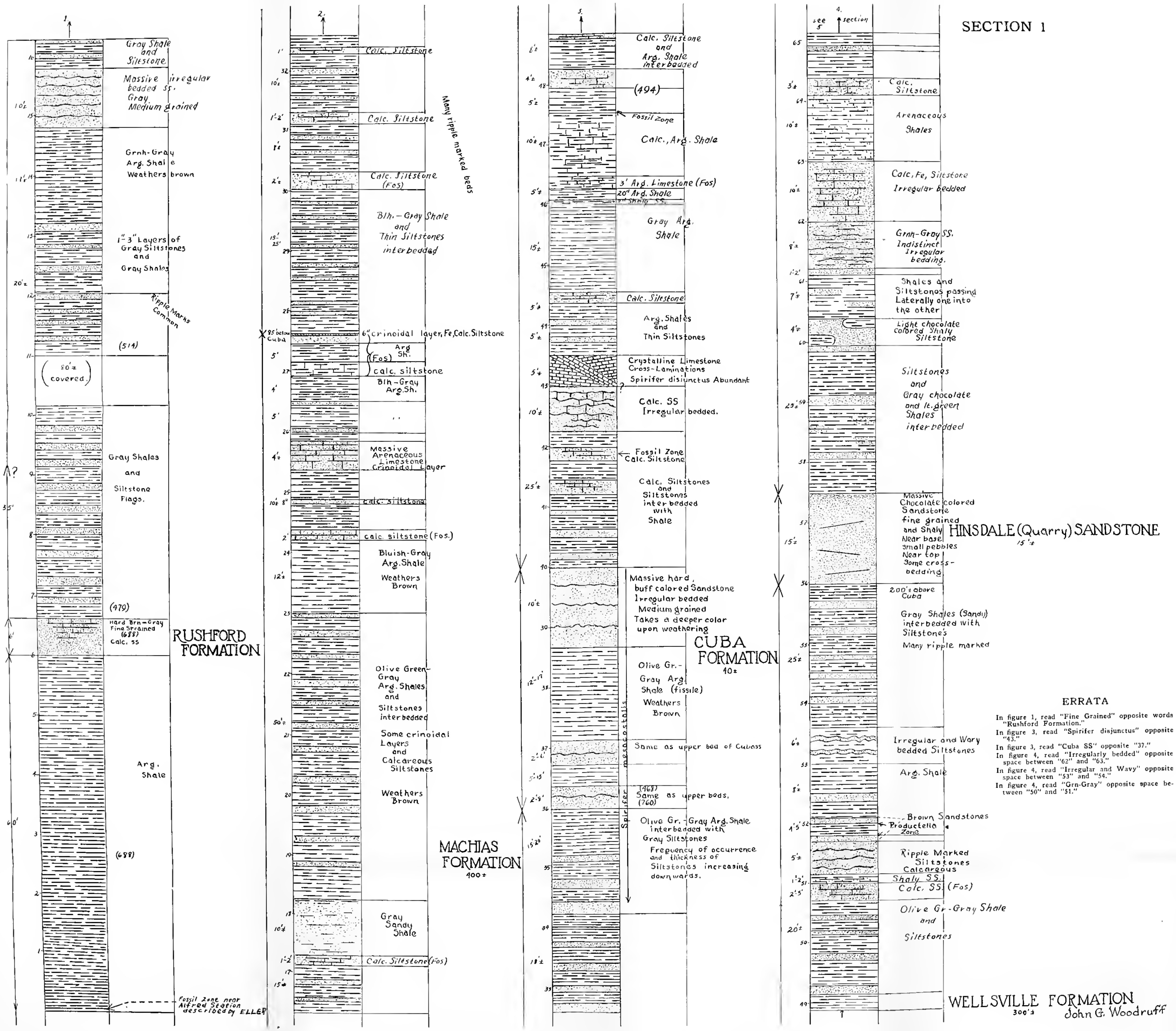
Winchell, A.

