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New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 148

GEOLOGY OF THE POUGHKEEPSIE QUADRANGLE

BY

C. E. GORDON

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

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New York State Education Department

Science Division, November 5, 1910

Hon. Andrew S. Draper LL. D.

Commissioner of Education

DEAR SIR: I beg to transmit to you herewith a manuscript entitled *The Geology of the Poughkeepsie Quadrangle,* accompanied by a geological map which has been prepared under my direction by Professor Clarence E. Gordon. The work has been executed with circumspection and accuracy and I recommend the publication of the matter transmitted, in the form of a bulletin of this Division.

Respectfully

JOHN M. CLARKE

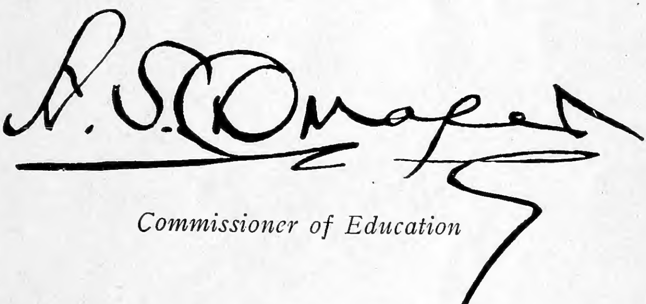
Director

STATE OF NEW YORK

EDUCATION DEPARTMENT

COMMISSIONER'S ROOM

Approved for publication this 7th day of November 1910



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GEOLOGY OF THE POUGHKEEPSIE QUADRANGLE

BY

CLARENCE E. GORDON

INTRODUCTION

The preparation of this paper was begun at the suggestion of Professor J. F. Kemp. The field work was carried on at intervals during the summers of 1906–7–8–9. During the intervening winters the extensive literature dealing with the geology of eastern New York State, western New England and the areas of similar rocks at the south was read with care.

A preliminary map of the quadrangle was prepared by a summer school party of Columbia University at work for a week under the direction of Professor Kemp, Professor A. W. Grabau and Dr C. P. Berkey. This was of great assistance in the field.

The writer owes much to Professor Kemp for kindly criticism. Dr Charles P. Berkey has offered important suggestions. Particular thanks are due Professor John M. Clarke for a generous interest which has made some of the field work easier of execution.

LOCATION AND OTHER GENERAL FEATURES OF THE QUADRANGLE

The Poughkeepsie quadrangle lies in the Hudson river valley about midway between New York city and Albany. It falls between parallels 41° 30′ and 41° 45′ north latitude and meridians 73° 45′ and 74° 00′ east longtitude, and is therefore 17.5 miles long by about 13.2 miles wide. It embraces an area of about 230 square miles. The Hudson river crosses the quadrangle from north to south near the western boundary. The river is slightly deflected to the west at New Hamburg and forms the quadrangle boundary at the southwest corner.

The larger portion of the area lies east of the Hudson in the southwestern part of Dutchess county. At the very southeast corner is a triangular bit of the township of Kent in Putnam county. West of the river is a strip of Ulster county and a block from the northeastern portion of Orange county.

Poughkeepsie, the county seat, is a city of about 25,000 inhabitants. Wappinger Falls on Wappinger creek, Matteawan on Fishkill creek and Fishkill Landing on the Hudson, opposite Newburgh, are important villages. Wappinger Falls and Matteawan are manufacturing towns and each owes its size and importance to the stream on which it is located. East of the Hudson the region is chiefly a farming country and is well adapted to tillage, grazing and fruit growing. West of the river the topography, soil and drainage are peculiarly adapted to the growing of fruit, for which the proximity of the river affords excellent climatic conditions.

Dutchess county was settled very early in the history of the State. The country is attractive. It is easy to imagine that immigrants voyaging up the Hudson through the inhospitable region of the Highlands would have been attracted by the stretches of open country which lay north of the rugged mountains.

The quadrangle is easy of access. Boats plying between New York and Albany stop at Newburgh and Poughkeepsie. The New York Central and West Shore lines, connecting with Albany and the West, follow the banks of the Hudson. The former joins with the Newburgh, Dutchess and Connecticut division of the Central New England at Dutchess Junction and Fishkill Landing, and at Poughkeepsie with the main line division of that road. At Poughkeepsie it also crosses the Highland division of the New York,

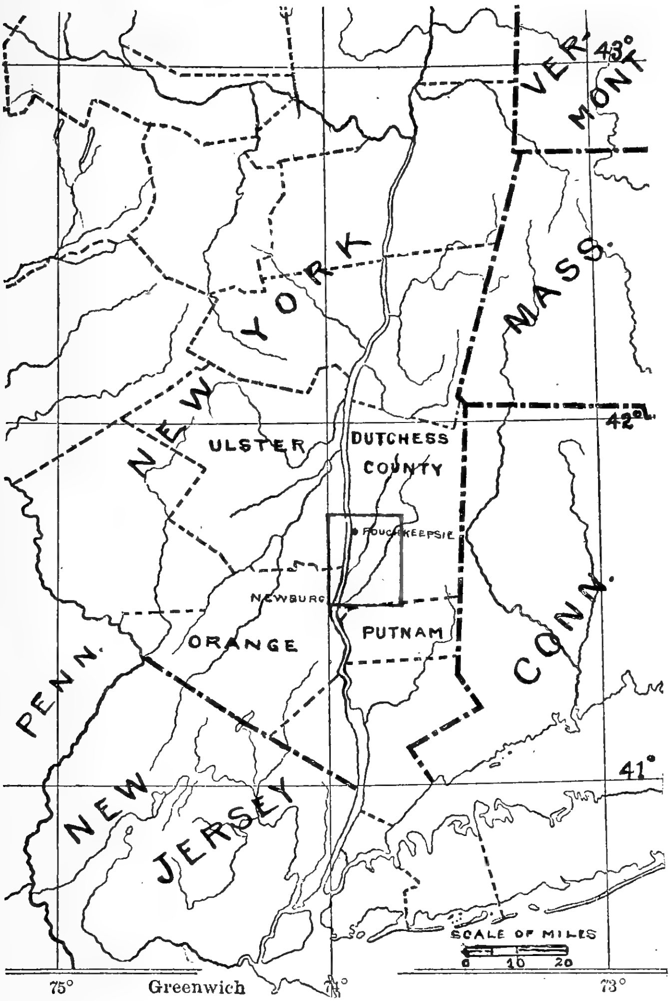


Fig. 1 Sketch map showing location of Poughkeepsie quadrangle

New Haven and Hartford. Ferries cross between Fishkill Landing and Newburgh and between Poughkeepsie and Highland on the West Shore Railroad.

TOPOGRAPHY

East of the Hudson the topography is chiefly that of a rolling upland of moderate elevation, which is due in part to the nature and structure of the underlying rock formations as affected by erosion, and in part to the mantle of glacial deposits.

Along the southern margin of the quadrangle are several rugged spurs of the Highlands. These are bold, often precipitous, and usually wooded. They are known as the Fishkill mountains, receiving their name from old Fishkill township, of which they are a part. These mountains are made up chiefly of Precambric gneisses and are flanked by and faulted with the Paleozoics of the valley.

The westernmost Highland spur is the northern extension of Breakneck mountain ridge and the part within this quadrangle is known as Bald hill (see plate 1). It has a maximum elevation of 1540 feet. The Mount Honness spur next east has an elevation of 840 feet at its northern extremity, Mount Honness proper, but reaches a height of 1300 feet near the quadrangle boundary (see plate 2). A short spur east of Honness, with an elevation of 885 feet, separates it from Shenandoah mountain, which has a maximum height of 1115 feet. East of Shenandoah mountain the Highland mass attains an elevation of 1232 feet at "Looking Rock," which is at the summit of the steep northwestern slope. This spot is widely known because of its fine view.

North of the Fishkill mountains the rocks within the quadrangle are principally shales, slates, grits, phyllites and limestones. The more metamorphic character of these strata as they are followed eastward from the Hudson finds expression in the higher elevation of the slate and graywacke in the northeastern part of the area. Here the hills in places reach a height between 700 and 800 feet. West of the Hudson the average elevation in the slates and grits is greater than on the east of the river, often attaining 400 to 600 feet. "Illinois mountain," the northern extremity of Marlborough mountain, is 1105 feet high.

In contrast to the heights is the gorge of the Hudson, which borings have shown reaches a depth near Storm King of over 700 feet.

DRAINAGE

The Hudson river is the dominating factor in the drainage of this area. The principal tributaries of the master river within this quadrangle come in from the east. The most important are Wappinger and Fishkill creeks; of lesser importance are Casper and Fallkill creeks.

Wappinger creek has its source near Pine Plains, some 16 or 17 miles northeast of Pleasant Valley, on the southwest of a narrow divide that separates its headwaters from the valley of Shekomeko creek. It has a general southwest course along a narrow limestone belt, and finally enters the Hudson at New Hamburg. At present it bears away somewhat from the limestone along its lower reaches and flows across the slates, over which it cascades gently in several places. At Wappinger Falls it makes a descent of about 60 feet over the slates, and from this village to the Hudson, a distance of about two miles, it occupies a drowned valley. It receives a few small tributaries within the quadrangle, the largest of which drains the slates southeast of Wappinger Falls and empties into the main stream below the village.

Wappinger creek furnishes power at Pleasant Valley, near Titusville, and at Wappinger Falls, and formerly was utilized at Rochdale.

Fishkill creek is a somewhat larger stream and has a greater watershed. It also drains a large part of the area just to the east, where the main stream has its source on the western slope of Chestnut ridge, a high mass of schist separating the Clove and Dover-Pawling valleys. East of the quadrangle it receives an important tributary with its source in Whaley pond. Sylvan lake sends a small tributary into this stream near the eastern edge of the quadrangle.

Several good-sized brooks join the main stream from the north. Of these Whortlekill creek is a small brook which enters the quadrangle just east of Arthursburg, about a mile from its source. It joins the Fishkill about a mile south of Hopewell Junction. Jackson and Sprout creeks are larger. The former drains the western slope of the ridge between Lagrangeville and the Clove valley, while the headwaters of Sprout creek extend to the narrow ridge northeast of Verbank, whose eastern slopes drain into the Dover-Pawling valley. Sprout and Jackson creeks join north of Fishkill Plains and the stream formed by their union flows into Fishkill creek, two miles north of Brinckerhoff.

Plate I

A view of Bald hill, shown in the left half of the picture, as seen from Mount Beacon

Plate 2

View of the Mount Honness spur of the Fishkill mountains, as seen from near the village of Glenham. The eminence on the left of the picture is Mount Honness proper

Several brooks which drain the northern slopes of the Fishkill mountains and the valleys between them join Fishkill creek from the south. Of these, the largest are those leaving the Highlands through Shenandoah hollow and the valley of East Fishkill Hook, and " Clove creek " south of Fishkill Village. Fishkill creek furnishes power at Hopewell, Brinckerhoff and Matteawan.

Casper creek rises near the northern boundary and flows southwest in a rather wide valley to the Hudson which it joins two and one-half miles north of New Hamburg.

Fallkill creek drains a large area to the north. It flows in a general southwest course to Poughkeepsie where it turns on itself, and, making a large loop, flows north for one-half of a mile and then west to join the Hudson.

Several brooks, but none of any size, drain the slopes on the west of the Hudson.

There are no natural lakes or ponds of conspicuous size within the quadrangle. Those of any consequence apparently date from the time of the retreat of the ice sheet from this region.

GENERAL GEOLOGY

The Fishkill mountains belong to the Highlands province of Precambric rocks. These have their greatest development in Putnam county just to the south. The spurs that have been mentioned are the northern terminations of ridges of gneisses which have a general northeast-southwest trend. Above Peekskill these gneisses are continued across the Hudson into New Jersey. Eastward they extend into Connecticut.

The summits of the Fishkill mountains, with those of neighboring ones at the south, present a fairly even sky line which may be followed northeastward along the crests of the ridges of the younger rocks. This general uniformity of level is believed by many to mark a former peneplain in this region toward the close of Cretacic time (see plate 3).

North of the Fishkill mountains are the younger rocks of the area. In general, these do not now tend to climb far up the flanks of the older masses. In most cases the two are faulted against each other and the rocks of the mountains reach close to their bases. In a few places the younger strata extend up a moderate distance on the older rocks and are disturbed relatively little.

These younger strata rest unconformably upon the Precambric. They are the southwestward representatives of the rocks of western Massachusetts and Vermont and are now known to include strata which range in time from the base of the Paleozoic to the upper part of the Ordovicic period. Northeastward these rocks extend into Massachusetts and Vermont and southwestward into New Jersey, Pennsylvania and beyond.

Within the quadrangle they are of considerably lower average elevation than the gneisses of the mountains. This reduced elevation is believed to represent the erosion that has taken place in these rocks below the Cretacic level after the peneplain had been elevated at the close of Cretacic time.

So far as now known, these younger strata have no later rocks older than the Quaternary overlying them within the limits of the quadrangle.

PREVIOUS GEOLOGIC WORK

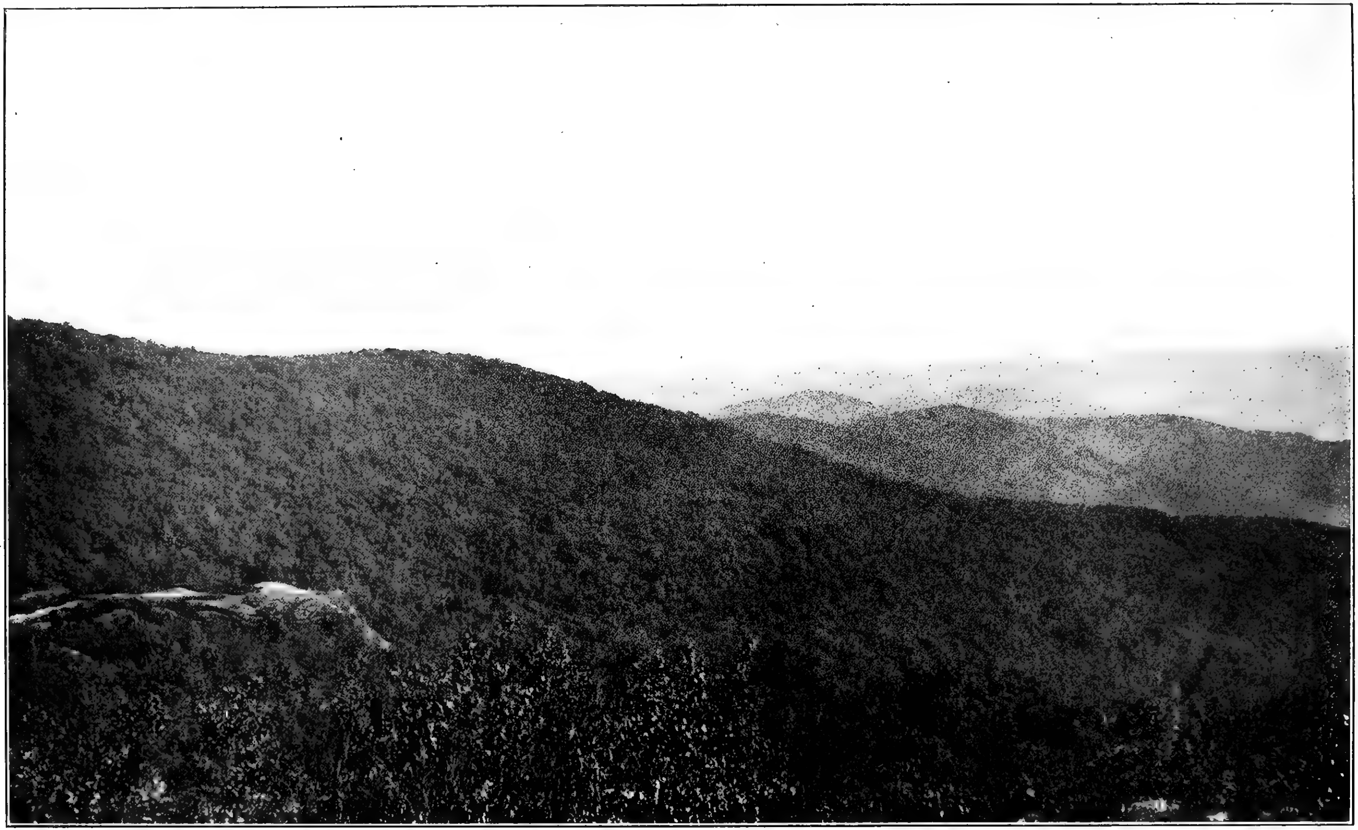
Because of the extensive geographic development of these rocks and their difficult geology there has appeared, during the last fifty years or more, a large body of literature dealing with them throughout their length and breadth. The work has been carried on under the auspices of State and federal surveys and by private enterprise. Work within this quadrangle was undertaken early in the history of serious geological investigation in this country.

In 1843 W. W. Mather submitted his quarto report on the Geology of the First District of the State of New York. This dealt with southeastern New York and was the first important contribution bearing on the geology of this area. With the exception, perhaps, of an excursion by Sir William Logan and James Hall in 1864, which resulted in the assignment of the younger rocks of this and neighboring areas to Logan's Quebec Group, and which introduced much confusion at the time, no other important contribution was made until 1878.

In that year T. Nelson Dale discovered fossils in the slates at Poughkeepsie. The fossils were assigned by Hall to the "Hudson River Group." The find attracted the attention of Professor J. D. Dana to the strata of southern Dutchess county. This eminent geologist, what the time was working at the difficult stratigraphy of western Massachusetts and the neighboring portion of New York State, now traced the limestones from the north to the Hudson river, discovered fossils in them at Pleasant Valley, and discussed their general geologic significance.

Apparently through the influence and encouragement of Dana, Professor W. B. Dwight began his fruitful investigations in the Wappinger limestones of Dutchess county. Professor Dwight's papers were published at intervals from 1879 to 1900. His investi-

Plate 3



A view from Mount Beacon southwestward along Breakneck mountain, across the Hudson river, showing the dissected Cretacic peneplain. The rounded dome of Storm King is shown on the right of the picture in the distance

gations greatly extended our knowledge regarding the age of the Wappinger limestones, particularly those of the Wappinger creek belt.

In 1886 J. C. Smock, as a part of a preliminary report on the Precambric rocks of the Highlands east of the Hudson, discussed the gneisses of the Fishkill mountains. But notwithstanding these contributions, the areal geology has not been mapped in detail up to the present time.

STRATIGRAPHICAL TABLE

PERIODS	SEDIMENTARY		ERUPTIVES
	Formations	Terranes	
Quaternary	Alluvium	Recent	
	Terraces Kames Drumlins (Unconformity)	Glacial	
Ordovicic	"Hudson River" slates, grits and phyllites	? Utica? Trenton	Hortontown hornblende rock
	Wappinger limestones and dolomites, in part	Trenton (Disconformity) Beekmantown	
Cambric	Wappinger limestones and dolomites, in part	(Disconformity?) Potsdam ? Georgian	
	Poughquag quartzite (Unconformity)	Georgian	
Precambric	Gneisses of the Fishkill mountains and inliers of these rocks	"Grenville"	Shenandoah granite Bald Hill granite gneiss

THE PRECAMBRIC GNEISSES

DISTRIBUTION

Within the Fishkill mountains the boundary of these rocks, as shown by the map, follows closely the lower contour lines of the spurs.

The Glenham belt is an inlier of these rocks. It has the same trend as the ridges of the gneisses in the Highlands and extends as a narrow strip from a point just north of the carpet mill at Glenham northeastward to "Vly mountain."[1]

[1] The hill marked Fly mountain on the map is just southeast of what, in this vicinity, is called Vly mountain, corrupted to Fly mountain. The swamp just south of the eminence doubtless suggested the name (Vly-swamp).

South of the Glenham belt, in the town of Matteawan, are two smaller inliers of the gneisses connecting the Glenham belt with the Highlands.

Between the rocks of the Highlands and those composing the masses of inliers there are some differences which help to throw light on the history of both. There are also marked resemblances which apparently serve to clinch their relationship.

PROBLEM OF THE GNEISSES

The study of the gneisses speedily develops very puzzling problems, which in all cases may not admit of satisfactory solution. In some way these rocks must express the several successive changes which they have experienced. A complex history is suggested, but all its events are not easy to trace.

PROMINENT STRUCTURAL FEATURES

The most impressive feature of the gneisses is the northeast-southwest alignment of the ridges which constitute their outcrop. Between the ridges are parallel longitudinal valleys. From the published descriptions, these features, with some exceptions, seem to hold for the entire Highlands and to extend southward into Westchester county.

The gneisses are uniformly banded or foliated throughout their entire breadth from west to east, and the strike of the foliations in general follows the trend of the ridges. In a few places only does the foliation approximate schistosity in any degree.

Over most of the area there is an easily distinguishable arrangement in parallel stratalike masses which also follow the topographic features. These do not show an orderly repetition, though masses of very similar mineralogy are irregularly repeated. Occasionally more massive types occur, but these, too, seem to follow the structural features just mentioned. The prevailing dip of the foliation planes to the southeast imparts a strongly isoclinal character.

The ridges clearly date from Postcambric time. It seems reasonable to infer that the other structural features just outlined have a common origin and belong to an earlier epoch.

There is much evidence of extensive faulting which is developed chiefly, or at least most prominently, along the strike. Such faulting might easily account for the lack of orderly repetition of characteristic rock types. Most of this faulting belongs to the disturbance that produced the ridges. The gneisses clearly show the effects of repeated orogenic disturbances.