1863 On the Identification of the Catskill Red Sandstone Group with the Chemung. Silliman's Jour., 2d Ser., 35:61–62. (A letter to Professor Dana.)

INDEX

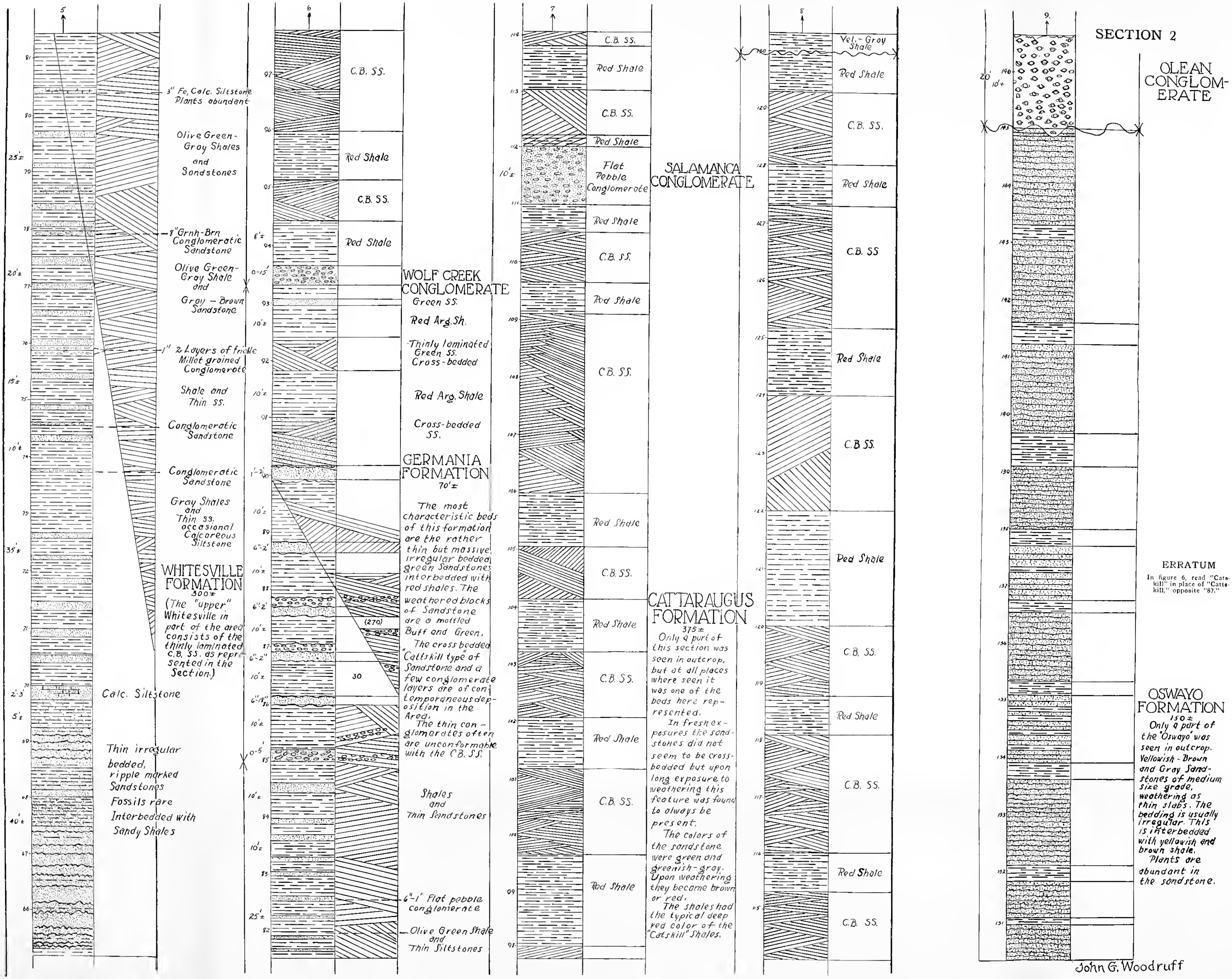
Section 1	Geologic section of the rocks in the Wellsville area
Section 2	Geologic section (continued)
Map 1	Areal geology of the Wellsville quadrangle (in colors)
Map 2	Showing distribution of rock sections
Map 3	Structural geology of the Wellsville quadrangle