In some places it is clear, from the position and structure of the overlying younger rocks, that most of the features of the gneisses date from Precambric time. Where the relationship of the basal quartzite to the underlying gneiss is most plainly seen, as in the West Fishkill Hook,[1] the latter stands at a high angle with a uniformly northeast-southwest strike, while the quartzite dips at a low angle with varying strike. In other places the discordance between the dips and strikes is plainly discernible. The quartzite has been folded relatively little in many places, and never within this quadrangle to the extent shown by the gneisses. Faulting, instead of extreme folding, occurred in connection with Postcambric movements within the gneisses.

The early crystalline condition of the gneisses would have favored faulting and shearing and would have prevented much later folding within them. It is certain that the isoclinal character is of Precambric age.

It seems possible, therefore, in a large way, to apportion the structural features of these gneisses as seen in the field among orogenic movements of Precambric and later time. It is quite uncertain how many different disturbances may have occurred in Precambric time and whether all the later structural features are of similar age.

The lines of foliation, as seen in outcrops, are usually rectilinear. When wavy, they are only slightly so. This latter feature seemed most noticeable on Shenandoah mountain. Crinkling is rare. Two or three instances of it were noted in the Glenham belt. Jointing is common and frequently gives the appearance of thick exfoliation.

Faults are divisible into two kinds, reversed and normal. It seems most likely that the normal faults followed the compression that produced the thrusts and are therefore of the nature of adjustments. All the faults that have been noted appear to belong to the great mountain building process of Ordovicic time which elevated the Paleozoics of the Green mountain belt. This is indicated by the relations which exist between the younger and older rocks and by the fact that the fault lines of the mountains are projected north-

[1] The recesses east and west of the short spur that separates Mount Honness from Shenandoah mountain are respectively known as East and West Fishkill Hook.

ward into the younger strata, where they show features that leave their age unmistakable.

Doubtless in some cases what now appear to be reversed faults of moderate displacement within the gneisses, or along contacts, are truncated thrusts of large size. This inference is borne out by the presence of large thrusts in the Paleozoics at the north.

It would appear that not only did distinct normal fault breaks occur as the result of adjustments following the elevation of the Green mountains, but that normal slips occurred along the planes of the earlier thrusts.

This feature is best shown in the relations now existing between Bald hill and the Mount Honness spur, and in similar ones between Shenandoah mountain and the mass of gneiss at the east of it. In these two instances the Paleozoics have clearly been dropped back between the gneiss spurs with a large throw on the west, marked in one case by the scarp on the east of Bald hill, and in the other by that on the east of Shenandoah mountain.

The two spurs in each case tended to act as a single block. The normal fault intersects the thrust at an acute angle forming a triangular valley narrowing southward. Some backward movement along the thrust plane must have accompanied the slump. Diminishing tension faulting eastward is marked by small scarps on the west of the Honness spur but is not noticeable on the eastern gneiss mass.

The Hook spur shows these features imperfectly developed.

PETROGRAPHY

General. The gneisses show much similarity in their mineralogy. Distinctive characters are furnished by the structure, the preponderance of some minerals, or the degree of alteration in the rock. A few composite types may thus be defined. It will be convenient to describe these first, while the variations in many instances may best be indicated in discussing their outcrops. The thin sections may be reviewed as a whole later. Possible ancient surface alterations must always be carried in mind.

Bald hill granite gneiss. This rock is prominently developed within and south of the quadrangle. There is great uniformity in its general color, mineralogy and texture. It shows a few variations, but as a whole is remarkably homogeneous. In outcrops it is commonly drab colored and granitelike in appearance. The thin section of the usual variety shows quartz in large and small anhedrons. Orthoclase and plagioclase are abundant, with the former slightly in excess. There is some microcline and hornblende is plentiful. Irregular grains of magnetite are frequent. There are a few scattered zircons.

Fig. 2 Bald hill granite gneiss. Actual size 3 mm. *Q*, quartz; *O*, orthoclase; *P*, plagioclase; *H*, hornblende; black, magnetite

In some instances, even where the hand specimen appears rather massive, the thin section shows a stringer-like arrangement of the hornblende (see figure 2). The magnetite is often hydrated, giving surface exposures a rusty color.

The principal variation is a rock of coarser texture, with the mineralogy of a diorite. It shows hornblende, abundant plagioclase and a very little quartz (see figure 3).

In one case where the rock was extremely fresh the magnetite formed a perfect pseudomorph after the amphibole and was abundant in the section, while the hornblende was greatly bleached.

Fig. 3 Diorite variation of the Bald hill gneiss. Actual size 3 mm. *P*, plagioclase; *H*, hornblende; *Q*, quartz

There is utter lack of evidence to show that the rock has undergone a complete change from an earlier condition. It would seem that, so far as the rock has just been discussed as to mineralogy and texture, we are dealing with primary features. On the whole, the sections indicate a rock of plutonic habit which took on a gneissic character and underwent certain other changes at the time of its formation. The gneissic character is best regarded as primary, justifying the use of the term gneissoid granite to qualify the name granite gneiss.

The restlessness of the magma at the time the minerals were forming seems to find expression in the stringerlike arrangement of the hornblendes and in parallelly arranged pellets of quartz occurring in the feldspars, which do not appear to be secondary and of later introduction. These features, with the rounded character and smaller size of some of the grains and the absence of micropegmatitic intergrowth, point to conditions hampering crystal formation.

The thin sections also show certain dynamic effects of later date, in common with all the gneisses of these mountains, in the form of strain phenomena of different kinds. There are one or two instances of comparative freedom from such in which the quartz always gives sharp, decisive extinction and in which prominent cracks and bent lamellae are absent.

Hornblende gneisses. The outcrops of these rocks are much alike and the thin sections which have been examined agree very closely. Exposures are dark in color. The essential minerals are chiefly plagioclase and hornblende, with some quartz and a little orthoclase. Magnetite is rather common as irregularly-shaped particles, or as dustings. Zircons are occasional. Some sections show biotite in addition to hornblende, but the former is decidedly subordinate and usually has every appearance of being secondary. It apparently belongs to that period of metamorphism which more usually found expression in strain phenomena of different kinds but which sometimes resulted in new minerals among the "primary" ones, especially in those cases where the rock had previously been exposed to unusual alteration. The feldspars also frequently show evidence of former decay. The indurated and general compact

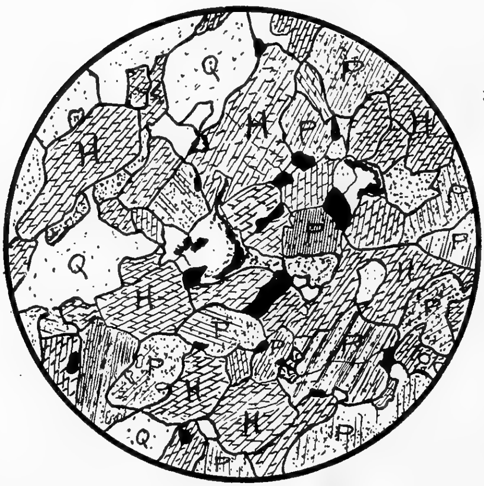


Fig. 4 Sketch of a hornblende gneiss. Actual size 3 mm. *Q*, quartz; *P*, plagioclase; *H*, hornblende; black, magnetite

condition indicates that the alteration is an ancient character. Figure 4 gives a sketch of a thin section of typical hornblende gneiss.

Fig. 5 Sketch of a micaceous gneiss. Actual size 3 mm. *Q*, quartz; *O*, orthoclase; *P*, plagioclase; *B*, biotite

Micaceous gneisses. These may be passed over briefly. Except that biotite plays the rôle of hornblende, they are very similar in their mineralogy. In some cases magnetite is associated with a mineral whose identity is lost or obscured. The thin sections often suggest that the prominent biotite is secondary and in these cases the outlines of another mineral, possibly hornblende, may be faintly traced. In these instances it is possible that the biotitic gneiss was first a hornblende rock and that it was subjected to more than usual alteration before recrystallization.

Microcline is rather abundant. Biotite occurs abundantly as a "primary" mineral independent of hornblende. Sometimes these gneisses show much quartz and are finegrained, strongly suggesting altered sediments.

Fig. 6 Shenandoah mountain granite. Actual size 3 mm. *Q*, quartz; *O*. orthoclase; *P*, plagioclase; *M*, microcline; *Mu*, muscovite

Shenandoah mountain granite. A coarse, white granite made up almost entirely of quartz and feldspar was noted on Shenandoah mountain at the summit of the steep northwestern slope, along the road from the East Hook to Hortontown. It is very massive in appearance in the ledge and hand specimen. The thin section shows quartz, orthoclase, microcline and plagioclase. A few small and scattered flakes of muscovite, which is probably a primary mineral, are present. Microcline is abundant. There is a tendency to microperthitic intergrowth of plagioclase and orthoclase. It has the earmarks of a plutonic rock and bears little evidence of gneissoid structure, so that if it is of Precambric age it must be thought of as having escaped any pronounced foliation. This seems remarkable, considering the prominence of foliation in the gneissic series. The effects of dynamic metamorphism are chiefly in the form of strain shadows in the quartzes.

Glenham gneiss. The prevailing and characteristic surface rock of the Glenham belt is a granitic gneiss. It appears to be an altered derivative of other gneisses which are entirely similar to those of the Highlands, and which are exposed in places within the belt. The surface gneiss is foliated in certain portions, while in others it is massive. There are minor variations in texture and in mineralogy which depend upon both an ancient and a more recent alteration. These varieties grade into one another. The gneiss is usually red from disseminated iron stains and over much of the belt is deeply chloritized.

Fig. 7 Glenham gneiss. Actual size 3 mm. *Q*, quartz; *M*, microcline; *P*, plagioclase; *Cb*, chlorite after biotite, carrying magnetite

The thin section shows abundant quartz with orthoclase, microcline, plagioclase, and biotite altered to chlorite. Magnetite is abundant and zircons are occasional.

Occasionally the rock consists of feldspar and quartz with very little or no mica.

OUTCROP OF THE FISHKILL MOUNTAIN GNEISSES

Matteawan. Gneisses which can be readily traced into those of the Fishkill mountains outcrop near their base in the eastern part


GEOLOGICAL
MAP
OF
MATTEAWAN
SCALE
1000'
LEGEND
GNEISS
QUARTZ-ITE
LIME-STONE
SLATE

Figure 8

of the town of Matteawan. The discussion of these may be followed by reference to the map of Matteawan (figure 8).

The most western outcrop which has been noted is at the corner of Vail avenue and Washington street. The gneiss at this spot is very similar to that which composes the two inliers shown on the map at the northwest. Another outcrop occurs at the junction of Prospect and Mountain streets. A line drawn between these two outcrops marks the western boundary of the gneisses of the mountains, so far as they can be followed by actual outcrops. East of Washington street along Prospect, Union, Robinson and Alice thoroughfares and along Green, Park, Duncan and Goodrich side streets, outcrops are numerous. North of Mountain street the gneisses pass beneath the drift. A quarter of a mile to the northeast they are exposed again in the gorge of Mount Beacon brook. The reddish and greenish colors, characteristic of the Glenham belt and the inliers farther west, and frequent epidotic gneiss, were noted among the surface exposures of the gneisses just described. Otherwise these exposures are similar to the rocks in the Mount Beacon brook section.

Mount Beacon brook section. Above and for a short distance below the bridge on Mountain street, near the foot of the mountain road, the brook has cut an interesting section in the gneisses. Just above the bridge the foliation and "bedding" planes strike n. 54° e. and dip about 75° s. e. Below the bridge the strike varies between this angle and 69° e. of north. The rocks in this section show an isoclinal arrangement in "beds" with high dip to the southeast.

Below the bridge, the lowest portion of the section involves some forty feet of dark hornblendic gneiss. This rock is banded, though in places for the width of several inches it is massive. When waterworn, such surfaces present a spangled appearance. This "stratum" is abruptly succeeded by a lighter colored one of much less uniformity of appearance. It is made up of imperfect alternations of granitic, quartzitic and composite "beds," which vary in thickness from the width of an inch or less to two feet. Some "beds" show light and darker bands. Others are uniformly light colored, often with little or no trace of a ferromagnesian constituent. This "stratum" continues up stream for a hundred feet or more and passes beneath the bridge. It is succeeded by the Bald hill gneiss with varieties that strongly resemble the rocks of the Glenham belt and the Matteawan inliers in texture and mineralogy.

In the upper portion of the gorge above the bridge the north wall for some distance is a rusty, pinkish rock of fine grain and rather massive appearance. It resembles certain phases of the basal quartzite which have been noted outside the quadrangle, particularly the outcrops in the brook crossed by the mountain road a mile south of Dutchess Junction. This rock is jointed, and rests upon the granitic derivative of the Bald hill gneiss.

Bald hill. The rock composing this spur of the Highlands was carefully examined along its base while tracing the quartzite, and also in two sections across its summit from west to east. One of these sections was made across the northern portion of the spur along an old wood road leading from the lane southeast of the Maddock farm near Glenham station. The other was taken partly along the road ascending Mount Beacon, then bearing to the left past the Graham place through " Hell Hollow " to the Cold Spring road. The rocks in the quarries near Mount Beacon reservoir, and in the excavations made for the new house at the summit of Beacon during the summer of 1908, as well as the section along the road descending from the reservoir to Matteawan, were studied. Comparisons were made with the outcrops along the base of the ridge to the quarry at Storm King station and in the railroad cuts from Storm King to Cold Spring. An examination of other parts of the ridge of which Bald hill is the northern extremity, was necessary in order to form a clear idea of the character of the gneiss.

Along the northwestern slope of the spur the gneiss is mainly a medium-grained, laminated hornblende rock with some micaceous variations. Along the basal portion of this slope the gneiss is usually rusty from included iron stains. Higher up it is commonly a drab or gray rock. The laminated character is more noticeable and the laminations are finer along the basal portion of the northwestern slope. Throughout most of the mountain the gneiss is rather coarsely or indistinctly foliated and in places is quite massive and granitic in appearance.

The characteristic rock of Bald hill, as just described, is identical in texture and mineralogy with the rock in the quarry at Storm King station and with the prevailing type in the railroad cuts between Storm King and Cold Spring. It is the chief variety in the quarries at Mount Beacon reservoir.

At the excavations for the new mountain house on Beacon, the drab-colored granitic gneiss passed into a variety composed of white feldspar and hornblende. In the hollow between Beacon and Bald hills, along the road descending from the reservoir, the granitic hornblende rock is often very dark in color, which corresponds with a greater freshness in the rock.

The presence of occasional micaceous variations has been noted. They are apparently confined to the more finely laminated portions of the gneiss and there is reason for thinking that the mica is secondary. The thin sections show abundant disseminated magnetite which has become hydrated in many places, giving surface exposures a rusty color.

The homogeneous character of the Bald hill granite gneiss is noteworthy. In areal extent, it covers about eleven square miles east of the Hudson. The general igneous character of the rock is very impressive. The varieties that have been described would appear to be explainable as normal variations from a common magma.

This rock is certainly of Precambric age. By its form and isolation it does not appear to have the character of a basal member. I have been unable to discover any other type which could reasonably be referred to this gneiss. If a basal formation, it should be of more frequent occurrence in these greatly eroded rocks. It therefore does not appear to be older than the other gneisses. All evidence of a possible unconformity would have been completely obliterated.

If contemporaneous with the other gneisses, on the assumption that they are sedimentary and that it is igneous and having the character of a sill, it should then occur also in other places to the east. It might be a laccolith, in which case it might have furnished the initial bulge at the time of folding. The more strongly banded character of the gneiss along the margin and the somewhat massive central portions might permit the interpretation of anticlinal structure.

The pronounced alignment which this granite has with the other gneisses favors the view that it was thrust up into the gneisses at the time of their folding. All possible exomorphic and endomorphic effects would have been neutralized by the agencies of regional metamorphism.

In addition to its other characters, the thickness of this formation is opposed to the idea that it is of sedimentary origin.

The Mount Honness spur. A short distance east of the Cold Spring road in the hollow between this spur and Bald hill the rock resembles the Bald hill gneiss. In some places it is granitelike, coarse-grained and only slightly foliated, looking like an altered derivative of the gneisses. The fault that borders Bald hill on the east may be within the Bald hill gneiss for a distance.

North along the road toward Fishkill Village the rock becomes more foliated. A thin section of this variety shows some biotite in addition to hornblende, but the former is decidedly subordinate and is apparently secondary.

Two mountain roads over this spur from the Cold Spring road to West Fishkill Hook give fair sections. There are also numerous outcrops in the fields to the north and south. Surface exposures are confusing both as to structure and petrographic characters. In some places the gneiss apparently dips to the northwest at low angles, but where the foliation planes may be detected, they dip to the southeast at high angles. The rock often has a granular and hybrid character that seems best interpreted as the condition resulting from the induration of a partially disintegrated rock which is primarily a very ancient character. The apparent northwest dip is accordingly best explained as a sort of exfoliation between the basal gneiss and the altered surface derivative.

On the whole, the section is across a series of " strata " showing tendency to definite alignment with each other and to variety of composition. In the main the rocks of this spur may be classified as micaceous and hornblendic gneisses forming rather thick " strata," which usually exhibit uniformity in mineralogy for some distance across the strike.

The road from Brinckerhoff to Johnsville crosses this spur north of Mount Honness proper. Fine exposures have been made in the dark colored hornblende gneisses along the road in the process of constructing the new State road, and in the quarries just south of Arvis Haight's, from which stone was removed. These sections show thick masses of the hornblende gneiss. Lighter colored gneisses have been noted interstratified with the hornblende varieties.

In connection with the question of the origin of the hybrid character of the gneiss along the northwestern slope of this spur it is interesting to note that the slope is gentle. Although it now lies in a faulted position against the limestone, the basal quartzite may have reposed on the gneiss along this slope subsequent to the elevation which brought the gneiss against the limestone.

More distinct " passage beds " overlying the inclined gneiss occur just beyond the point where the two mountain roads cross on the crest of the ridge. Between the eastern fork of the roads thus formed, west of the barn of Irving Knapp, thick masses, resembling both the gneisses and the quartzite in their mineralogy, dip to the north at a moderate angle. Farther along the road to the east of the house, ledges more closely resembling the quartzite were found. The woods and thick covering of drift, however, greatly obscure everything to and for a short distance beyond the west road into the mountains. South of the Carey farm, between the brook and the road, the quartzite was found grading downward into a hybrid rock.

The Hook district. South of the quartzite slope, back of the farm of Garrett Smith, the thick woods obscure the succession in the gneisses and good outcrops are scattered. The outcrops in the field southwest of Alonzo Smith's house (see plate 4) on the east road into the mountains and in the neighboring woods, are micaceous gneisses. Within the small space of the outcrop shown in the plate the gneiss passes from a rather coarse rock with quartz stringers through one with finer laminations into a purplish rock with still finer laminations.

A comparison of the thin sections of these varieties shows a similarity as to essential "primary" minerals with biotite as the ferromagnesian constituent. The feldspar is chiefly plagioclase. Quartz is abundant. The degree of alteration of the primary minerals varies much. It is severe both in the feldspars and the biotite, but shows itself chiefly in the latter. In the coarser gneiss the biotite is only slightly altered, while in the finely laminated purplish rock it is represented by masses of magnetite and a great abundance of finely granular material, probably sericite, with only occasional traces of the boundaries of the original mineral (see figure 9). The second variety mentioned shows a gradation between the

Fig. 9 Altered micaceous gneiss from the Hook district. Actual size 3 mm. *Q*, quartz; *P*, plagioclase; black, magnetite from biotite

other two. The purplish color of the darker rock is plainly due to the abundant magnetite.

Though apparently greatly decomposed, these rocks are firm and compact in the hand specimen. The magnetite is not altered into hematite or limonite. The conditions suggest that the alteration of these rocks dates back to an epoch preceding the deposition of the basal quartzite, which, as the proximity of this formation shows, formerly covered the gneisses, probably until glacial time.

East of the east road into the mountains the quartzite has been dropped by a fault. It extends farther to the south than on the west of the road, partly on this account and partly because of a syncline at this point. No peculiar variations were noted in crossing the Hook spur to East Fishkill Hook. The southward extension of the quartzite leaves comparatively few outcrops outside the thickly-wooded area of the spur.

Shenandoah mountain.[1] Above the drift-covered slope of the quartzite, along the northwestern slope of the mountain, dark, micaceous gneisses were noted in conspicuous ledges. Along the road from the East Hook to Hortontown, these were succeeded near the summit of the mountain by a light granite interbedded with the gneisses and estimated to be from forty to sixty feet thick. I have called this the Shenandoah mountain granite. With the exception of one or two quartzitic members, the usual succession of the gneisses is crossed in going from the granite " stratum " across the mountain to Hortontown. On the whole, the micaceous types seemed more abundant. Outcrops are numerous along the road and in the fields on each side.

The age of the granite can not be affirmed. It appears to have the strike of the adjacent gneisses; but it did not prove possible to trace it more than a few hundred feet. The quartzite formation, or its possible equivalent, was not found resting on the granite, so that its age could not be definitely assigned by showing an unconformity. If thrust up into the gneisses at the time of their folding, it has escaped foliation. It probably belongs to the Precambric series. If so, the absence of foliation indicates that Postcambric movements did not contribute to the characteristic foliation of the gneisses.

The eastern gneiss mass. The rocks along the northwestern base of the eastern gneiss mass in some cases suggest a continuation of those of Shenandoah mountain.

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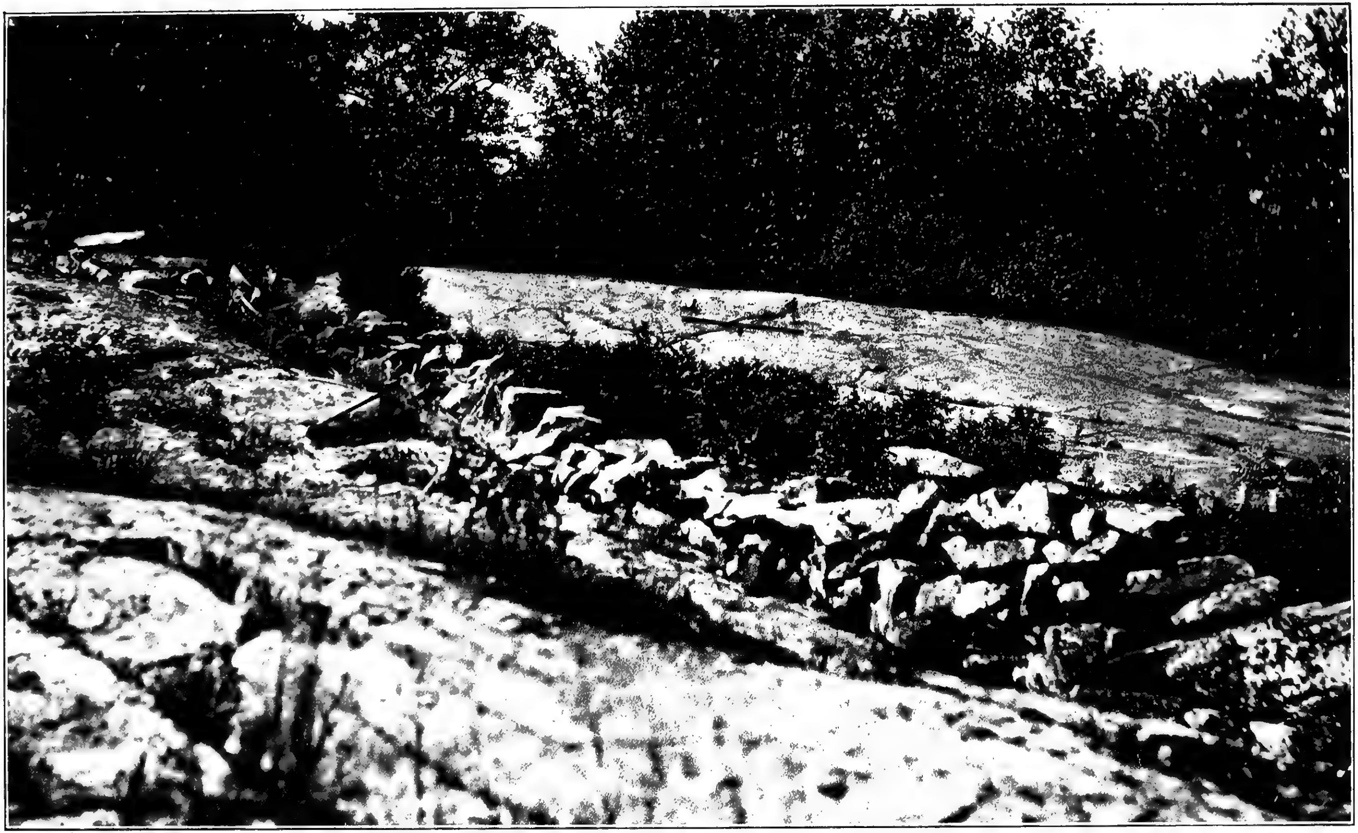
[1] The spur next east is locally known as Shenandoah mountain, from the hamlet of that name at its northern termination. The Shenandoah of the map is East Fishkill Hook.

Plate 4



Showing the unconformity between the Precambric gneiss and the Lower Cambric quartzite. The glaciated gneiss beyond the wall dips to the east by southeast at a high angle, while the quartzite in the foreground dips to the northeast at a low angle. Photograph taken on the farm of Alonzo Smith in the West Fishkill Hook district

At Fowler's kaolin mine, east of Shenandoah, a rock was found beneath the kaolin deposits that was almost identical with the Shenandoah mountain granite, though coarser in texture. The decomposed rock, from which the kaolin was derived, is usually coarse, showing quartz chunks the size of a walnut in a mass of altered feldspar. Probably the kaolin is the product of the disintegration of a pegmatitic granite. The clay beds are apparently not very extensive, although their exact extent is obscured by glacial deposits along the slope. If the kaolin is thought of as the decomposition product of an arkosic, conglomeratic quartzite, it is difficult to account for the granitoid texture of certain specimens examined and the perfect résemblance which they have to the Shenandoah mountain granite. The quartz chunks are not rounded as one would expect in a conglomerate. A careful search failed to reveal the quartzite in the neighborhood.

The structural features suggest that certain gneisses of this mass probably are faulted portions of the Shenandoah spur. Their resemblance might, of course, be explained as due to repetition.

At Hortontown, near the quadrangle boundary, there were noted certain gneisses which had an almost unmistakable sedimentary appearance. Though firmly crystalline, the quartzes frequently show a granular character on the fresh surface of the hand specimen, and the thin interlocking and dovetailing light and dark bands and fine texture indicate an impure sediment. There is nothing about such varieties that points to an altered igneous rock.

The gneisses of the eastern mass were examined in their outcrops along the base of the northwestern slope, along the mountain roads and to some extent along the wooded summit. It did not prove possible to assemble them into an orderly series. They present irregular repetitions of hornblendic and micaceous gneisses with some few minor variations. The micaceous gneisses were the more abundant.

No decidedly massive types were noted. The thin sections are not conclusive as to the early condition of these gneisses, although in many cases they hint at altered sediments or ancient derivatives.

THE GNEISS INLIERS

The Glenham belt. The southern extremity of this belt is a few yards northwest of the dam at Groveville. Above the dam it forms the west wall of the gorge of Fishkill creek as far as Glenham. Northeastward it may be followed distinctly as a narrow belt as far as Vly mountain. North of this hill it disappears against the slates. The belt is bounded by the slates on the west throughout its entire length. Vly mountain is cut off from the main mass by a transverse fault which has offset the main belt to the west by its own breadth. This fault is occupied by a large swamp, to which the eminence probably owes its name. The mountain is bounded on the east by the slates and on the south by the Fishkill limestones. The latter border the main portion of the belt on the east to its southern extremity. The southern end of the strip is faulted against the slates.

Mather called this mass a "granite rock" in his description[1] and in his section the "Matteawan granite" (see plate 12, loc. cit.). He separated it from the gneiss of Bald hill, but apparently regarded it as a part of the Highlands.

E. Emmons[2] cited this rock as an example of the uplift of inferior rocks into the newer ones. He described the relations at Glenham. His section is given herewith.

Fig. 10 *a*, slate; *b*, granite (of Glenham belt); *c*, limestone; *e*, Fishkill mountain. (After Emmons)

Hall and Logan, in 1864, called it an 'altered sandstone,"[3] J. D. Dana, in 1879,[4] referred to it as "bastard granite" and described it as one of the "stratified deposits as is shown by its conformable position and by its taking the color of the slate near its junction." The Highlands were the source.

Smock in 1886[5] expressed doubts of its being stratified. He placed it with the Highlands, though the prevailing types of rock were unlike the characteristic varieties of the Fishkill mountains.

In the southern portion of the Glenham belt the prevailing rock is a massive variety of the granitic gneiss. This is exposed for some depth in the railroad cut west of Glenham station. It is of dark green color and shows scarcely any tendency to foliation. South of this cut and for some distance to the north, surface outcrops are almost always of this type of rock, though varying in

[1] Geology of the First District, 1843, p. 437.
[2] Agriculture of New York, Part IV, 1846, p. 103.
[3] Amer. Jour. Sci., Ser. 2, 39:97.
[4] Amer. Jour. Sci., Ser. 3, 27:386.
[5] Thirty-ninth Ann. Rep't N. Y. State Museum, p. 176.

the degree of chloritization of the mica. It is without evidence of bedding. This rock grades in places at the south into a laminated finer-grained variety which is common in the gorge of the creek below the railroad bridge at Glenham. At the north this type is more abundant, outcropping frequently between the road from Fishkill Village to Wappinger Falls and Vly mountain.

Vly mountain is composed of this variety. It grades into the coarser rock and, like the latter, is usually chloritized, though the red color of the iron usually predominates. The laminations strike between n. 12° e. and n. 15° e. As was noted in the petrographic description of this gneiss, it occasionally passes into a rock composed only of feldspar and quartz.

The varieties so far described make up the surface rock of the Glenham belt and are the ones which have been emphasized by most observers.

The road from Fishkill Village to Wappinger Falls crosses the Glenham belt diagonally about midway of its length. Several shallow cuts have been made in the gneisses along the road. Beginning at the first cut on the south, the section is through about one hundred feet of a coarse, granitic hybrid rock. This is followed by hornblende gneiss and at the top of the hill the latter is succeeded by a banded, slightly crinkled gneiss with pinkish red and dark green laminae. A hundred yards beyond to the north of this rock on the west side of the road is a massive, coarse granitoid gneiss with quartz, light colored feldspar and biotite as the chief minerals. The joints in this rock are filled or faced with epidote. Beyond this is a fine-grained pinkish rock carrying epidote in many places and very similar in essential mineralogy to that described in the Mount Beacon brook section as composing the wall of the gorge above the bridge. Beyond this the cut is for some distance through medium-grained hornblende gneiss exposed on both sides of the road. The last section, on the east side of the road, is mainly through this hornblende rock which shows slight variations and fairly distinct "bedding," with a southeast dip.

These gneisses of the Glenham belt show no distinct types, except as described above for the surface exposures. On the other hand, the hornblende and other gneisses show marked resemblance to the mountain rocks. Roughly correcting the section for the gradient, the bearing of the road and the angle of dip, which seems a little smaller than that of the mountain gneisses, the thickness of the gneissoid types is similar to those observed in the gneisses of the spurs.

The Matteawan inliers. The coarse granitic rock so characteristic of the southern portion of the Glenham belt forms a small inlier farther south in Matteawan. It begins in "Rock Hollow," just west of the intersection of Washington avenue and the road that connects the latter with Liberty street, and extends south across Rock Hollow road (Walnut street) to Anderson street, and then as a narrower strip to Grove street. (See map of Matteawan, fig. 8.) The rock here is not quite so deeply chloritized as in the Glenham belt.

Another mass of similar rock, about 700 feet long by 400 feet wide, lies to the south of this and forms the conspicuous knoll on which the Matteawan schoolhouse stands. The principal outcrops are between Spring, East and Falconer streets. This mass almost certainly connects with the gneisses in the eastern part of the town, but outcrops are concealed along Mill, Louisa and Washington streets and Mountain avenue between this mass and the westernmost outcrop of the gneisses at the east. Limestone may overlie the gneiss in this interval. The latter outcrops between Woodall and Henderson streets, and presumably has or had an eastward extension from here.

The first inlier described above is succeeded at the south by the basal quartzite which forms a knoll between Anderson, Walnut and Grove streets, and is separated from the Precambric on the north and west by Anderson street. The contact could not be found; it may be faulted. The quartzite is overlain by the limestone on the east and south and on the west for a distance of 75 feet north of Grove street. A small mass of slate has been faulted in between the limestone and the spur of the Precambric on the west of Anderson street, near the house of Mrs C. E. Phillips.

At the northern end of the Glenham belt on the southwest side of Vly mountain, north of the road at its base, a small knoll of quartzite, overlain by limestone, has been faulted with the gneiss of the mountain. It is separated from the main mass of foliated, reddish granitic gneiss by a narrow gully.

As noted above, a coarse granitic rock of a mineralogy quite similar to that of the coarse granitic variety of the Glenham belt and the inliers at the south, occurs in places in the bed of Mount Beacon brook above the bridge. It occurs in outcrops among the gneisses in the eastern part of the town and was noted on Prospect street, 50 feet north of its junction with Walcott avenue and at the corner of Vail avenue and Washington street.

The mineral epidote is of frequent occurrence in the Glenham belt and in places among the gneisses in the eastern part of the town of

Matteawan, and the rock which carries it in these different localities is often of very similar mineralogy and appearance in other respects.

Interpretation. The Matteawan inliers connect the Glenham belt with the Highlands in a very satisfactory way. Other field relations which are cited above, show that the rocks composing these inliers are of Precambric age. The banded gneisses seen in the section on the Wappinger Falls road across the Glenham belt, bear strong resemblance to many of the gneisses outcropping in the town of Matteawan along the base of the mountain. The hornblende gneiss in places is identical with those occurring on the road from Brinckerhoff to Johnsville across the Honness spur. When the dip may be observed in the gneisses along the Wappinger Falls road, it is practically the same as that of the Highlands rocks. The essential identity as to the age and fundamental likeness in mineralogy and relations of these inliers with the Highlands is almost certain.

The character shown by the rocks which make up so much of these inlying masses, and upon which most observers have dwelt, apparently admits of ready interpretation.

During the time the early Paleozoic sediments of this region were being laid down the sea was progressively transgressing upon and overlappi g the old land mass from which its sediments were derived. This old land mass would doubtless have become decayed for moderate depths beneath the surface, or at least would have suffered some changes in the minerals composing the rock. Where subaerial disintegration actually took place, its products may have remained undisturbed in favorable places, and it is possible to imagine that they were finally covered by the advancing waters without having been much sorted. In other cases they would have been washed away, leaving only the firmer rock, which probably, however, had undergone some mineralogical changes, such as the alteration of its ferromagnesian mineral. In other instances the disintegrated rock would have undergone partial sorting. In other cases it would have been completely sorted and a pure sandstone formed. In some places the advance of the sea would have been rapid enough to leave most of the material unsorted and only a superficial layer of partially sorted stuff. All would probably have been covered finally by a thoroughly worked over quartzitic sand that deepened offshore as the sea advanced.

In the process of time burial in itself would have brought some changes in the subjacent altered gneisses; but the principal ones would have been effected by the same processes that changed the basal sandstone to a quartzite and metamorphosed the overlying limestone and slate. The partly disintegrated upper portions of the gneisses would have been thoroughly indurated into a compact rock and probably partially recrystallized. The less altered gneiss would also have been changed, although not necessarily in such a way as to form entirely new minerals. Chlorite would now appear in a firm rock as a pseudomorph after biotite, or hornblende, and the old iron oxids would have been preserved as magnetite or hematite. In places where alteration had not taken place, the practically unchanged gneiss would be preserved.

It is possible in this manner to account for the peculiar rock types of the Glenham belt and for the occurrence of such features as a coarse granitic "stratum" resting on upturned gneisses and followed by a somewhat foliated, finer-grained, quartzitic rock as shown in the gorge of Mount Beacon brook; or for the occurrence of such extensive surface developments of rock as the chief varieties of the Glenham belt, which so certainly rest upon and grade into the inclined gneisses. Conditions would have been very favorable for the interaction of feldspars and ferromagnesians, which now find expression in the abundant and widely distributed epidote that clearly belongs to an ancient period of alteration.

A relatively large proportion of the ancient altered gneisses has been preserved in the Glenham belt. The section along the Wappinger Falls road, with its assemblage of altered and unaltered types, seems intelligible from this explanation.

At places, as at Vly mountain, and near "Rock Hollow" in Matteawan, fragments of the quartzite have been preserved and these apparently grade into the underlying rock with which they are both unconformable and coextensive.

These principles of subaerial decay have been applied in the foregoing discussion to certain altered gneisses and hybrid rocks occurring in many places among the Fishkill mountains. They serve to account for an evident ancient alteration in these rocks and for the occurrence of certain types that are intermediate in character between the quartzite and the underlying gneiss.

SUMMARY OF THE MICROSCOPIC CHARACTERS OF THE GNEISSES

A microscopic examination has been made of about twenty-five sections of the gneisses of the Fishkill mountains, selected from types which were believed to show the principal variations in the gneissic series from west to east. A half dozen were also selected from the Glenham belt.

These sections, except perhaps, those of the Bald hill granite gneiss and the Shenandoah mountain granite, do not afford any convincing evidence of the original character of the gneisses. They give some support to the inference made as to their alteration and afford some ideas of the age of different characters in the rocks. In instances, they bear out the character as seen in the hand specimen and in the outcrop. In other cases, on account of the coarseness of the rock, they entirely fail to show the megascopic structural features.

There are no striking variations in the kinds of " primary " minerals present, except in the ferromagnesian, although the proportions vary. Quartz is usually present, frequently in large anhedrons only, but oftener both as large and smaller ones. Sometimes it is absent from the section or quite insignificant. Plagioclase is universal, often with orthoclase, but occasionally alone in types with much ferromagnesian content and little or no quartz. Orthoclase is occasionally in apparent excess of plagioclase and microcline is frequent. Biotite often appears alone as a primary constituent, being clearly of the same age as the other essential minerals. Hornblende often occurs alone in the same relationships. Biotite sometimes occurs with hornblende, but then often suggests a secondary character from its distribution and subordinate amount.

Magnetite is abundant and is evidently secondary. It occurs chiefly in irregular grains in bunches or as dust masses in or near the ferromagnesians, or scattered about the section within the feldspars and along fractures. It is occasionally pseudomorphic after the ferromagnesian. The latter are plainly very ferruginous in character. Zircons are numerous and widely distributed. Titanite apparently occurs as leucoxene about the magnetite at times. Chlorite is abundant, often replacing all or most of the ferromagnesians in the section, but this mineral is associated with the gneisses which, in the hand specimen, betray an ancient alteration. Muscovite or sericite occur only as secondary minerals in the feldspar, except possibly in the Shenandoah mountain granite.

The textural features present some variations, but they do not as a rule help much in deciding the question of whether the rock is sedimentary or igneous in origin. Very often the arrangement is very similar to that in plutonic rocks of the granitic or dioritic types and the modifications shown might readily be explained as due to conditions imposed on a magma. Other gneisses, either from a more granular character or from the abundance of the ferromagnesian mineral, suggest altered sedimentary types. But these features are plainly far from decisive. On the whole, the sections are less satisfactory than the field outcrops; but so far as they go they sustain the uncertainty of the field examination.

If these gneisses are mainly altered sediments they have been so thoroughly crystallized that they now often closely resemble igneous types. The hornblendes in their relation to the feldspars sometimes indicate a formation in the usual order of crystallization from a magma. If mainly of igneous origin, these gneisses were greatly squeezed in their formation and would now be more properly designated gneissoid eruptives than eruptive gneisses. In either case the primary minerals (that is, those plainly belonging to the last change that affected the whole rock) and their essential arrangement are of contemporaneous origin.

So far as examined, the sections are entirely free of the minerals usually found in areas of profound dynamic metamorphism. It is, of course, impossible to tell how many complete metasomatic or other changes these rocks may have undergone, but there appear to be no traces of any antecedent generations of minerals.

The sections sustain the belief that the primary features of the gneisses, as a whole, are of very ancient character and of Precambric age. They show, on the other hand, many evidences of subsequent metamorphism.

This later metamorphism is shown in the sections in several ways, but chiefly as pressure effects. In almost all cases the quartz crystals show pronounced strain phenomena, such as strain shadows and wavy extinction, and are often cracked. The plagioclases almost always show pinched-out, bent or broken lamellae. Fractures and long cracks are common. In places where the gneiss evidently had undergone an early alteration, the rock was indurated and occasionally new minerals formed. Some molecular movement is indicated by chloritic fillings, disseminated magnetite and secondary quartz injected into the feldspars. Some biotite very clearly belongs to this later metamorphism.

Some of the sections from the Bald hill gneiss and those in the bed of Mount Beacon brook show fewer apparent strain effects than those from the spurs farther east, which may be interpreted as the expression within these rocks of a somewhat lesser degree of metamorphism at the west. The conclusion that the primary gneissic characters were changed very little in Postcambric time seems inevitable. As the field relations show the gneisses had reached practically their present crystalline condition and gneissic structure in Precambric time. Because of their early crystalline condition, these gneisses would have undergone fewer changes and a relatively lesser degree of metamorphism than the sediments which overlay them, during the mountain building process of Ordovicic time. Such changes as they underwent from this cause should, however, show some correspondence with those in the younger rocks, as is perhaps afforded in the apparent lesser degree of metamorphism at the west. This difference is not, however, noticeable in the field unless the more clearly " bedded " strata in the bed of Mount Beacon brook and the more clearly definable nature of the altered Precambric gneisses of the Glenham belt are indications of it.

An examination of the thin sections of the gneissoid types from the Glenham belt entirely supports the assertion that these rocks are members of the Highlands gneiss series. In mineralogy, texture and metamorphic characters they are entirely similar. The thin sections of the more characteristic types of this belt afford the clue to their interprétation and seem to show their original nature. They also carry characteristic strain effects.

FAULTS IN THE GNEISSES

During the Green mountain uplift the Precambric gneisses apparently buckled somewhat, but seem to have yielded chiefly by breaking. These faults greatly complicate the problem of the configuration of the Precambric land mass while the quartzite was being laid down.