SECTION 1



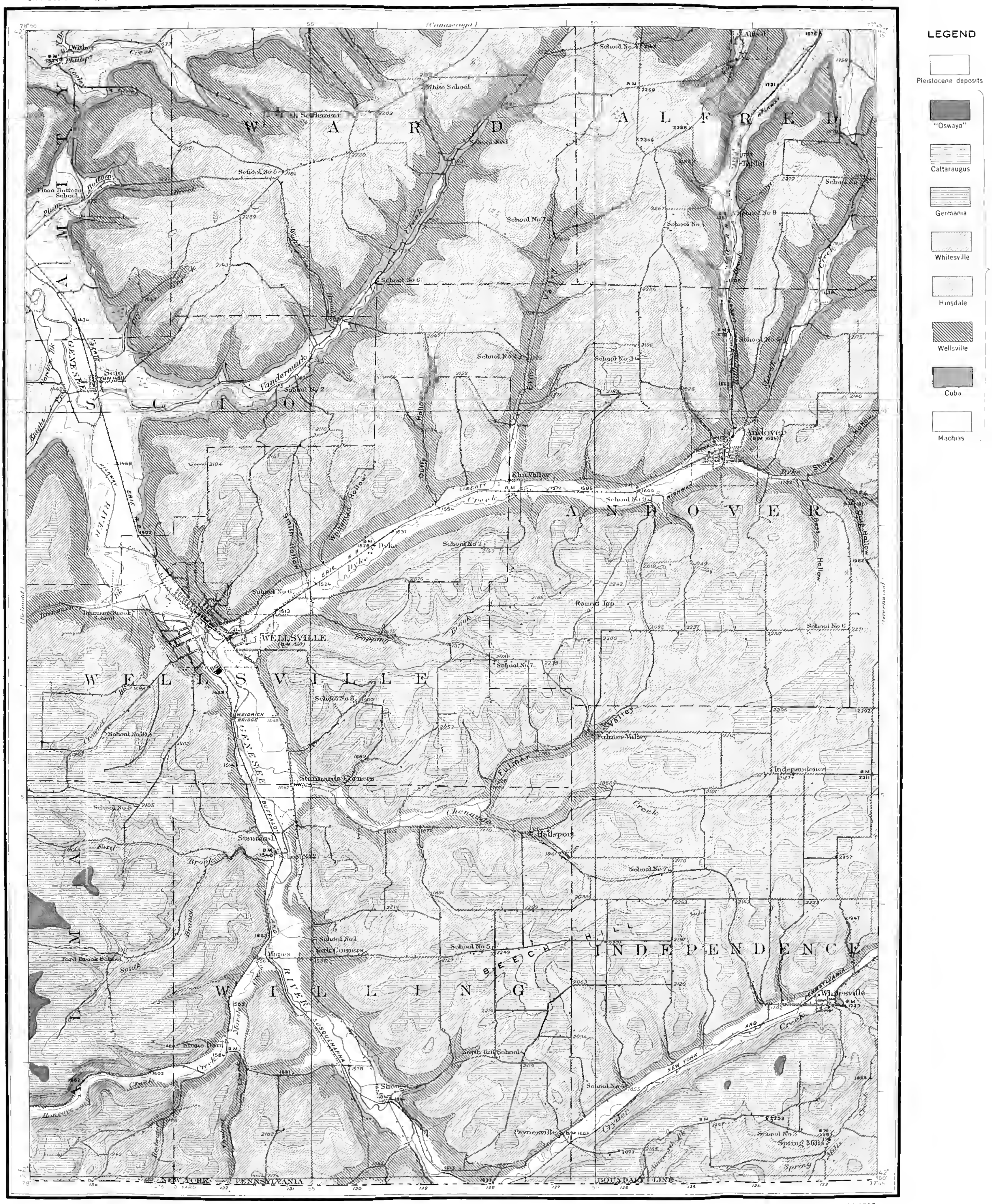
ERRATA

In figure 1, read "Fine Grained" opposite words "Rushford Formation."
In figure 3, read "Spirifer disjunctus" opposite "43."
In figure 3, read "Cuba SS" opposite "37."
In figure 4, read "Irregularly bedded" opposite space between "62" and "63."
In figure 4, read "Irregular and Wavy" opposite space between "53" and "54."
In figure 4, read "Grn-Gray" opposite space between "50" and "51."



ERRATUM

In figure 6, read "Catskill" in place of "Cattskill," opposite "87."