Beginning at the west, the first fault is that shown by the Glenham belt. A reversed or thrust fault has thrown the gneisses against the slates on the west and south. Evidently the slates were folded and overturned and then overridden by the older rocks. The stratigraphic displacement necessary to elevate the Precambric into contact with the slates must have been an extensive one. Apparently at Vly mountain the upthrust was greater, resulting in the elevation of the mountain mass above the main portion of the belt and causing the transverse break between the two. That Vly mountain is not mainly an erosional feature is indicated by its relationships. It forms an isolated block which is faulted against the slates on the west, north and east. The transverse fault on the south involved the limestones which were bought against the slates on the east of them. The gneiss and limestone form the upthrow as a result of reversed faulting, both resting against the slate. The gneiss apparently also moved with reference to the limestone. Projected southward, the fault on the east of Vly mountain falls in line with the scarp on the east of Bald hill (see plate 5).

The gneiss inliers in Matteawan, south of the Glenham belt, are also clearly faulted against the slates on the west. A long swamp borders the northern one of these on the west, while on the north it is in faulted contact with the slates.

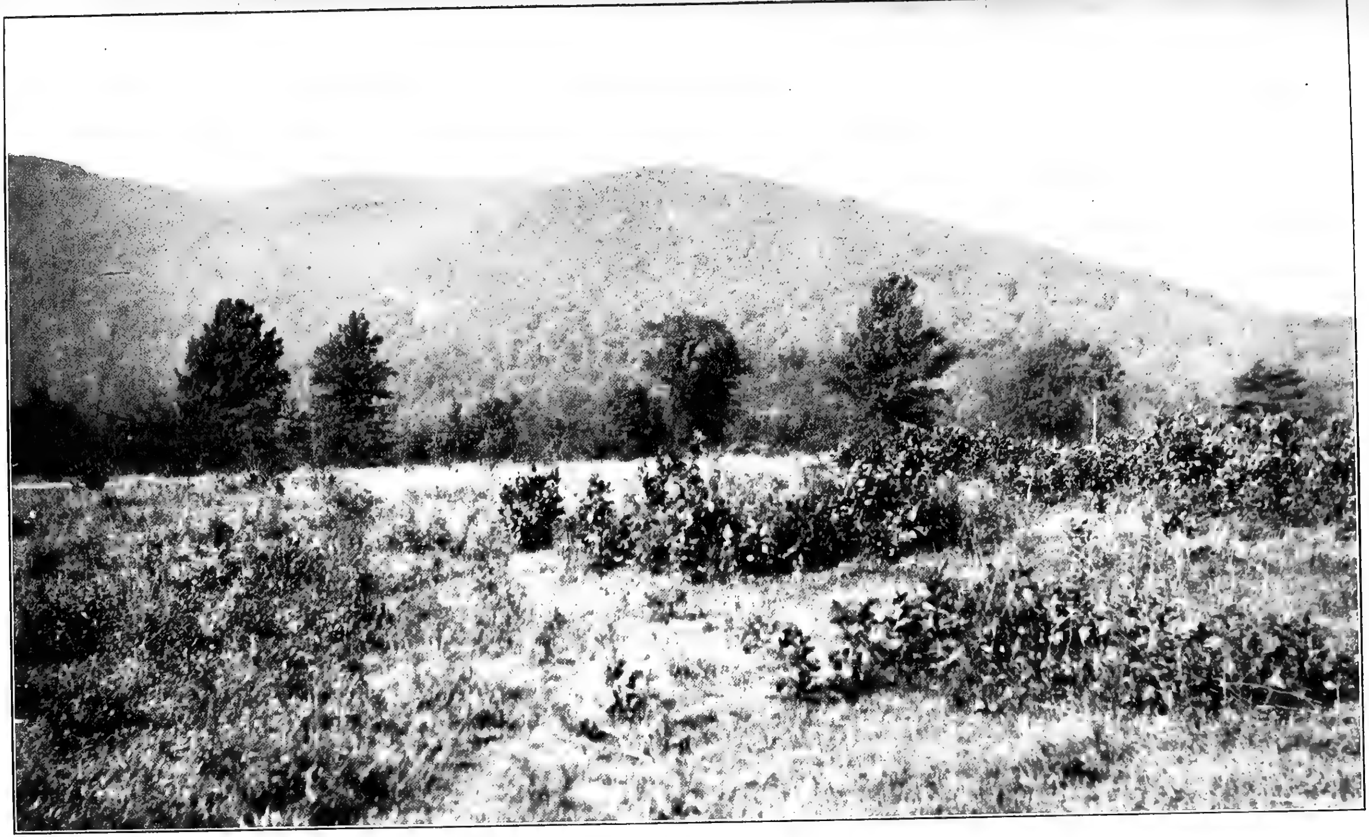
The relationship existing between the limestone and the gneiss all along the eastern margin of the Glenham belt and the smaller masses at the south, is far from plain. Although relatively small, there is probably some stratigraphic displacement, in places at least.

The Bald hill mass shows a still greater vertical displacement. As now uncovered, the break is partly within the gneiss itself and partly along a contact with the limestone, and probably in some places with the quartzite. The slope of the gneiss is always very steep and often precipitous. A moderate slope at the base, in places, may be interpreted as that of the quartzite or the surface from which it has been removed in late geological time. This kind of slope usually changes abruptly to a sharp angle with the vertical in ascending the mountain. The abundant talus at the bases of these scarps is misleading and gives the appearance of a much gentler slope than they really possess. The complementary result of recession of the summits by weathering is also confusing.

Apparently the overthrust which elevated the Bald hill mass involved a larger area of the gneiss. It seems reasonable to explain the faulted contact of the gneiss of the Mount Honness spur and the Fishkill limestone on the northwest of it as primarily due to this thrust. Later or simultaneous tension faulting dropped the limestone east of Bald hill into its present position. A number of scarp faces at different elevations along the northwestern slope of the Honness spur in line with the strike of the gneisses, and visible even in the season of foliage, mark tension strike faulting of diminishing intensity eastward from the great normal fault on the east of Bald hill.

The eastern face of Honness is marked by a rather conspicuous normal fault scarp which diminishes and dies away to the southward (see plate 6). The throw here was not so great as on the east of Bald hill.

Along the west side of the east road from West Fishkill Hook into the mountains, is a drop fault of small displacement. It is marked first by a cliff of the quartzite, but higher up the mountain it is in the gneisses.



Fault scarp on the east of Bald hill

On the east of the Hook spur another fault of moderate displacement has dropped the quartzite and limestone into the East Hook.

The northwestern slope of Shenandoah mountain is very steep from the point where it cuts the southern boundary of the quadrangle nearly to Shenandoah. The quartzite has a northwest dip of approximately 50°. The gneiss in places shows precipitous ledges, though these are not very high. The angle of slope changes abruptly from quartzite to gneiss. The steep dip of the quartzite shows considerable disturbance before the break occurred.

East of Shenandoah mountain is a clearly defined normal fault scarp along which the younger rocks were dropped. Their erosion has formed Shenandoah hollow.

Along the northwestern slope of the eastern gneiss mass are very steep and precipitous scarps, sharper even than those of Bald hill. The drift-covered talus slopes at their bases are not to be confused with the quartzite. It is probable, however, that in places the quartzite was involved in the upthrow and was brought against the limestone.

These breaks are interpreted as the result, primarily, of the compression producing the Green mountain elevation. The tendency was to produce a system of flexures like those in the younger rocks at the north. The gneisses buckled relatively little but, unable to resist the great pressure, were broken and thrust up into the younger rocks. Tension faulting within the expanded arc accompanied or followed the upward thrusting.

The faulting in the gneisses is clearly subsequent to the deposition of the quartzite. The only disturbance capable of producing these effects would appear to have belonged to the close of Ordovicic time.

These faults would certainly have greatly disturbed any orderly sequence which the gneisses may have had.

SUMMARY AND CONCLUSIONS

The relatively brief treatment of the gneisses of this quadrangle given above results from the impossibility of assembling them into an orderly sequence. The thickly-wooded character of the country, the presence of faults and the difficulties introduced by ancient subaerial alteration, greatly hinder their study and make a satisfactory map practically impossible.

The origin of the gneisses is very obscure. In some respects they appear to be largely igneous in character. In many places their sedimentary origin seems almost certain. It is entirely possible that the two kinds occur together in a parallel and roughly alternate arrangement, but faulting makes it impossible to decide this point in the face of the other difficulties present. The thickness is too great to permit the interpretation of a monoclinal series.

It seems entirely justifiable to attribute the apparent igneous character to profound metamorphism. It is plain that if the gneisses represent a sedimentary series in any part, the strata must have been jammed into close folds and overturned. If folding was accompanied by the injection of igneous rocks along the axes of the anticlines, the accompanying alteration would have been very severe and both sedimentary and igneous types would have come strongly to resemble each other. There would probably be no distinguishable exomorphic and endomorphic effects to aid in separating the two.

The gneisses below the bridge in the Mount Beacon brook section show a " bedded " character more clearly than at any other place.

The general absence of crumpling and crinkling in the gneisses is noteworthy in considering the possibility of their sedimentary origin.

Interbedded limestones, if such could be found, were thought of as likely to afford the most convincing evidence of a sedimentary series in these gneisses. Dr C. P. Berkey has discovered such limestones in the Highlands farther south[1] and in the Fordham gneiss of New York city.[2] The possibility that the basic rock and bastite ledges at Hortontown, described in the following pages, might be altered calcareous and magnesian sediments of Precambric age was considered, but the field relations do not easily permit this interpretation.

Taken as a whole, the gneisses in this quadrangle present sufficient diversity to be considered, at least in part, as an altered sedimentary series.

NAME AND CORRELATION

Dr C. P. Berkey[3] has correlated the basal member of the Manhattan series with the basal gneisses of the Highlands and has

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[1] Structural and Stratigraphic Features of the Basal Gneisses of the Highlands. N. Y. State Mus. Bul. 107, 1907.

[2] Science. n. s., 37:936.

[3] Structural and Stratigraphic Features of the Basal Gneisses of the Highlands. N. Y. State Mus. Bul. 107, 1907, p. 361.

Plate 6

Fault scarp on the east of Mount Honness, as seen from the West Hook district

called the whole the Fordham gneiss. This he correlates with the Grenville of Canada and the Adirondacks.

THE HORTONTOWN BASIC ERUPTIVE AND ASSOCIATED METAMORPHIC ROCKS

General relations. In the orchard by the house and near the barn on the farm of Albert Lawrence at Hortontown, are several outcrops of a massive, compact, greenish rock. One or two ledges are of moderate size, but most of the outcrops are small and inconspicuous. This rock is traceable only a short way to the north or south by actual outcrops, but in the fields and stone walls south of the orchard there are numerous boulders of this rock. The actual ledges disappear beneath the hill to the southwest of the orchard. At the summit of this hill, in a west by southwest direction from the house, and about 200 or 300 yards away, are numerous ledges of a rusty, blackish rock, which may be followed to the southwest for a short distance and then are lost. Just to the west of these outcrops, on both sides of the road and in the road itself, are numerous outcrops of quartzite with southeast dip and a strike east of north. A conspicuous ledge of this quartzite borders the west side of the road. West of this is a gully about 50 or 75 feet in width which at the west is bounded by a perpendicular cliff of the gneisses. The relationships just described are indicated on the accompanying sketch map (see figure 11).

It was not possible to determine the configuration of the mass to which the greenish rock belongs. The east-west distance between outcrops was estimated at 50 feet, but there is reason for thinking that the rock has a greater extent.

Petrography and general description. The greenish rock is very tough. It shows variations from a greenish black rock, streaked with lighter green, through a mottled variety to a lighter, greener rock with a tendency to fibrous structure.

The rock may be cut with a knife. Some varieties, when polished, give a rich, dark, glossy finish. When powdered and tested by the magnet it reveals large quantities of magnetite to which the darker hues are due. Weathered surfaces show freckles of black and greenish yellow, caused by the bleaching of the microscopic crystals among the magnetite grains. The thin section in transmitted light shows innumerable dustings and irregular grains of magnetite, while the rest of the section is yellowish white. With crossed nicols the latter appears as a network of spindles, flakes and needles of bastite. There seems to be no trace of an antecedent mineral (see figure 12).

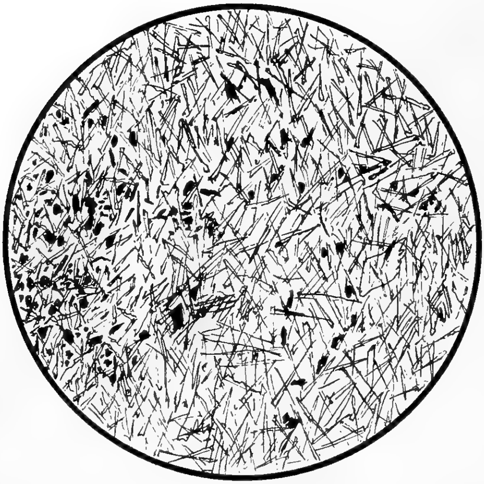

Fig. 12 Bastite rock at Hortontown. Actual size 3 mm. Showing a network of bastite needles and spindles with many grains of magnetite

The ledges of the black rock are prevailingly rusty. Excavation has been made at one place to a depth of two or three feet, apparently in a search for ore.

These ledges are inconspicuous, and, when surrounded and overgrown by grass, are readily missed, except in systematic search.

The hand specimen shows a very coarse texture. The rock is made up chiefly of massive hornblende. There are patches of finer texture in which magnetite is abundant. Small pyrite grains are frequent. In some places the hand specimen shows a relatively porous mass of rounded grains as though some mineral had been dissolved away. The rock has a high specific gravity and in almost all cases is rusty in color. The thin section shows large, irregular pleochroic brown and green hornblendes, with some pyroxene. Magnetite inclusions are numerous and this mineral also occurs abundantly along numerous cracks, sometimes in association with serpentine borders or fillings.

The ledges of the quartzite are more numerous and more extensive than those of either of the other rocks. Its apparent width is about 75 or 100 feet. It is thin-bedded and steeply inclined. It is very similar to the basal quartzite as seen at certain places and appears to belong to that formation. It may be followed distinctly for several hundred feet.

At the north and south these types give way to the characteristic gneisses of the mountains.

The exact field relations of these rocks are very obscure. No contacts could be found. Seemingly the only clue to their age and relationships is to be obtained from the structural features and the associations.

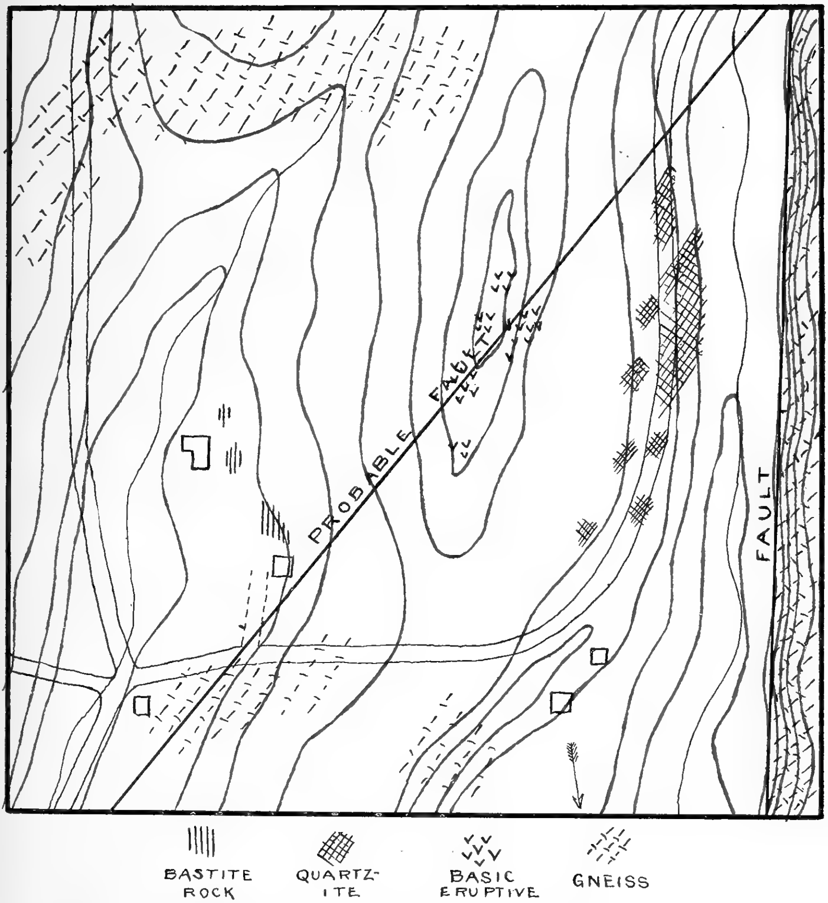

Fig. 11 · Sketch map to show the general relationships at Hortontown. Scale approximately 200 feet to the inch.

Interpretation. The possibility suggested itself that some of these rocks might be members of the basal gneiss series. The quartzite, however, is almost certainly Paleozoic in age. The black hornblende rock has the characters of a basic eruptive. The green serpentine variety gives little idea of its original character, but it is apparently not an altered pyroxenic rock.

The southwestward continuation of the reversed fault along the northwestern slope of the eastern gneiss mass would apparently intersect the fault on the east of Shenandoah mountain in this neighborhood. The latter scarp is only a short distance west of the quartzite. This intersection would have been a most favorable point for an igneous intrusion. Some of the basal Paleozoics were evidently caught at this intersection and intruded by the hornblende rock. The quartzite offered little for the eruptive to act upon. The bastite rock very probably represents an impure ferruginous dolomite. From what is known of bastite, it is commonly, at least, the alteration product of orthorhombic pyroxene; but the present rock gives no indication of the former presence of any antecedent mineral. There seems to be no grave objection to the inference that the passage was direct.[1]

This is the only occurrence within the quadrangle that permits the interpretation that an eruptive has penetrated and altered the overlying Paleozoics.

THE BASAL QUARTZITE (POUGHQUAG)

Distribution and general structural features. This formation, which has frequently been mentioned in connection with the gneisses, in this quadrangle occurs only in proximity to the Precambric rocks.

In the town of Matteawan the quartzite forms a small inlier as described above, in connection with the first small inlier of gneiss south of the Glenham belt (see page 28). Outcrops were also seen just north of Howland avenue in the open field at the foot of the Mount Beacon incline. The only other outcrops which have been noted in this vicinity occur farther north along the base of Bald hill on the Maddock estate.[2] About 300 yards south of the house and well up in the woods, about 200 or 300 feet east of the private

[1] Professor B. K. Emerson assisted the writer in the identification of the mineral bastite.

[2] The presence of the quartzite at this point was discovered by a companion, Mr W. R. Clarke.

drive, are two or three good-sized ledges. Farther up the hill on Mountain street at the point where it forks, going east, is an outcrop of the quartzite. This was first interpreted as a boulder, but the proximity of this rock in place farther down the hill suggests that it is a small ledge which has been preserved. These outcrops are the only ones which were noted in this town, after a careful search, which were referable to the quartzite as typically developed in this quadrangle.

As has been discussed above, there is strong reason for thinking that certain phases of the gneiss owe their peculiar character to the subaerial decay and partial sorting which took place during the epoch of the transgression of the sea in which the quartzite was laid down, and are therefore of the same general age.

At Vly mountain a small patch of the quartzite has been preserved just north of the road on the south side of the mountain at the summit of the hill as the road descends into the swamp, going west.

A careful search was made along the northwestern base of Bald hill from the Maddock farm to the northeastern end of the spur. The topography between the more precipitous portion of the hill and Fishkill creek often suggests the presence of the quartzite. Outcrops are few and the gentler basal portions of the slope are usually drift-covered. The foliated Bald hill gneiss outcrops in places north of the Maddock residence between it and the farmhouse at the northeast. Outcrops are absent at the base of the gneiss to the northeast of this farm, nearly to the end of the spur. The ledges of gneiss often rise precipitously from the edge of the gentler portion of the slope and the bases of the scarps are hidden by abundant talus which, in many cases, doubtless forms the gentler slopes. Near the extremity of the spur, due south from Fishkill Village, a ledge of the quartzite was discovered in the woods near the edge of the gneiss. The gneiss extends to the north of this ledge.

The Bald hill thrust carried the quartzite with it in places before the rupture occurred and in these places a characteristic quartzite slope has been preserved. Only a few scattered ledges now mark the former presence of this formation in the eastern part of the town of Matteawan. The small ledge near the extremity of the spur seemingly belongs with the upthrow block and probably rests by thrust against the limestone. It is a question whether the precipitous ledges of the gneiss northeast of the Maddock farmhouse rest against the quartzite or the limestone.

The map represents the quartzite slope, with the break to the southeast of it passing into the limestone southwest of the Maddock farmhouse. Northeast of that point it shows the gneiss against the limestone for a distance as indicating the tendency of the thrust, and then against the quartzite, with a probable break between the quartzite and the limestone.

There are no traces of the quartzite south of Fishkill Village in the valley of Clove creek, nor along the northwestern base of the Honness spur. Along the northwestern base of Mount Honness proper the gneiss is only 50 or 100 feet from the limestone, from which it rises in bold ledges. The quartzite may once have covered a portion of the northwestern slope of this spur.

East of Honness, about one-third of a mile south of Johnsville, the compact quartzite with some conglomerate outcrops for a short distance in the woods at the base of the scarp, but is soon lost beneath the kames which rest against the cliff. South of these kames on the farm of Irving Knapp, as mentioned above, a large mass of rock with northerly dip forms conspicuous ledges in the east fork of the mountain roads. It resembles both the quartzite and the gneiss and probably represents a transition from one to the other. The quartzite outcrops along the road east of Knapp's, in one or two places, but is mostly concealed by drift west of the west road from the Hook into the mountains. It was found in the bed of the brook just west of John Ireland's house and about 300 yards south of the Thomas Carey farm on the roadside just above the brook. Some conglomerate occurs at this point. Eastward from the Carey farm, on the farms of Garrett Smith and Ward Ladue, it forms large conspicuous ledges and extends to a point one-fourth of a mile south of Garrett Smith's and terminates with an abrupt talus slope in the woods. The unconformity between the quartzite and gneiss is plainly shown just south of Alonzo Smith's (see plate 4). East of the east road into the mountains, the quartzite extends a little farther south before the gneisses are reached. The southern boundary swings round northwest of the McCarthy place and then east through the woods across the Hook spur to the fault on the east of this. At this point the quartzite was dropped by a fault and is now concealed by surface deposits nearly to the quadrangle boundary. Just north of the road on the west side of the brook it appears in large ledges. Low ledges of limestone outcrop in the meadow just east of the brook.

Near the quadrangle boundary a small brook, which comes down from Shenandoah mountain, has cut through the surface deposits.

The quartzite was found exposed well up the slope in the bed of this brook dipping 50° to the northwest with a strike of n. 49° e. following closely the strike of the ridge. For a mile and a half to the northeastward this formation forms a clear topographic feature, though concealed by drift. Farther on it outcrops frequently and in large ledges along the south side of the road from the East Hook to Shenandoah. It crosses the road less than one-fourth of a mile west of that hamlet and is succeeded by the gneisses. There are numerous outcrops of the quartzite just north of Shenandoah. It is probably cut off at the east by the fault that borders the mountain on the east.

The quartzite is absent along the eastern base of Shenandoah mountain until one reaches the mass associated with the basic eruptive at Hortontown (see page 39).

Along the northwestern slope of the eastern gneiss mass the topography from the schoolhouse near Hortontown to Fowler's kaolin mine suggests the presence of this formation. The quartzite was not found and the lower portion of the slope is covered with drift which contains frequent large quartzite boulders. The kaolin rock at Fowler's mine may represent the quartzite. It seems likely that the gneiss rests against the limestone southeast of Shenandoah, and that the quartzite has since been eroded. South of the junction of the Hortontown and Mountain roads, gneiss is the outcropping rock in the valley of the brook as far as Hortontown.

Along the slope of the eastern mountain mass, northeast of the kaolin beds and the ore deposits, everything is beneath the drift for a long distance at the base of the mountain. The gentle slope which is present is probably due to talus. No outcrops of the quartzite were found. South and southeast of Charles E. Bailey's the limestone is only a short distance from the precipitous gneiss. Just north of the road at the base of the mountain scarp, east of Bailey's, a wide swamp extends northeastward. Three-fourths of a mile east of the point where this road turns southward into the mountains the quartzite was found in good-sized ledges within the edge of the woods.

The conditions along this slope resemble those described for Bald hill. There was a tendency for the quartzite to fold somewhat before the rupture occurred, and the slope of the hill marks the slope of the quartzite as seen southeast of Shenandoah. Toward the northeast the rupture occurred earlier, so that the gneiss now stands in precipitous ledges against the limestone. Farther on, east of Bailey's, the quartzite was brought against the limestone marking a diminishing tendency in the thrust to the east. As shown on the map portions of the quartzite are yet preserved near the quadrangle boundary. Where the quartzite could not be found the gneiss is represented as resting against the limestone; but in some cases, as discussed above, the quartzite may have once been present.

The wide swamp east of Bailey's marks the northeastward continuation of the great thrust fault along the limestone-quartzite contact.

Petrography and general description. This formation has great uniformity of appearance and general character throughout the area. Its principal variations may be stated very briefly. The predominating variety is a compact, granular quartz-rock of medium grain. This grades into a fine conglomerate at the base in a few places and in others at the top into finer-grained quartzitic shales. The predominating variety is either white or pinkish in color. Feldspathic varieties are rare.

Within the quadrangle there does not appear to be any appreciable difference in metamorphism in this formation from west to east. At the type locality at Poughquag there is indication of a gneissoid character. Within this quadrangle the quartzite apparently never was involved violently enough to induce this structure.

The thin-bedded varieties, often with shaly character, were noted at the northern end of the Hook spur south of the Hupfel estate, in the steep bed of the brook in the East Hook near the quadrangle boundary, north of Shenandoah and at Hortontown. Conglomeratic phases were seen southwest of Johnsville near Honness mountain, south of the Thomas Carey farm in the West Hook and north of the McCarthy place to the east of Ward Ladue's.

Strikes and dips in this formation vary greatly. In Matteawan good observations could not be made in the thick quartzite south of Anderson street nor at the foot of the Mount Beacon incline. Readings taken just south of the Maddock residence gave a strike of n. 75° e. and a dip of 54° n. w. The gneiss, only 30 feet away, dipped 50° to the southeast. Observations at the quartzite ledge at the extremity of the Bald hill spur gave a strike of n. 42° e. and a dip of 48° to the northwest. A reading taken on the east of Honness gave a strike of n. 42° e. and a dip of 35° southeast. South of the Carey farm in the West Hook the dip is 15° to the northeast. On the farms of Garrett Smith and Ward Ladue, west of the fault, the dip is to the northwest. East of the fault it is to the northeast. As the boundary swings round the western slope of the Hook spur, the dip changes from northeast to north and northwest, and at the northern end of the spur from northwest to north. On Shenandoah mountain in the East Hook, near the quadrangle boundary, the strike is n. 49° e. and the dip 50° n. w. This general strike and dip holds to Shenandoah. North of Shenandoah the dip changes to north. The quartzite disappears at the east under a mass of kames. Readings made a mile east of Bailey's gave a strike of s. 70° e. and a dip of about 18° n. e.

The quartzite thus follows the folds of the gneisses and, although eroded and disturbed by faulting, tends to fringe the spurs and hollows along the northern margin of the Highlands.

The conformable series at West Fishkill Hook. East of the normal fault that extends along the east road into the mountains, the basal quartzite is overlain by bluish-gray limestones having the same dip as the quartzite. The nearest approach to actual contact is in Ward Ladue's orchard, a few feet north of Jones's barn. The pinkish ledges of granular quartz rock are only a few feet away from the limestone and the two are seen to be in strict conformity. The limestone, which is greatly broken up into large blocks, can be followed to the south and east. In both directions it is succeeded by the quartzite. The limestone swings round the northwestern slope of the Hook spur and appears in numerous ledges in the fields southeast of W. L. Ladue's barns. Here it is conformably overlain by gray calcareous shales. At the eastern side of the pasture, south of the orchard on W. L. Ladue's farm, the shales dip to the northwest and north. A little farther west, in the center of the field, the interbedded shales and shaly limestones have buckled into a low anticline.

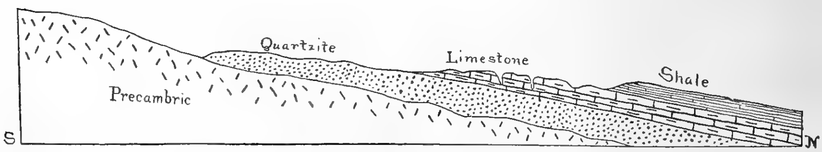

Fig. 13 Generalized section to show the conformable series of the Lower Cambric in the West Hook district. Distance approximately one-third of a mile

Fossils from the quartzite and overlying limestone. With the exception of a few worm borings found in the quartzite along the west road from the West Hook into the mountains in the summer of 1906 (see figure 14), fossils had not been discovered in this formation up to the summer of 1909.

Fig. 14 Worm borings in Lower Cambric quartzite

In August of that year the writer discovered in the yard of Ward Ladue at the West Hook a fossiliferous slab of compact quartzite, about three feet square, and plainly derived from a bed about five inches thick. Both surfaces were covered with fossils, chiefly brachiopods and the cephalic borders and spines of trilobites. Some of the latter were from one and one-half to two inches long.

This slab was from a fine-grained, gray quartzite bed and was very compact and resistant. The fresh surface showed numerous rusty markings.

This discovery led to persistent search for the fossiliferous rock in place.

Directly south from Ward Ladue's house a gorge in the quartzite apparently marks the beginning of the normal fault displacement that extends southward just to the west of the public road. The western wall of this gorge is composed of thickly bedded compact quartzite. The eastern wall shows thinner rusty layers interbedded with the compact rock. The fact that only a hundred feet or so to the eastward the quartzite is overlain by the limestone, together with the evidence of faulting, were taken to indicate that the rocks in the eastern wall are younger than those on the western or upthrow side. With this assumption as a basis, and in the belief that the rusty layers interbedded in the superficial portion of the quartzite should yield fossils, if such were present, the eastern wall was given a very careful examination. No fossils could be found between Ladue's and the point where the gorge intersects the road. Although the dip of the quartzite is very gentle along here, the thickness crossed is considerable.

The gorge was then traced southward from the road. A rich assemblage of fossils was discovered in the eastern wall about 250 yards southeast of Herman Adam's house. The ledge occurs just beneath an old stone wall that separates the gully from an old orchard. The fossil traces were first discovered in the compact rock similar to that seen in the slab in Ladue's yard, and showing the same rusty markings on the fresh surface. This rock overlies some thinner, rusty, decomposed layers in which fragments of trilobites and brachiopods are very abundant. The trilobite fragments are smaller than those displayed on the slab described above, but in other respects are quite similar. They were identified as fragments of Olenellus, probably thompsoni. The brachiopods bear a strong resemblance to Obolella. Two specimens of the rusty quartzite crowded with fossils are shown in figure 15.

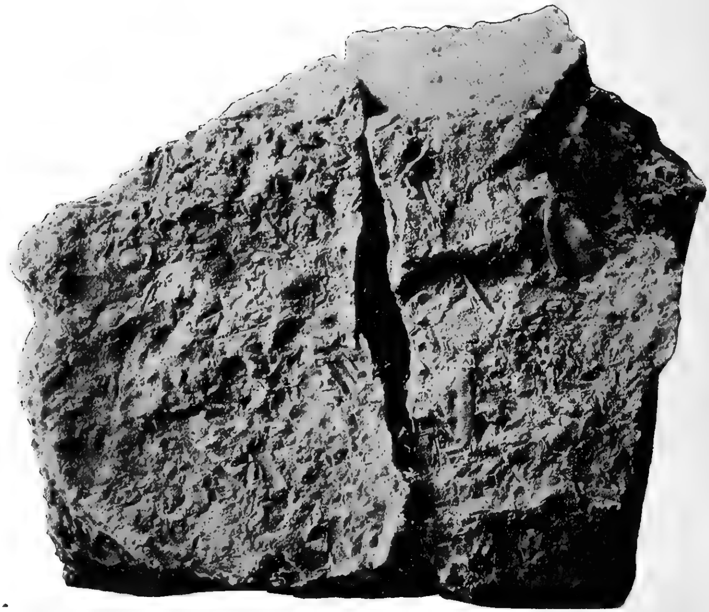

Fig. 15 Fossiliferous Lower Cambric quartzite

In the summer of 1908 the opercula of Hyolithellus micans were discovered in the limestone overlying the compact quartzite in Ladue's orchard at an estimated distance of 20 feet above the latter. After a careful search another operculum was found at a slightly higher level in the first ledge east of the lower barn on Jones's farm.

Age and correlation. These fossils prove the quartzite to be of Lower Cambric age. The similar relations which it has to the underlying gneiss indicate that it is the equivalent of the basal quartzite at Poughquag. The latter was described and named by Prof. J. D. Dana[1] as the Poughquag quartzite.

[1] Amer. Jour. Sci., Ser. 3, 1872, 3:250–56.

Summary and conclusions. The relationships among the quartzite, limestone and calcareous shale described above are exhibited nowhere else in this quadrangle.

The field relations of the gneisses and the quartzite indicate that the older rocks have been thrust up into the younger series and that in general their present relative position must be regarded as very different from that which obtained when the Cambric sea overlapped the older land. It is plain that the quartzite was involved in the thrust movement and, although never violently folded, was yet greatly disturbed by folding in certain places. In many instances the quartzite was moved bodily with the gneisses, so that where it is now present, or was apparently present up to a comparatively recent epoch, it is not contiguous with the limestones of its own epoch, but with later ones on which it has been thrust.

A not unreasonable restoration of the Precambric floor, which is thus assumed to have been fractured and elevated, would allow a considerable extension of the thick quartzite formation southward from its present northern position. The actual evidence for such a former extent consists in the faulted mass at Hortontown, which, since the thrust movement was northwestward, could hardly have had an original position farther northwest, but which might readily have come from the southeast, and in occasional ledges observed in the woods during a reconnoissance south from West Fishkill Hook across the quadrangle boundary. The character of the slope of the quartzite where least disturbed, as in West Fishkill Hook, its thickness and the rather steep southern termination at certain places, indicate a former southward extension.

The varying strike and dip of this formation is best interpreted as the result of disturbance subsequent to its deposition, rather than to original initial slope.

In attempting to explain the present valley position of the younger rocks along the northern border of the Highlands, instead of assuming that they were deposited in valleys, we are offered the alternative explanation of down-faulting, and subsequent partial or entire erosion in which the ice sheet may have played an important part.

The Precambric masses may have stood as islands in the early Paleozoic sea, but the present relationships do not require such an interpretation.

The disturbance of the quartzite has given it such inclination that it might be regarded as of different geological age at different altitudes. Of this there is no evidence.

THE WAPPINGER (BARNEGATE) LIMESTONE

This formation appears within the quadrangle in two main belts with some smaller faulted masses lying between them. The westernmost main belt is the Barnegate limestone of Mather,[1] but now commonly referred to as the Wappinger creek or New Hamburg belt. It is followed by Wappinger creek from the latter's source near Pine Plains to the Hudson river, and its eastern contact with the overlying "Hudson River" formation crosses the river at New Hamburg. The eastern belt is known as the Fishkill limestone, as it lies chiefly in the town of old Fishkill.

THE WAPPINGER CREEK BELT

This belt enters the quadrangle from the north at Pleasant Valley and continues in a southeast by south course to New Hamburg. It reappears west of the Hudson and continues in the same direction beyond the western boundary. East of the Hudson it is broken up into a central strip, with a large rectangular strip on the west of this along its southern half and separated from it by a narrow band of the slates, and several smaller masses lying to the east of the central strip along its middle portion.

THE WESTERN STRIP

Boundaries. This strip is clearly faulted against the slates at the north. The fault line runs in a southeast-northwest direction across the Poughkeepsie driving park. The western contact is marked at many places by swamps or scarps which indicate that the western margin is also a faulted one.[2] The presence of a fault along here receives confirmation from the apparent age of the limestone in contact with, or in proximity to, the slates. The western boundary begins just southeast of the junction of Hooker avenue and the road that runs southward from it on the west of the driving park and passes across the northwestern part of the Ruppert farm and just west of the old Hinckley house, and then may be traced by swampy ground or a low scarp to the schoolhouse at the corner of the Spackenkill and Poughkeepsie roads; thence under drift to the first road leading to the river. The limestone outcrops on the north side of this road in low-lying ledges and in more conspicuous ones south of it in proximity to the slates. From here the contact is

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[1] Geology of the First District, 1843, p. 410.

[2] This fault was described by Professor W. B. Dwight. See Amer. Jour. Sci. Feb. 1886, 31:125-37, with map.

indistinctly followed to the river, where the limestone terminates in a bluff. The northern portion of its eastern boundary is concealed by drift, but farther south to the east of the road that runs southward on the east of the driving park the limestone forms a conspicuous feature for several hundred yards along the eastern edge of R. J. Kimlin's farm. Southwest from here it apparently follows Casper creek to the Hudson river. The slates which come in between it and the central strip form conspicuous ledges both north and south of the Spackenkill road and were noted southwest of the Poughkeepsie-Wappinger Falls road, on the east side of the road to New Hamburg, and also near the Hudson river. The lower reaches of Casper creek, west of the Poughkeepsie road, are choked with kame deposits.

Terranes present. The Potsdam and Trenton horizons have been recognized in the strata composing this western strip of limestone.

The Potsdam. Fossils belonging to this horizon have been discovered in a few places. The first were reported by Professor W. B. Dwight[1] from the northern portion of the strip. Just south of the Poughkeepsie driving park, and to the west of the new private road which runs south from the park to the Ruppert farmhouse, are a number of low-lying ledges. They have yielded: "Lingulepis pinniformis, L. minima, L. acuminata, Obolella (Lingulella) prima, Obolella . . . resembling 'nana,' Platyceras, Ptychoparia (Conocephalites) n. sp. Dicellocephalus, Ptychaspis, Stromatocerium, encrinal columns." A few months later Professor Dwight reported other Potsdam fossils from a locality about a mile southeast by south on the Spackenkill road, about one-half mile east of the Ruppert farmhouse, at the point where the private road to the Varick farm leaves the main road. In addition to Lingulepis pinniformis and allied species found at the first locality, he identified Ptychoparia saratogensis Walcott, and P. calcifera Walcott.[2] These fossils may be seen in the museum of the Vassar Brothers' Institute at Poughkeepsie. Another ledge yielding L. pinniformis was found by Professor Dwight near the eastern margin of the belt about one-half mile southeast of the first locality described.[3] This ledge is just east

[1] Amer. Jour. Sci., Feb. 1886, 31:125–37. See also Trans. Vassar Bros. Inst., 4:130–41.

[2] Trans. Vassar Bros. Inst., v. 4, pt. 2, p. 206–14.

[3] Amer. Jour. Sci., July, 1887, 34:28–32.

of the little house north of Mr R. J. Kimlin's barn. The ledge carrying Solenopora compacta found by Professor Dwight is only a short distance to the southeast.

In the summer of 1908 a new Potsdam locality was discovered by the writer. The beds yielding fossils were found in the quarry on the Ruppert farm about 200 yards north of the Spackenkill road. The rock was being removed for lime and blasting operations greatly facilitated the search for fossils. These are scattered and usually fragmentary. They are embedded in compact, resistant limestone which made the search difficult. A half dozen good specimens of Lingulepis pinniformis were found, besides numerous fragments; also a head of Ptychoparia sp. A photograph of the quarry is shown in plate 7. Fossils seemed most abundant in the middle layers. Figure 16 shows two of the best preserved specimens of L. pinniformis.

Fig. 16 Two specimens of Lingulepis pinniformis from the arenaceous Upper Cambric limestone beds at Ruppert's quarry

The rock in the floor of this quarry showed many peculiar markings of concentric rings from three-fourths to one inch in diameter. These were sectioned and examined by Professor John M. Clarke. A part of a letter from Dr Clarke referring to these structures is given below.

"I have had the specimen you sent to me cut and polished in the hope of bringing out some structure from the concentric masses therein. The result is not very satisfactory, except as indicating what seems to be an inorganic origin, though I would not be willing to say that the masses were not spongoid like Streptochaetus. The successive laminae might indicate such a structure, but the intimate composition of the skeleton has been so altered by granulation as to seem to leave possibility of organic structure pretty hazy; yet I am inclined to believe that the rock carries organic remains, as

Plate 7

Showing the almost horizontal Upper Cambric beds in the quarry at Ruppert's farm southeast of Poughkeepsie. These beds dip slightly to the west. The middle layers have yielded Lingula pinniformis and Ptychoparia sp.

indicated by apparent fragments of shells seen on polished surfaces and in section. I return these specimens to you for your examination. I notice that one side of the rock specimen exposes something that suggests a head of Conocephalus or other primitive trilobite."

Figure 17 is a photomicrograph of a section of this rock and shows what appears to be a fragment of a tiny shell. The microscope failed to bring out any structure in the concentric masses.

Fig. 17 Showing a thin section of the limestone in the floor of Ruppert's quarry

In addition to the suggestive marking referred to by Doctor Clarke as possibly representing a trilobite cephalon, the writer noted another strongly suggesting a Hyolithes.

The rock layers in the floor of the quarry are about ten or twelve feet below the layers yielding L. pinniformis and the whole are conformable.

The Trenton. This horizon; as mentioned above, was reported by Professor Dwight from the eastern margin of the belt on the farm of R. J. Kimlin and was recognized by the presence of Solenopora compacta. No other localities have been described.

Petrographic characters and further description. The Potsdam rock in the locality first reported by Professor Dwight was described as varying from a tough compact limestone through fissile, shaly argillaceous types and arenaceous and oolitic limestones, into quartzitic varieties which were sometimes brecciated. All were calcareous. These may be verified for the most part. The calcareous quartzite is often friable from the loss of the carbonate and rusty from iron discoloration. It frequently carries shell-like depressions or molds. Along the western margin of this strip large quantities of sand are dug and shipped away for molding purposes. In appearance, it strongly suggests the rusty quartzitic phase of the Potsdam of this western strip. As favorable a place as any for observing this sand is on the farm of Mr Toel on the Camelot road north of Casper creek.

A section beginning at the eastern margin of the belt, just southeast of R. J. Kimlin's farm, and running west along the Spackenkill road to the Poughkeepsie road, and then continued to the river along the road to the molding sand dock a mile and a half north of Camelot,[1] and thence along or just east of the track to Camelot station gives all the principal varieties of rock that have been met with north of Stoneco quarry.

Beginning at the east, south of Kimlin's farm, at the top of the hill on the Spackenkill road, the rock in the ledges is of a light steel-blue color and of medium grain (letter A in the section, fig. 18).