GEOLOGIC MAP OF THE WELLSVILLE QUADRANGLE

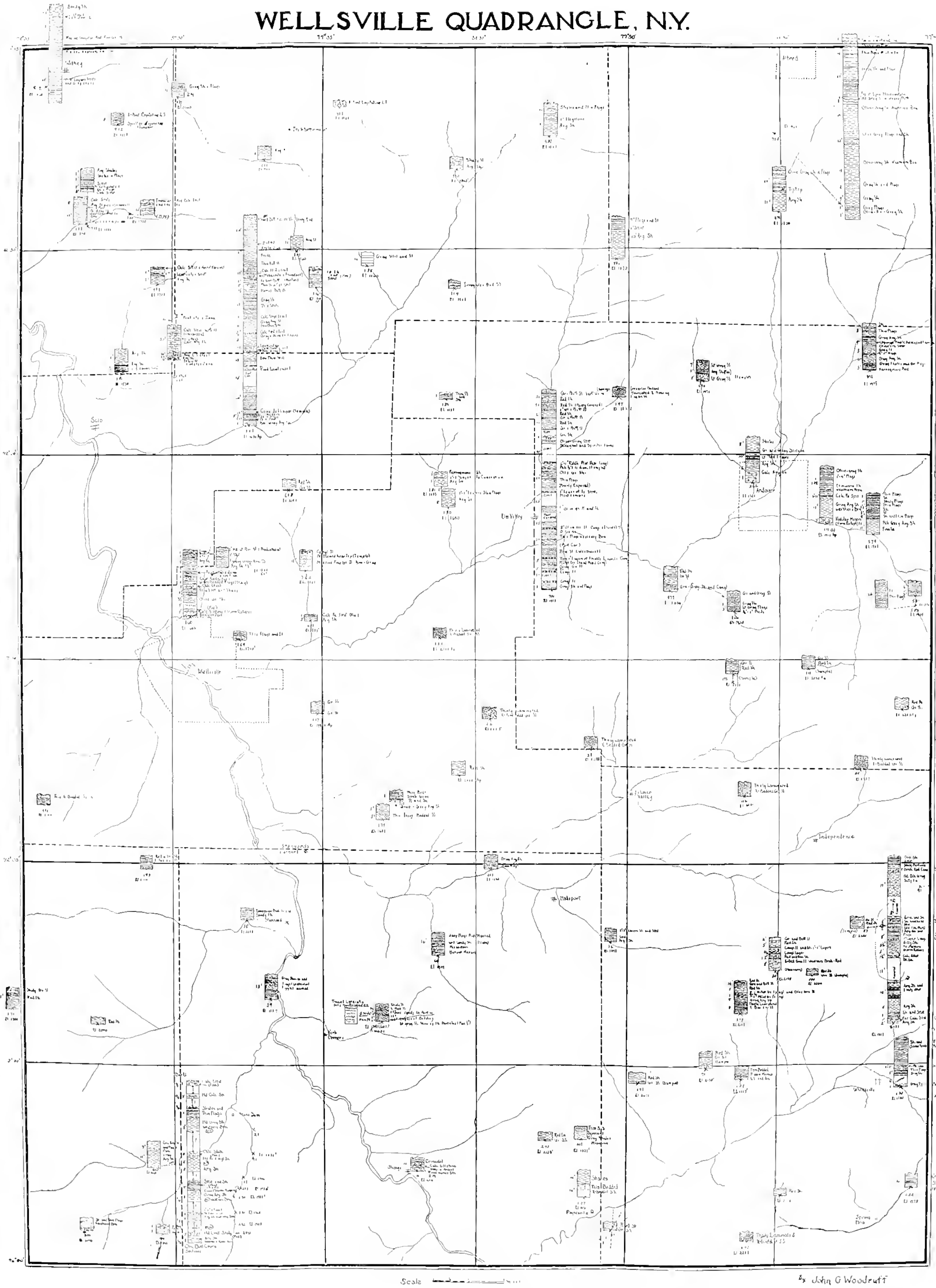
Geology by John G. Woodruff, 1932-1935

Scale 1/62500

Contour interval 20 feet

Datum is mean sea level

WELLSVILLE QUADRANGLE, N.Y.



AREAL GEOLOGY

SHOWING

× LOCATION OF OUTCROP ═ ELEVATION OF BASE OF OUTCROP ABOVE MEAN SEA LEVEL. CHARACTER OF ROCK IN OUTCROP DRAWN IN SECTIONS

THE STATION NUMBERS ARE PLACED UNDER THE FORMATION REPRESENTED AT THE BASE OF THE OUTCROP.

CATTARAUGUS FORMATION
454, 603, 674

GERMANIA FORMATION
577, 172, 313, 99, 126, 87, 30, 590, 79, 647, 121, 243, 28, 26, 320, 698, 317

WHITESVILLE FORMATION
566, 279, 630, 667, 619, 652, 615, 627, 607, 66, 32, 574, 315, 701, 547, 328, 144

HINSDALE FORMATION
572, 762, 561 (?), 35

WELLSVILLE FORMATION
562, 112 (L), 579, 581, 582, 81, 82, 480, 481, 483, 524, 535, 510, 488, 486, 755, 512, 529, 505, 716, 493, 404, 459, 560, 464, 39, 21, 46, 47, 229, 230, 231, 232

CUBA SANDSTONE FORMATION
SEE SECTIONS 468, 470

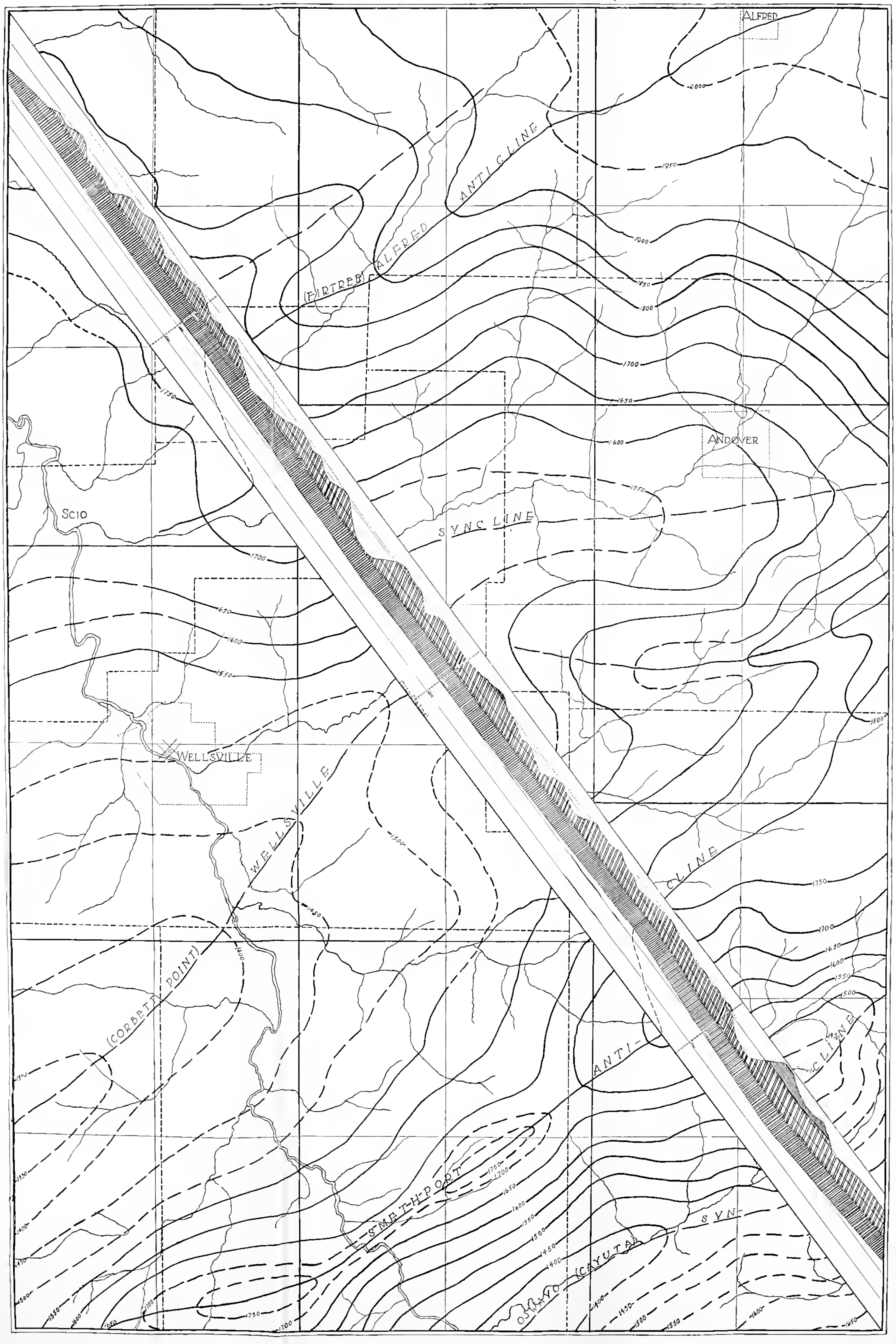
MACHIAS FORMATION
760, 470, 690, 11, 314, 517, 498, 499, 500, 468, 496

Scale

Scale of sections 1 cm = 20'

By John G Woodruff

WELLSVILLE QUADRANGLE, N.Y.



STRUCTURAL GEOLOGY

SHOWING

CROSS SECTION AND STRUCTURAL CONTOURS

VERTICAL SCALE OF CROSS SECTION – ¼" – 1000'

CONTOUR INTERVAL – 50'

KEY BEDS { BASE OF GERMANIA FORM. / TOP OF CUBA FORMATION } 300'±

LEGEND

- OSWAYO ? (MISSISSIPPIAN ?) ?
- CATTARAUGUS
- CONNEAUT { GERMANIA, WHITESVILLE; HINSDALE, WELLSVILLE (VOLUSIA), CUBA }
- CANADAWAY { MACHIAS (NORTHEAST), RUSHFORD, CANEADEA }

It should be noted that the sub-surface structure of the Oriskany sandstone horizon conforms to the surface structure in its general shape only. The regional dip, thickening of beds, and the horizontal shifting of the upper beds must be considered in determining the position of the Oriskany sandstone.

J.G. WOODRUFF