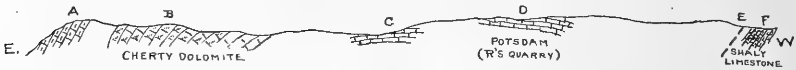

Fig. 18 Section along the Spackenkill road

It often carries on fresh surfaces markings of calcite, shaped like the segments of various curves, and blackened depressions and pits which have no particular or definite form. Just north of the junction of the two roads at this point on the east side of the road that passes Kimlin's house a brecciated conglomerate was noted resembling the Trenton as seen elsewhere in the quadrangle and carrying masses that resembled Solenopora compacta.

The next cut west on the Spackenkill road shows many chertlike masses and scroll effects of silicious material that have weathered out. North of here in the fields of Mr Mulkemus and in the neighboring woods the ledges carrying this variety of rock are very numerous and may be traced some distance east and west (lettered B, fig. 18).

This rock gives place, near and at the junction with the Varick road, to dull gray ledges of arenaceous limestone which has a coarse sandpaperlike appearance on weathered surfaces. One-fourth mile beyond this, rock outcrops on the north side of the road and lies quite flat (lettered C, fig. 18). The rock at Ruppert's quarry, one-fourth mile farther west (lettered D, fig. 18), in general character is almost identical with that of the two previous outcrops. The rock in the quarry varies in color from black to gray. The beds average thicker at the base and grow thinner toward the top. There are a few shaly layers. The strike of the quarry rock is about n. 75° e. and the dip about 10° northwest.

At the corner of the Spackenkill and Poughkeepsie roads impure limestone outcrops on the east side of the latter road with

[1] Camelot station is at the point marked Stoneco on the map. The name Stoneco is usually applied to the Clinton Point Stone Company's quarry, a mile below Camelot station.

a strike of n. 23° e. and a dip of 70° s. e. This may belong with the slate formation and may therefore be on the downthrow side (lettered F, fig. 18).

Ledges of rock similar to that in Ruppert's quarry occur to the southeast along the western margin of the belt, to the north and south of the first road leading to the river, and west of the road leading from this toward Camelot station. East of Camelot station, about 100 feet up the hill, on the south side of the New Hamburg road, ledges of rock identical with that in Ruppert's quarry strike approximately east and west and dip about 12° to the south.

The first road leading to the river, south of the Spackenkill road, leaves the Poughkeepsie road (old Albany turnpike) one-fourth mile south of the schoolhouse. The river road gives off two branches, the shorter, lower one going to the dock of the Whitehead Sand Company and the other to Camelot station.

On the east side of the lower road, just north of the red house, coarse conglomerate, familiar in Trenton localities within this quadrangle, outcrops in one or two large ledges. This rock, in a brecciated condition, was also noted farther south along the upper road where this runs parallel with the railway track, about one-fourth mile north of Camelot station.

Along the middle portion of this western strip the topography generally indicates a very gently sloping almost flat substratum of rock, and the extraordinary width of the belt is plainly due to the nearly horizontal position of the underlying strata for long distances.

The varieties of rock described by Professor Dwight would seem to be accounted for mainly as outcrops across the dip of several beds showing variations of texture and composition, and partly to the different effects of weathering on these, as well as to possible frictional brecciation.

The portion of the section which may be seen at Stoneco in the quarry of the Clinton Point Stone Company is between one-fourth and one-third of the breadth of the strip from its eastern margin

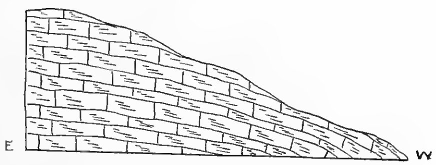

Fig. 19 Section at Stoneco quarry

and displays a thick mass of dolomitic limestone dipping gently to the west (see plate 8). For the most part it is thick-bedded. There are some thinner layers near the top and in the middle. Some beds carry numerous chertlike masses and in this particular, as well as in general character, the rock strongly resembles the variety described above along the Spackenkill road on the farm of Mr Mulkemus near the eastern margin of the belt. No fossils were found in the beds of this quarry and hence no definite idea of its age could be obtained.

Just east of Camelot station, as described above, arenaceous limestone identical with that in Ruppert's quarry, dips to the south at an angle of 12°. This suggests a southward pitch and a superior position for the strata in the Stoneco quarry, a mile to the south of Camelot.

The stratigraphic position and estimated thickness of the Stoneco beds agree with those of the cherty rocks along the Spackenkill road to the northeast. Presumably these strata once entirely covered the Upper Cambric (Potsdam) along the central and western portions of the strip and have been preserved at the south on account of the pitch of the series.

Structural features. It is not possible to tell with absolute certainty what the exact relationships are among the different strata composing the series of this western strip. Presumably the Upper Cambric beds are followed conformably by those which apparently have a superior stratigraphic position. But in these latter strata it is necessary to recognize a probable interval of erosion as is indicated by relationships which can be determined with more exactness within the central strip and which is shown by the presence of a conglomeratic layer, even in this western belt. As will be discussed farther on this conglomerate, though possessing peculiar features, marks a change in fauna as well as in the lithic character of the rock and must be taken as marking a definite hiatus.

The present almost horizontal position of the Upper Cambric and overlying beds theoretically admits of two explanations. It either represents a close overturned, recumbent fold, or else a reversed fault accompanied by westward thrusting, which was preceded by only relatively little folding.

These rocks show no indications of extensive slickensiding, of compression of layers, or of flow structures such as would be expected in violently folded strata. There is evidence of some brecciation and slipping in the rock along the eastern margin, but this is not severe. There is extensive fracturing which is, however, readily explained by the hypothesis of reversed faulting and thrusting.

The field relations point to an upward movement of older strata into overlying younger ones similar to that already described for

Plate 8

A portion of the southeast wall at the quarry of the Clinton Point Stone Company, Stoneco, showing the thickly bedded limestones dipping to the west

the gneisses. Along the western margin of the strip the compression brought the Upper Cambric beds against the slates, which were first folded and overturned and then overridden. At the quarry at Stoneco and below Marlboro station across the river the westward dipping younger strata show a diminution in the upward thrust toward the southwest which may be associated with an earlier release that elevated the Glenham belt.

As already indicated, the conglomerate appears in places along the western margin of the strip. It is best interpreted as belonging with the downthrow block and is to be associated with the slate rather than with the limestone. It is likely that there was a strong horizontal component in the thrust that carried the older beds over the slates to the west of this strip.

The conglomerate along the eastern margin would appear to occupy a normal position, but the fact that it is brecciated is noteworthy. The presence of ledges yielding Lingulepis pinniformis, as described above (see page 49), along the eastern margin in the near neighborhood of the Trenton, seems best explained as an instance of faulting. The Potsdam beds seem clearly to have been overlain by younger strata, as is now the case at Stoneco quarry. It does not seem possible from the relationships exhibited elsewhere that the overlying strata were eroded so as to expose the Potsdam before the deposition of the Trenton.

Apparently the limestone on the west of the Hudson is essentially the continuation of this western strip, but presumably the beds are younger even than those of the quarry at Stoneco. Some of them resemble the beds of the central strip, as shown at the New Hamburg tunnel. On the west of the Hudson, near the river's edge at Danskammer, the limestone dips to the southeast at an angle of 10°. Along the western margin, as shown just below Marlboro station, the dip is to the northwest. The limestones rest by overthrust on the slates at the west.

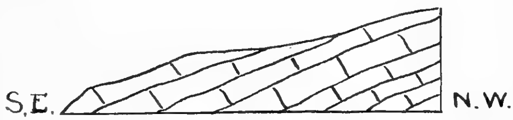

Fig. 20 Section at Danskammer

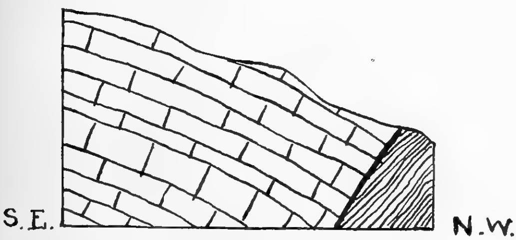

Fig. 21 Section below Marlboro station

Metamorphism and alteration. Brecciation has been noted along both margins of the strip. Fracturing has been extensive, producing many small cracks that have been healed by calcite. The broken surfaces of the rock along the eastern margin of the strip show by the smooth, distorted blackened depressions that there has been some movement in the rock. The alteration is least where the beds are flattest. The principal changes then are due to granulation which usually has been sufficient to conceal or destroy organic remains.

Summary. Presumably the Upper Cambric beds are followed in this strip by the Beekmantown (Calciferous), as is the case in the central strip; but fossils belonging to this horizon have not yet been discovered. This terrane may be represented by all or part of the dolomitic strata shown in the Stoneco quarry and their apparent equivalents to the north.[1]

Locally about Saratoga a very fossiliferous limestone lens appears in the basal portion of the dolomite formation.[2]

The trilobites discovered by Professor Dwight on the Spackenkill road, as mentioned on page 49, were like those discovered by Mr Walcott at Saratoga.[3]

No fossils have been reported from the limestone on the western bank of the Hudson within this quadrangle. In 1879 R. P. Whitfield[4] reported M a c l u r e a m a g n a from these limestones at Newburgh and in 1880 W. B. Dwight[5] found an assemblage of Trenton fossils in that city.

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[1] The description of the cherty, dolomitic limestone at the Stoneco quarry and overlying the Potsdam beds along the Spackenkill road was written in October 1909. At the meeting of the Geological Society at Cambridge, Mass., the following December, Professors Ulrich and Cushing described a dolomite in the Mohawk valley which "is found to consist of two distinct formations, the lower a dolomite formation of Ozarkic age, the upper a limestone of Lower Beekmantown age with a distinct unconformity between the two." The Beekmantown was described as thinning to the west, so that west of Little Falls the Lowville rests on the Ozarkic. The unconformity may be followed into the Champlain valley, reappears in the St Lawrence region "and is believed to mark the line of division between the two formations everywhere in northern New York."

[2] Preliminary list of papers. G. S. A., 22d winter meeting at Boston-Cambridge, December 1909.

[3] See Thirty-second Ann. Rept. N. Y. State Mus.; also U. S. G. S. Bul. 30, p. 21, and Science, 1884, 3:136–37.

[4] Amer. Jour. Sci., Ser. 3, 18:227.

[5] Amer. Jour. Sci., Ser. 3, 19:50–54.

THE CENTRAL STRIP

Boundaries. This strip enters the quadrangle from the north at Pleasant Valley. Its eastern margin forms the western bank of Wappinger creek north of the covered bridge at Pleasant Valley and southward follows the creek closely as far as Rochdale. At this place the limestone is in contact with the slate at the dam and on the island just below it. South of Rochdale the limestone follows the creek for one-half mile and then bears slightly to the west. It apparently ends just north of the terrace one-fourth of a mile east of Tompkins's house (see plate 17) on the Pleasant Valley road. This terrace fringes an old meander of the creek and extends around to the south side where the limestone appears again just south of the road that skirts its edge. East of the portion of this road running north and south, just west of Frank De Garmo's house, are numerous outcrops of the slates, but these disappear at the terrace slope and no outcrops appear in the deep westward embayment formed by the old meander.

This embayment is regarded as lying in a zone of transverse faulting. It seems probable that the slates were dropped down in here. At any rate, either on this account or because of faulting, a weakness was produced which the base-leveling forces caught and finally left as a gap in the ridge of limestone. It seems probable from the dimensions of certain faulted limestone blocks a short distance to the eastward that they belong in or near this gap. The slate has been dropped between the faulted masses and the dismembered main strip.

South of the break in the central strip its eastern margin follows the road until the latter turns eastward and then extends as a conspicuous wooded scarp in a north and south line to a point about one-third of a mile south of Frank De Garmo's house. At this point the limestone sends a sharp angular spur eastward for about 200 yards, as shown on the map. The strike of the slates just west of De Garmo's house, projected southward, would bring them sharply against the limestone in the included angle of this spur, showing a transverse fault between the slates and the spur and indicating that the eastern marginal scarp south of De Garmo's is a faulted one.

Limestone outcrops at the apex of this spur, whence it may be traced by continuous outcrop along the margin of the slate to and across the railroad track and highway west of Manchester Bridge. South of here the eastern margin follows the eastern base of an immense drumlin and south of this distinctly to the Poughkeepsie-

New Hackensack road; then across this and for a short distance to the south. The margin is then apparently broken by a spur in a manner similar to that just described, although this time the break appears to be along an extensive fault line. The slates which outcrop south of the Poughkeepsie-New Hackensack road and west of the cross road that leads from it to the Spackenkill road, lie in the included angle of this spur.

The contact is then easily followed southward by the steep marginal scarp in the limestone, from the point where the cross road just mentioned makes its turn, to and across the Spackenkill road, and east of the old Boardman farm. The gully which, as shown on the map, cuts across this central strip west of the northern termination of the narrow faulted strip lying on the east, may represent a fault.

South of the Spackenkill road slates outcrop in numerous places between the main strip and the narrow faulted mass just east and south through the swamp to the southern end of the small strip, leaving no doubt but that, at the surface, the two limestone masses are separated by a narrow band of the slates. The eastern contact is then very readily followed through the fields to Channingville and then less distinctly under the drift between the creek and the New Hamburg road to the bank of Wappinger creek near its junction with the Hudson.

The western margin of the central strip could be determined with much more exactness in certain places than in others. At the north the surface deposits conceal it for the most part, but swamps and other topographical features and occasional outcrops enable one to follow it approximately, and in a few places distinctly, until it crosses the Pleasant Valley road just west of Rochdale. The limestone then forms a distinct scarp east of the road to the break just southeast of Tompkins's house. South of this the margin is distinct to the railroad, but across this it is soon lost under the drift composing the large drumlin at this point. The limestone reappears on the south side of this hill and again a little farther south as a scarp which crosses the Poughkeepsie-New Hackensack road. South of this road the margin is readily followed, often with the limestone and slate in close proximity, to the Poughkeepsie-Wappinger Falls road which, going south, ascends the western scarp of the limestone. South along the New Hamburg road the contact is clearly for a distance on the east side of the road as the slate was noted in the latter. But along here the kame deposits effectually conceal the exact relationships between the limestone and slate. At the northern end of the New Hamburg tunnel the limestone rests by overthrust upon the slate (see plate 9) and occasionally the limestone outcrops along the slope to the northeast for a short distance.

Terranes present. The Potsdam, Beekmantown (Calciferous-Rochdale group) and Trenton horizons have been identified along this central strip within the quadrangle.

The Potsdam. This horizon was first noted in this strip just a little north of the quadrangle boundary half way between Pleasant Valley and Salt Point.[1] At Pleasant Valley Lingulepis pinniformis was reported along or near the western margin of the strip to the northwest of the village in rather characteristic argillaceous limestone, and also from some hills to the north of the village between the old Poughkeepsie and Eastern Railroad bed and Wappinger creek.[2] At the latter place the beds carrying L. pinniformis also had small brachiopods, apparently Orthis and Triplecia, as well as minute gastropods, fragments of trilobites and Ophileta compacta. These beds were mixed with Calciferous and Trenton strata carrying other fossils characteristic of these limestones in this region. The Potsdam was identified near Rochdale, just west of the Poughkeepsie-Pleasant Valley road. The beds exposed in the quarry just northwest of Alson De Garmo's house, from which stone was removed for the State road, are possibly of Upper Cambric age. A search for fossils in this quarry was unrewarded. In a note to his paper on the discovery of Potsdam fossils in Poughkeepsie, south of the driving park, as described for the western strip, Professor Dwight[3] mentioned the discovery of a fragment of brachiopod shell which he believed to be that of Lingulepis pinniformis in a rock very similar to that at the locality south of the driving park. He described this new locality as about one-half of a mile south of the Boardman mansion on the Spackenkill road, but it is uncertain from his description at just what point the fossil was found.

The Beekmantown (Calciferous-Rochdale group). In January 1880, Professor Dwight[4] reported the discovery of a rich assemblage of fossils of Pretrenton age at Rochdale, a small factory hamlet four miles northeast of Poughkeepsie.

[1] W. B. Dwight. Amer. Jour. Sci., July, 1881, 34:27–32.

[2] (W. B. Dwight) J. M. Clarke. Guide to the Fossiliferous Rocks of New York State. N. Y. State Mus. Handbook 15, p. 9–10.

[3] Amer. Jour. Sci., Feb. 1886, 31:136.

[4] Amer. Jour. Sci., January, 1880, 19:50 et seq.

The following named fossils were enumerated as the most important:

"Ophileta complanata (possibly Ophileta compacta), O. levata, O. sordida (Maclurea sordida), Orthoceras primigenium." Other univalves were noted but not identified. A network of "fucoidal fronds" might be Bythotrephis antiquata. The fossils of the neighboring Trenton at the east were absent from this rock and it was believed to lie beneath the Trenton, both strata having an eastward dip. It was called the Calciferous.[1]

In October 1880, Dwight[2] found at the Rochdale locality another remarkable assemblage: "great numbers of Orthocerata and other fossils, many of which are not reported as occurring in New York State." In lithology this rock was identical with that previously assigned to the Calciferous. Orthocerata were abundant and discoidal gastropods very plentiful. In addition to its own peculiar fossils, it contained the "fucoids" and other types of the adjacent Calciferous. Dwight hesitated to announce the exact stratigraphical position of this new fossil assemblage. The wealth of cephalopods separated it very sharply from any other known terrane in the United States below the Black River-Trenton, to which it was inferior. In its numerous orthoceratite cephalopods it resembled the Quebec group of Canada.

In 1882 Diwght[3] reported tracing the Calciferous in this strip to a point five miles below Poughkeepsie. In addition to the abovenamed "Calciferous" fossils he announced in this paper: A large Holopea and smaller ones not identified, many Pleurotomaria resembling Canadian forms, a minute Ophileta n. sp., a Murchisonia resembling gracilis of the Trenton, one or two orthides, many undeterminable fragments of Bathyurus, Chaetetes lycoperdon var. ramosa, not hitherto reported below the Trenton, 25 to 30 species of Orthocerata, all apparently new in the United States, two species of Lituites and a Cyrtoceras. In 1884[4] a number of these fossils were described with figures; trilobite fragments were provisionally assigned to the genus Bathyurus (B.

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[1] The ledges at the summit of the hill north of Alson DeGarmo's house on the Pleasant Valley road belong, in part at least, to Dwight's Calciferous locality.

[2] Amer. Jour. Sci., Ser. 3, 21:78.

[3] Proc. Amer. Assoc. Adv. Sci. (Montreal meeting), v. 31. Abstract Aug. 1882, p. 3-6.

[4] Amer. Jour. Sci., Ser. 3, April, 1884, 27:249-59.

taurifrons and B. crotalifrons). New cephalopod species were described as Cyrtoceras vassarina, C. ? dactyloides, C. microscopicum, Orthoceras apissiseptum; O. henrietta, Oncoceras vassiforme.

In 1900 Dwight[1] designated the main Calciferous strata as the Cyrtoceras vassarina beds and called attention to the great persistence for a distance of nearly thirty miles in the Wappinger limestone, of a layer which contains a fauna quite different from that of the main beds. It lacked cephalopods entirely. There were no important fossils in common in the two beds except two or three always present in the Calciferous. In some respects it resembled the Fort Cassin of Vermont, but differed in the extreme scarcity of cephalopods. The presence of Lingulepis pinniformis suggested a low horizon in the Calciferous. What Dwight has called a low horizon in the Calciferous may be Upper Cambric disconformably overlain by Beekmantown.

The Trenton. Fossils belonging to this horizon were the first to be discovered in the Dutchess county limestone and were first reported from the area within this quadrangle.

Mather referred only in a footnote to their having been found in a quarry south of Pleasant Valley by Professor Briggs. His assignment of the age of this formation was based on fossils found in the beds of limestone within the slate formation a mile or so north of Barnegate.

In 1879 Professor Dwight[2] found the following Trenton fossils at Rochdale: Leptaena (Plectambonites) sericea, Orthis tricenaria, Receptaculites sp. A week after the discovery Dwight and Dana visited this locality. The following fossils were found: L. (P) sericea, Escharapora recta, Ptilodictya acuta, the caudal shield of a trilobite probably Asaphus vetustus, Orthis tricenaria, O. pectinella, O. testudinaria, an Endoceras, an Orthoceras, specimens of Chaetetes, and encrinal columns.[3] On this same excursion the quarry south of Pleasant Valley, mentioned by Mather, was visited. A fossil assemblage very like that at Rochdale was at once discovered. Subsequent examination of this collection showed Strophomena alternata fragments. The Chaetetes was named by Dwight C. tenuissima.

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[1] Bul. Geol. Soc. Amer., v. 12, 1900, abstract.

[2] Amer. Jour. Sci., May, 1879, 17:389.

[3] Amer. Jour. Sci., May, 1879, 17:390. See also p. 381.

In 1880 Professor Dwight[1] added to the above from the Rochdale locality: a number of cyathophylloid corals, among them Petraia corniculum, a head of Echinoencrinites anatiformis, and the caudal shield of a trilobite identified as Illaenus crassicauda. The C. tenuissima was identified as in part at least, Stromatopora compacta Billings (Chaetetes compacta Dawson). This fossil is now recognized as Solenopora compacta.

The Trenton also occurs at Pleasant Valley in the railroad cut just east of the Central New England station on the old Poughkeepsie and Eastern road. The Trenton beds here have yielded Tetradium cellulosum and great numbers of entomostraca and fragments of small trilobites.[2] The characteristic Trenton conglomerate carrying Solenopora compacta occurs at the northeast end of the cut. The Trenton apparently has an extension eastward in the village. The conglomerate carrying fossils was noted by the writer at the hose house.

It is quite probable that other Trenton localities in later years were noted by Professor Dwight which were never published.

Petrography and further description. Beds from this strip, which have been referred to the Potsdam, vary from argillaceous to arenaceous limestones with occasional shaly layers. It is not possible to say much about the extent of the Potsdam along this strip to the south. It may occur at many places for which, however, there is at present no paleontologic evidence. The structural features suggest that it is probably confined to the northern and central portions of the strip and that the beds at the south are probably younger. The shaly limestones in the quarry west of the tunnel at New Hamburg have been thought to be of Potsdam age on stratigraphic grounds.

The Beekmantown (Calciferous) of this strip is best studied at its type locality at Rochdale. It is often, if not characteristically, arenaceous and varies in color from a bluish gray to a gray with lighter chamois-colored layers which weather very white. The two are interstratified, though the writer's observations indicate that the bluish beds are usually near the eastern margin and therefore in the upper layers. The bluish beds carry grayish wavy markings and are very tough and splintery, breaking with conchoidal fracture.

[1] Amer. Jour. Sci., v. 19, January 1880.

[2] (W B. Dwight) J. M. Clarke. Guide to the Fossiliferous Rocks of New York State. N. Y. State Museum Handbook 15.

The lower portion of the Calciferous shows many thick, grayish layers in places.

Apparently the Beekmantown has a wide distribution in this strip. It forms the main mass of the high hill northwest of the Trenton in the cut at Pleasant Valley and may be traced rather satisfactorily as a lithic unit to Rochdale, where it is seen to have a great thickness, estimated at from 1000 to 1200 feet. Dwight claimed to have traced it definitely to a point five miles below Poughkeepsie (see above). The beds resting on the slates at the New Hamburg tunnel are probably of Beekmantown age.

At Rochdale the Beekmantown in places passes through a heavy conglomerate into the Trenton which rests upon it. Just a little way south of a ledge of this conglomerate on the property of Henry Titus, along the road, are fine exposures of the bluish-gray beds. These give place at the west to the gray and dove-colored beds which compose most of the hill between Rochdale and the Pleasant Valley turnpike.

The bluish-gray beds were noted farther south near the eastern margin just north of the break in this strip. Taking the apparent thickness at Rochdale as a guide, the beds intervening between these blue beds and the scarp just east of Tompkins's house are probably all Beekmantown. South of here the lithology does not convey very much, though indicating on the whole the southward continuation of the lower portion of the Beekmantown as shown at Rochdale.

Within this strip farther south, about one-fourth mile north of the Spackenkill road, along an old wood road, or cow path, are probable beds of the Beekmantown within a few rods of coarse Trenton conglomerate apparently carrying Solenopora compacta. The road from the orchard on the north side of the Spackenkill road, opposite the old Boardman farm, leads to these outcrops. This locality is seemingly not so far south as Professor Dwight claimed to have traced the Beekmantown; but the writer has not been able to add anything definite to the age of this belt to the south of this point.

The Trenton, within this strip, is usually a dark blue rather crystalline rock of quite different appearance from the Beekmantown. Its lower portion is conglomeratic and carries colonies of the coral S. compacta which, without careful examination, might be taken for pebbles. This coral, or a conglomerate appearance, is often the only means for identifying this member of the limestone formation. The Trenton is also somewhat finely conglomeratic at times. The conglomerate was noted at Pleasant

Valley, at Rochdale and north of the Spackenkill road. The Trenton also is probably present in places not yet discovered along the eastern margin of this strip. At Rochdale the dark blue Trenton beds have a thickness apparently between 60 and 100 feet and form a conspicuous stratum.

Strikes and dips within this strip show much uniformity. In the Poughkeepsie and Eastern Railroad cut at Pleasant Valley the Trenton beds show a strike about n. 37° e. and a southeast dip. In the quarry on the Pleasant Valley road to the west of Rochdale the supposedly Potsdam beds strike n. 42° e. and dip 60° to the southeast; at Rochdale in the road near the mill site, the strike is n. 40° e. and the dip 55° southeast; at the conglomerate ledge on the Titus place approximately n. 43° e. and 58° s.e.; at the eastern margin east of Tompkins's n. 28° e. and 35° southeast; north of the Spackenkill road in the woods near the old barn n. 53° e. and 42° s.e.; at the New Hamburg tunnel about n. 60° e. and 30° s.e.

Structural features. The presence of an erosion interval between the Trenton beds and the Beekmantown is conclusively shown by the relationships at Rochdale. The Beekmantown is separated from the Trenton by a heavy conglomeratic layer, and the fauna and lithologic character of the two strata are markedly different. The general uniformity of dip shows a "deceptive unconformity" or "disconformity."[1] From the apparent thickness of the Beekmantown at Rochdale, it would seem that this formation was not extensively eroded here.

The limestones of this central strip rest against the slates on the west by overthrust. This is best shown at the north end of the New Hamburg tunnel (see plate 9). The occurrences of the Potsdam along this western margin is also evidence of it. Frequent slips along and across the strike within the limestone are probably present.

The slates along the eastern margin of the strip may be at places in conformable relationship with the limestone. In other cases such is almost certainly not the case.

Metamorphism and alteration. The strata composing this strip are all visibly altered. Fossils have usually been greatly obscured. The Beekmantown shows the metamorphism most. Fossils in it are recognized or identified usually with difficulty although they sometimes weather out with distinctness. The Trenton beds are usually somewhat crystalline, but fossils are preserved in them in better condition than in the Beekmantown.

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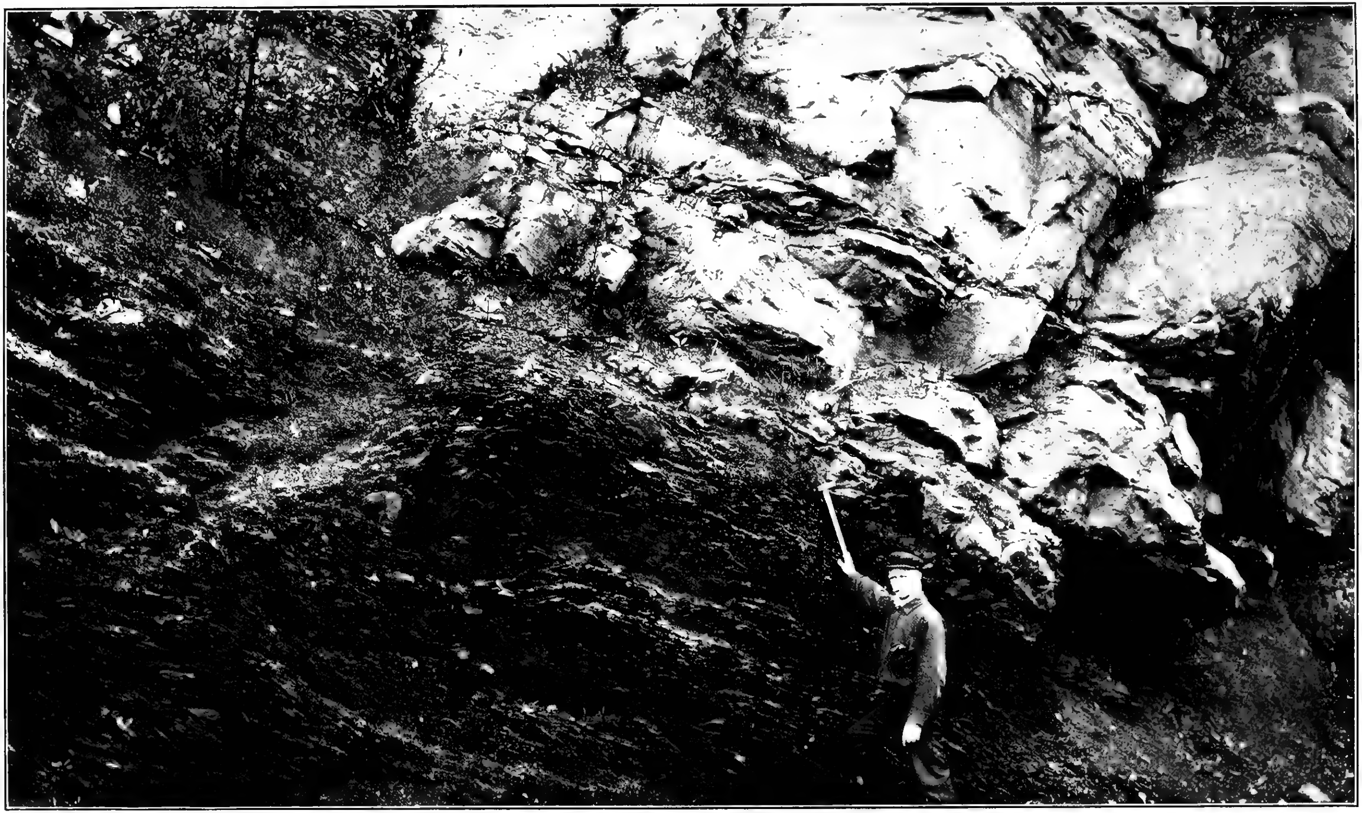
[1] Professor A. W. Grabau. Science, n. s., *22*:534.



Limestones overthrust on the slates at the northern end of the New Hamburg tunnel

Summary and conclusion. The absence of the Trenton conglomerate at places along the eastern margin of the central strip might be interpreted as the result of faulting and, in any event, is probably due in part, at least, to faulting.

The presence of Tetradium cellulosum in the Poughkeepsie and Eastern Railroad cut at Pleasant Valley is noteworthy. Professor Clarke[1] has indicated that elsewhere this fossil is characteristic of the Lowville. The Trenton conglomerate at this locality is apparently a few feet above the beds carrying this fossil. This would seem to indicate that the Lowville might have been deposited here. Doctor Ruedemann[2] has discussed the Trenton, as descrbed by Dwight, as probably not lower than Midtrenton in age.

The examination of this strip leaves one in great doubt as to how to represent its structure. It is certainly very different from Professor Dana's early representation as a simple fold.[3] It is best interpreted as belonging to the same thrust that pushed the western strip on the slates, but as the map shows the limestone broke both along and across the strike and at the south was pushed farther west, apparently feeling the influence of the Highlands mass.

MISCELLANEOUS FAULTED BLOCKS OF THE WAPPINGER CREEK BELT

Several smaller limestone masses, each of which can be reasonably shown to be a detached and separate block, forming an inlier in the slates, are scattered to the east of the central strip along its middle portion. The mantle of the surface deposits at times greatly obscures their exact relationships to the slates, but as a rule the field relations leave scarcely any doubt of their inlying character. In most, if not all cases, these relations point to faulting, both along and across the strike between the limestone masses and the slates which surround them.

These blocks will be described separately and will be designated by numbers from north to south. The occurrence of these faulted blocks of limestone to the east of the central strip seems to be directly due to the thrust which carried the limestone of this belt over the slates. They have been left, stranded as it were, behind the main mass.

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[1] Guide to the Fossiliferous Rocks of New York State. N. Y. State Mus. Handbook 15, p. 9.

[2] Hudson River Beds near Albany and their Taxonomic Equivalents. N. Y. State Mus. Bul. 42, 1901, p. 501.

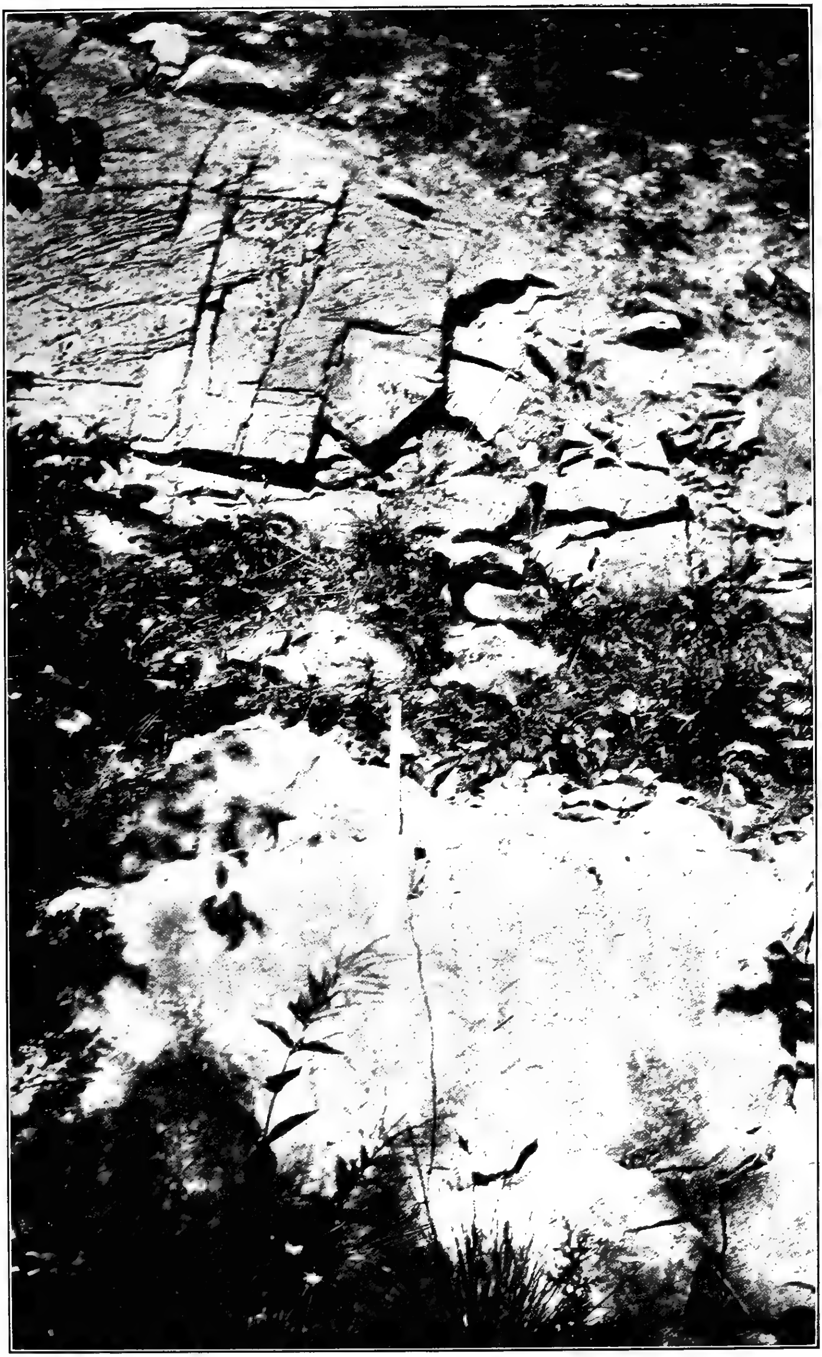
[3] Amer. Jour. Sci., May, 1879. 17:382.

Faulted block number 1. This block of limestone, which is the most northerly of these masses, lies about a mile north of Manchester Bridge on the farms of A. W. Sleight and George Byer. Its apparent northern boundary is along a northwest-southeast line that crosses the Sleight farm just north of the barn and intersects the roads to Pleasant Valley and to Overlook. About 75 yards south of the Overlook road, where this makes its first turn in ascending the hill, the visible northeastern boundary of the limestone is marked by a ledge. Its eastern boundary extends south from here for about one-fourth of a mile. At the southeast the limestone is represented by impure shaly limestone. At a point just north of the wall between the Byer farm and Hart's orchard, the slate outcrops and continues to outcrop to the south for a mile or more. The slates are in close proximity to the limestone in many places along the eastern border. Just south of the sheep pen they form a scarp between which and the limestone the farm road descends. The road is, however, apparently on the limestone. The limestone outcrops just south of the farm road at the base of the hill and continues as a steep scarp just within the woods northward from this point for several hundred yards and then turns west and crosses the road and ends in a large ledge 50 feet west of the road. North from here it is finally lost under drift, but is readily followed along the road toward Sleight's house. There are no outcrops of any kind between Byer's house and barns, which stand on a knoll of limestone, and the steep scarp 200 yards east of the road. Ledges of limestone probably determined the terrace slope just west of Sleight's house. Drift conceals outcrops north of Sleight's barns. Quartzitic rock of the slate formation outcrops between the Pleasant Valley and Overlook roads 100 feet north of the latter. Between here and the outcrop of limestone marking the northeast corner of the block there are no outcrops. Presumably the limestone, in part at least, underlies the flat terrace level just east of Byer's house.

On the eastern margin of this block, partly on the property of A. W. Sleight and partly on that of George Byer, is an old quarry, which many years ago furnished stone for the abutments of the bridge at Manchester. The fact that this is a rich fossil locality appears up to this time to have escaped attention.

There are two varieties of rock in the quarry. The one which was quarried chiefly and which makes up most of the quarry is a dark blue rock which varies in texture from a fine calcareous con-

Plate 10



A portion of the wall in A. W. Sleight's quarry. In the foreground Trenton conglomerate with *Solenopora compacta* resting on probable "Calciferous" which is exposed in the upper half of the picture. The two are disconformable, but have the same dip to the southeast

glomerate, shown at the south end and in the central part of the quarry, to a dense fine-grained mud rock at the northern part. The bedding surfaces are distinct, and good-sized blocks, frequently a foot or more in thickness, have been removed. The rock has been weakened by blasting. It still breaks with difficulty into thin irregular pieces that are often crowded with fossils and their fragments. The removal of the mud rock at the south end of the quarry has exposed the basal conglomeratic portion which contains abundant crinoid stems, colonies of Solenopora compacta and some brachiopods. The quarry faces east. The beds of limestone strike n. 40° e. and dip 42° s.e. At the top of the quarry, under the bank and at the summit of the ridge the rock changes to a chamois or gray color but retains the same strike and dip.

About seven or eight feet in thickness have been preserved of the finer-textured blue mud rock at the north end of the quarry. Fossils are distributed through it, but could be removed in numbers only from the surface layers. The rock has yielded:

Orthis pectinella	31
Plectambonites sericeus	18
Dalmanella testudinaria	13
Strophomena alternata	1
Orthis lynx	3
Streptelasma sp. (resembling parvula)	2
Chaetetes lycoperdon	3
Ceraurus pleurexanthemus (probably)	3
Platynotus trentonensis (probably)	1
Calymmene senaria	6
Phacops sp. (probably)	1
Illaenus crassicauda (probably)	1
Ostracod (undetermined)	1

At the western base of the ridge, somewhat to the southwest of this quarry, and now completely hidden by thick underbrush within the edge of the woods, is another and older quarry from which it appears the rock was removed and burned for lime a good many years ago. Solenopora compacta was noted here.

The width of the dark blue limestone stratum on the east is probably less than a score of feet. A small diagonal fault crosses the limestone just west of the road that ascends to the sheep pens.

The blue rock of the quarry is the same as that at Pleasant Valley and Rochdale. The chamois-colored or gray rock is assumed to be the Beekmantown (as qualified above).

The presence of the Trenton along the western scarp, as marked by S. compacta, accompanied as it is by a scarp, suggests that it probably is faulted in here.

Faulted block number 2. Whether this block is distinct from number 1 might be a matter of interpretation. The house and barns of George Byer are built on the summit of the western scarp of this block which, west of the house, descends abruptly to the level of the present flood plain of the creek. The northern margin ends 100 yards north of the barn. The most eastern outcrop at the north is separated from the ledge, marking the visible western margin of block number 1 by a shallow gully. The two may unite below the surface. At the south the limestone is lost under the terrace, but it is assumed to continue south for a distance. The slates do not outcrop between its western scarp and Wappinger creek, but as the slates extend well up in this space in the bed of Wappinger creek and west of it they almost certainly underlie the interval where outcrops are concealed. The block is regarded as a dismembered part of the central strip. The slates have been dropped down between the latter and these two blocks at the east.

Faulted block number 3. The evidence for the presence of the limestone at this point consists of two small detached ledges apparently in place, and a scarplike topography. The low hill shown on the map at this place was approached through the fields south of Manchester Bridge station. The northern slope of the hill is made up of drift, but along the wooded western slope a careful examination disclosed a small ledge of conglomeratic rock with a strike of n. 5° w. and a dip of 32° e. The base of the slope is marked by a swamp. A few hundred feet to the southeast is another ledgelike mass of the limestone with nearly the same strike. North near the railroad and east and west outside the cover of the drift and in the fields at the south are low-lying ledges of slate.

Faulted block number 4. The visible northern termination of this block is on the farm of Mr Rothenburg at Titusville. The limestone forms a conspicuous ledge just southeast of the barn. Its eastern margin may be followed southward as a low scarp across the road where the limestone abruptly disappears under the lowland along Wappinger creek. In places along the eastern margin, and well shown in two ledges just southeast of Rothenburg's house, the apparent dip is about 55° w. and the strike about n. 44° e. and the rock appears somewhat thin-bedded. The western margin is indistinct. The limestone outcrops just under the road bank, where the road turns east, and rests against the slates in the bed of the brook.

On the north side of the road near the turn is an old quarry. No fossils were found, but the quarry rock resembles the dark blue mud rock of the Trenton.

Faulted block number 5. Between this block and number 4 is an interval of lowland forming the present flood plain of Wappinger creek. This interval is probably underlain by the slate which was dropped down in here and which, in connection with faulting, produced a line of weakness which the base-leveling forces early reduced and which has been perpetuated by the present stream. Outcrops are concealed in the flood plain interval except near the southwest corner of block number 4. At this point there is a large patch of slate that has been planed down and which disappears under the alluvium at the southeast.

The rather steep slope on the southwest side of this interval is taken as representing the northern margin of block number 5. The eastern and western margins are approximately those shown on the map, while the southern margin appears to be along the great fault line at this point. Surface deposits conceal the northern margin, but outcrops are occasional to the north of the Poughkeepsie-New Hackensack road, and almost continuous along it from east to west. The western margin is easily followed along the crossroad to the Spackenkill road until the limestone is cut off by the fault. No fossils were found in this patch of limestone and the lithology did not help in making any provisional correlation with other localities.

Faulted block number 6. This small strip lies south of the Spackenkill road and is a little over a mile long and less than one-fourth of a mile wide. It is separated from the main central strip by a narrow band of the slates which form conspicuous ledges for a few hundred yards south of the Spackenkill road and are traceable along the edge of the swamp through the woods to the southern termination. At the south the limestone disappears abruptly beneath the slates just north of the old barn and probably is faulted here. At the north it also gives place to the slates north of the Spackenkill road and is certainly faulted here. The limestone of this strip forms a conspicuous ridge throughout its length. No fossils were found although a careful search was made, particularly near the southern extremity.

Faulted block number 7. This block lies farthest east of all. The boundaries are best indicated by the map. The entire strip has a northeast-southwest bearing which closely follows the general strike of the limestone. It is about one and one-fourth miles long and one-fourth of a mile wide. At the north it disappears beneath the low ground along the railroad and gives way at the north to slates, although some distance intervenes between outcrops. The northern margin is plainly a faulted one and lies along the very prominent but narrow valley that forms the route of the Central New England Railroad track almost the entire distance from Hopewell Junction to Manchester Bridge. That this represents a line of faulting is reasonably certain. As a topographic feature it may be followed across country for miles. It is often swampy, frequently for long distances, and this feature was probably still more prominent before the railroad bed was put in. It does not have the appearance of having been a prominent line of drainage, but rather a more extensive illustration of the topographic effect of base-leveling forces operating along a continuous line of weakness such as a great fault would produce. There are other conspicuous illustrations of the same kind, both within the slates and limestones of this quadrangle.

The southern margin is obscured by a great mass of drift, but the limestone is almost certainly cut by a fault on the southwest.

A mile and a half north of New Hackensack a crossroad connects the New Hackensack road with another running for some distance parallel with the railroad track. The northwestern margin may be followed from this road northeastward to the railroad track, outcrops appearing between the latter and the road just south of it. Along this margin the limestone shows a low scarp for some distance. The eastern margin is also easily followed as a scarp from the crossroad where the limestone appears in contact with the black, splintery slates northeastward to the railroad. Outcrops occur along the public road at the north. Everything is concealed south of the crossroad at the south.

The limestone of this block is of a very dark bluish-gray color. It often shows veinlets and nests of calcite. Fresh surfaces show darker and more crystalline bunches in a rock of dark gray color. The rock is more crystalline than other members of the Wappinger creek belt. In lithology, it often has a strong resemblance to varieties met with in the Fishkill limestone, notably southeast of Hopewell. No fossils were found. The average strike is about n. 60° e. and the dip 40° s.e. The block forms a distinct topographic feature.

THE FISHKILL LIMESTONE

The belt of which this limestone is a part may be traced with some interruptions from Millerton in the northeastern corner of Dutchess county nearly to the Hudson river. The portion within

A view from "Bonney hill" south of Hopewell Junction, looking northward. Near the center of the picture is the village of Hopewell Junction. North of the village is the triangular valley in the faulted Fishkill limestone (see map)

this quadrangle occurs as a great fault-bounded block north of the Fishkill mountains. Northeastward it may be followed up the Clove valley, east of which it passes under the mass of schist composing Chestnut ridge and reappears in the Dover-Pawling valley.

The overlying slate formation has been removed from this faulted limestone mass within this quadrangle, which makes it convenient to discuss the mass as a unit.

Boundaries. The northern boundary enters the quadrangle from the town of Beekman and extends southwestward along the old roadbed of the Clove branch of the Newburgh, Dutchess and Connecticut Railroad to a point about one mile east of old Hopewell, where it intersects a northwest-southeast fault and turns with a sharp angle to the northwest. The actual contact of limestone and slate usually can not be seen, but the field relations and obvious fault features approximately determine the course of the boundary. Somewhere south of Arthursburg, the actual point being concealed, the boundary again turns abruptly, this time to the southwest, as shown on the map, and follows the valley of the Whortlekill to a point just west of Hopewell Junction, and then turns to the northwest to follow the fault previously referred to, along the raliroad. Three-fourths of a mile west of here a ledge of shaly limestone marks the northwest limit of the limestone along this fault line. The slates extend down into the included angles of these fault lines, as shown on the map. Southwest from the ledge of shaly limestone just mentioned the boundary is easily followed across the fields, often with a clear scarp or other distinct topographic feature, and with slate and limestone frequently in close proximity, to the fault that bounds Vly mountain on the east; then north along this fault, with the slates again in the included angle, to Vly mountain, which is bounded by the limestone on the south. Southwest of Vly mountain the limestone bounds the Glenham belt to the carpet mill at Glenham. South of here it is faulted against the slates for half a mile, then rests against the gneiss of the northernmost inlier in the town of Matteawan, then on the quartzite patch just south of this, and again on the gneiss.

Its southern margin has been described sufficiently in connection with the gneisses and the quartzite.

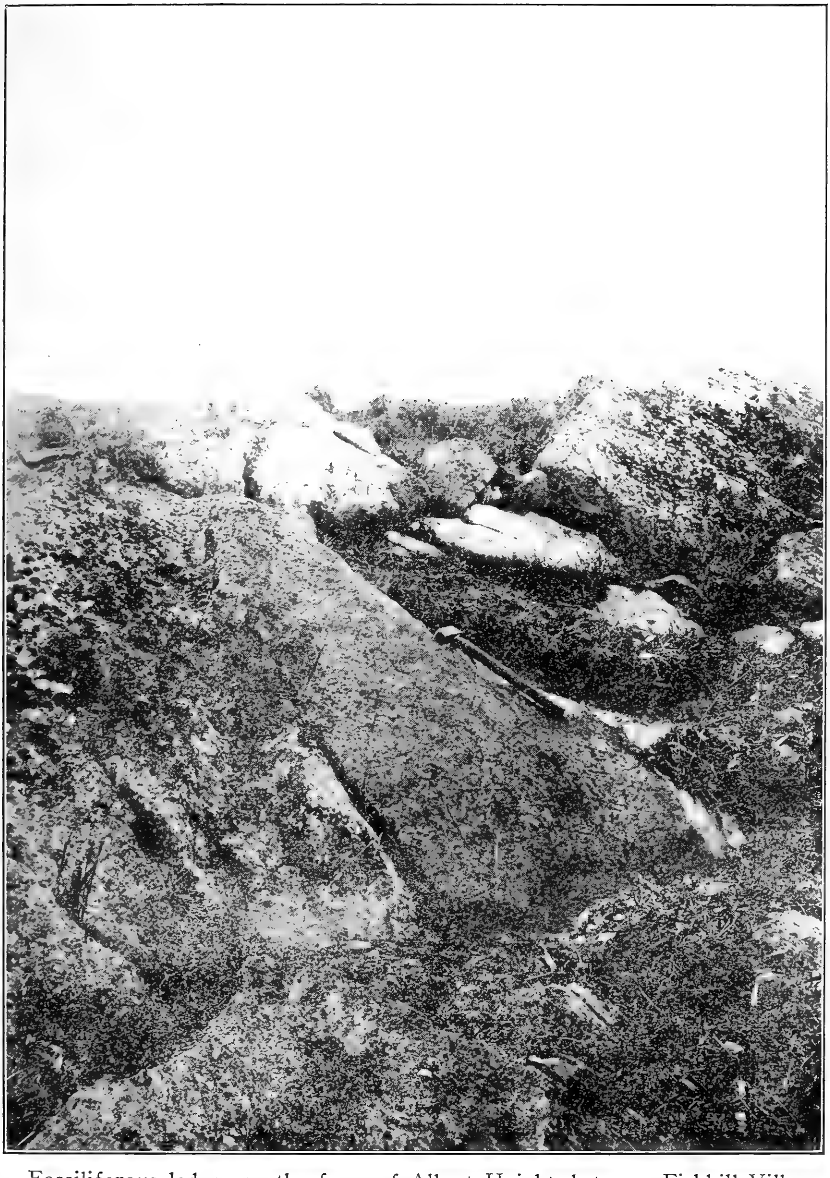
Terranes present. The fossil localities so far discovered in this limestone are limited in number and in distribution. The Lower Cambric (Georgian), Beekmantown and Trenton have been definitely identified. In the systematic and extensive examination of outcrops in cuts and weathered surfaces, suggestive markings have been noted and collected at several places. Increasing metamorphism to the eastward has destroyed or otherwise effaced traces of organic remains, besides making very difficult any provisional correlation on the basis of lithological resemblance. Folding, faulting and erosion have added great confusion.

The Lower Cambric (Georgian). Strata belonging to this horizon have been described under the heading, " The conformable series of West Fishkill Hook (see page 44). The reasons for their preservation here are not quite clear, but evidently the conditions are peculiar. As previously discussed, it seems probable that the Lower Cambric limestone is, as a rule, not in association with the quartzite of that epoch which more probably rests against younger strata at most places. The patches of limestone resting upon the quartzite at Vly mountain and in Matteawan may be of the same age. Some peculiar, very thinly-bedded metamorphosed strata, which were noted standing on end in the swampy areas east of Mount Honness, may represent the shaly member of the Lower Cambric series and these Lower Cambric rocks may have an extension to the north from here in certain rock types that will be described beyond.

The Beekmantown. Fossils belonging to this horizon were found along the western margin of the Fishkill limestone. They were first noted north of the road from Fishkill Village to Glenham on the farm of Albert Haight, in the second field west of Haight's house, about 300 or 400 yards from the public road. The rock carrying the fossils is of a light gray or steel-gray color and is interbedded with other rock which weathers to a soiled gray. The weathered surface of the former shows many spiral coils. The fresh surface reveals a much altered rock. No traces of the whorls, so plainly visible on the weathered rock, can be seen on the freshly-broken surface; but the latter is often dotted or splotched with numerous orange or pollen-yellow markings.

In this field there are two conspicuous ledges of the fossiliferous stratum besides many outcrops of other ledges, for the most part soil-covered. In the northwest corner of the next field to the north on Haight's farm is another ledge of the light gray rock covered with the coiled markings. This stratum was traced by scattered outcrops carrying the coils along and within the edge of the woods and thick brush for a mile to the northeast, to within about half a mile of the road from Fishkill Village to Glenham, and then was lost. Beyond this road it has not been noted, unless it may be

Plate 12



Fossiliferous ledges on the farm of Albert Haight, between Fishkill Village and Glenham. The surface marked by the hammer is covered with the whorls of *Ophileta compacta*, some of which are visible in the plate

represented by a somewhat banded bluish rock without visible fossils which was found on the very edge of the limestone about four miles to the northeast at Swartoutville, a hamlet two and one-half miles north of Brinckerhoff. On the Haight farm the fossiliferous limestone is well exposed in the fields, but in the brush it is followed with great difficulty. This rock, or that with which it is interbedded, is overlain by a calcareous conglomerate in certain places.

The fossiliferous limestone is very dense and compact. It is quite impossible to remove the coils from the smooth surface. A hard blow with the sledge simply chips the rock into small pieces with conchoidal fracture. The chisel makes no impression.

The coils are most distinct when at right angles, or nearly so, to the axis of the whorls. They then show as fine spiral lines, resembling a fine loosely-coiled watch spring, which have weathered out very sharply into bas-reliefs. When in the plane of the axis, or at a small angle with it, the lines are thick and patchy. The fine coils vary in diameter from one and one-half inches to three-fourths

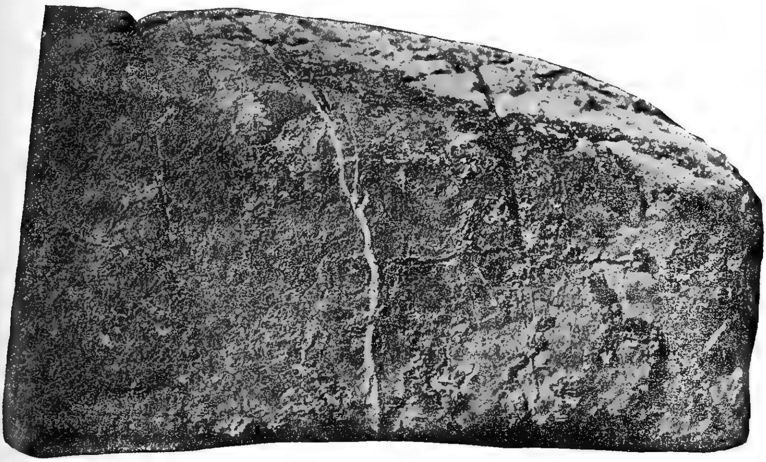


Fig. 22 Whorls of a discoidal gastropod identified as Ophileta compacta Salter, from the ledge shown in plate 12

of an inch. The medium-sized are most abundant. They bear the closest resemblance to the discoidal gastropod Ophileta compacta Salter, as described for the Calciferous of the Quebec group[1] (see plate 12).

[1] Canadian Organic Remains, 1859. Decade 1, p. 16, plate 3.

The smaller coils resemble the Maclurea sordida and Ophileta levata of the Calciferous of New York.[1] One form, which very closely resembles the Ophileta complanata as figured by Hall,[2] was noted.

The fossiliferous rock at Haight's farm lies just east of the Glenham gneiss belt with outcrops of the latter not more than 150 or 200 feet away. The strike of the limestone varies from n. 15° w. to n.–s. and the dip from 35° to 40° e. The strike is such as to carry the limestone diagonally across the gneiss belt. The distance separating the gneiss is too short to allow a very great thickness of older beds to come between the two. South of the fossiliferous ledges in the quarry used by the State road contractors on the farm of Mr Wilsey, are thick-bedded arenaceous limestones with a strike of n. 35° e. and a dip of 51° s.e. These are probably older beds.

East of the ledges of Beekmantown outcropping along the Glenham belt, this horizon has not been definitely identified. In the town of Old Hopewell, just east of Fishkill creek, is a prominent hill which has some beds strongly suggesting the blue beds interstratified with the gray ones in the main strip of the Wappinger creek belt at Rochdale and two or three miles south of that hamlet. The two rocks look very like each other and the resemblance is strengthened by the presence of the peculiar seaweed-like markings which have been described. The rock at Hopewell is more metamorphosed. Along the track of the Highland division of the New York, New Haven & Hartford Railroad, in the cut three-fourths of a mile east of the railroad bridge crossing the creek east of Hopewell Junction, these blue layers form the upper portion of a gentle, northward-pitching anticlinal fold (see plate 13). A distinct fault is seen just east of here crossing the track and, when traced northward, this is seen to be in line with the recess shown on the map just south of the point where the creek turns northward in making its detour around the hill. East of this northward bend the creek has cut a gorge in the limestone, having been deflected southward by a great mass of glacial deposits that flanks the limestone knoll north of Gregory's mill. On the weathered surface of this knoll a fossil, which looked like a cephalopod, was found.

This rock resembles the blue layer just described. It often shows a banded character which recalls the banded marbles or crystalline limestones seen in the quarry two miles southwest of Millerton.

1 Palaeontology of New York. 1:10–11, plate 3.

2 *loc. cit.*, p. 11, plate 3.

Presumably the beds with which the bluish beds are interstratified belong with them and the Beekmantown may be fairly well represented. Elsewhere it has not proved possible to make any correlation even of a provisional character with this horizon.

The Trenton. The presence of this horizon within the Fishkill limestone was first indicated on the basis of fossils by Professor J. D. Dana.[1] He described the white fine-grained and gray limestones north and east of Shenandoah and announced the discovery in the gray rock "one-third of a mile north of Shenandoah Corners" of "large shells of a Strophomena like S. alternata, distinct in form though disguised by pressure and slight alteration, indicating for the beds a Trenton age." He also noted suggestive forms and markings between Hopewell and Fishkill,[2] but nothing of distinctive value was obtained.

This horizon, as known from the Wappinger belt, was definitely identified by the writer along the western margin of this limestone in close association with the beds carrying Ophileta compacta. In the second field northwest of the barn on the farm of Albert Haight, on the road from Fishkill Village to Glenham, a ledge of coarse conglomerate lies just south of the ledge showing the O. compacta. A few yards east of the latter ledge a finer conglomerate carrying Solenopora compacta was discovered. The latter is almost covered with soil and this rock is exposed in only a few places. The conglomerate was also followed along the edge of the wood in a series of low-lying knolls for some distance. About half a mile northeast of these ledges, about 350 yards northeast of the Southard house, and the same distance north of the public road, near the edge of the woods, at the point where an old wood road leaves the woods, the light grayish-colored rock passes into a thin layer of fine conglomerate of the same color and then abruptly into a dark blue fine-grained conglomerate. The ledge showing this transition is in place, but is very narrow and lies nearly flat, dipping at a very slight angle to the southeast. A hundred feet northeast of this ledge, beyond a stone wall, the coarse conglomerate outcrops. What appeared to be brecciated conglomerate was noted in one or two ledges farther north.

There is thus a narrow, but well defined, strip of the Trenton conglomerate along the western margin of this limestone. Its former eastward extension is wholly problematical.

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1 Amer. Jour. Sci. Ser. 3. Dec. 1880. 20:452.

2 Amer. Jour. Sci. Ser. 3. May, 1879. 17:383.

At Swartoutville, a little hamlet about half way between Brinckerhoff and Hopewell Junction, on the farm of Irving Hitchcock, a calcareous conglomerate, with the pebbles squeezed into bands, outcrops in places between the bluish-gray limestone, referred to above as possibly representing the Beekmantown, and the calcareous shales with interbedded limestone layers, the latter lying on the west along the margin of the limestone. In other places the shales with their interbedded limestones grade downward into a fine conglomerate with what looked like S. compacta and other fossils.

During the spring of 1909 a number of new cuts were made in the limestones along the road from Johnsville to Stormville in the process of constructing the State road. In one of these, about two miles east of Johnsville, a fairly distinct impression was found. This may be a fossil. The general form is apparently preserved, but the details are obliterated. Other blackened and much more distorted impressions were noted. These impressions, together with other markings, such as bunches of calcite crystals, mark the rock as probably fossiliferous.

Some peculiar lithic variations within the Fishkill limestone. Northeast of Johnsville, on the farms of Messrs Gildersleeve and Taylor, are frequent outcrops of a coarse silicious limestone, which was not noted elsewhere in this limestone belt. It somewhat resembles the basal quartzite at times. It is always calcareous, effervescing readily with cold dilute acid, but leaving a prominent residue of quartz. It is interbedded with other limestones, which in their lithological characters recall the chamois-colored beds in the Beekmantown of the Wappinger creek belt. The silicious rock just referred to outcrops along the road south of Bonney hill north of Taylor's house, while Bonney hill seems to be largely made up of the medium-bedded chamois-colored rock, except at the west along the lower portion of the scarp slope, where it gives place to a gray limestone. No fossils were discovered in these limestones. It is noteworthy that they lie close to the northward continuation of the strike of the rocks in the West Fishkill Hook district.

A diligent search was made within this limestone east of the western margin for a conglomeratic layer, but none was found. What appear to be coarse brecciated zones are of frequent occurrence, particularly west of the Honness spur. These were noted just southeast of Milton C. Hustis's house at Brinckerhoff, between Mount Honness and Fishkill creek, where the rock is mashed, and in the Newburgh, Dutchess & Connecticut Railroad cuts between Fishkill Village and Brinckerhoff, and less noticeably but plainly elsewhere to the north toward Hopewell Junction and east toward Stormville. The discussion of the structural features will bring out the fact that there must have been a strong tendency toward crushing and mashing along the limbs of minor folds within this formation.

In the woods west of Wood's greenhouses at Fishkill Village are numerous outcrops of a very fine-grained metamorphosed rock which suggests an altered silicious ooze. It was noted in several places within short distances of each other and not far from ledges carrying Ophileta compacta. It appears to be a rather abrupt variation of the rock with which it is associated, and probably is to be regarded as a variation of the Beekmantown.

Certain varieties are plainly the products of metamorphism and will be referred to again under that heading.

In most cases, the lithology of the Fishkill limestones does not convey anything definite of which one may make use for provisional correlation. In the new cuts along the road from Brinckerhoff to Stormville even the fresh surfaces convey very little. In some of the ledges near Gayhead [1] the fresh surface carries numerous rusty patches, possibly siderite, which recall some surfaces seen in the quarry at Stoneco.

The magnesian character of some of these limestones is well known. There is some reason for thinking that they were accumulated in somewhat restricted bodies of water. Possibly they are partly the products of precipitation from saturated solutions.

If during the time these deposits were accumulating there were several basins more or less completely cut off from each other, it is easy to understand that there would have been some diversity in the condition of sedimentation in this region. In some places there would have been normal marine conditions with characteristic animal forms, while in others, perhaps, there would have been an accumulation of sediments peculiar to basins more or less completely cut off from the sea with an absence of animal forms. An influx of the sea in these restricted basins would carry with it a change in sediments and a marine fauna and a fossiliferous lens might thus be produced within a barren dolomite.

The absence of the conglomerate and overlying formations over most of the Fishkill limestone indicates that it is composed chiefly of older strata, probably ranging discontinuously from Lower Cambric to Beekmantown. As the folds in the limestones are

[1] East Fishkill is invariably referred to as "Gayhead," in this region. The name seems to have originated from the head adornments of the ladies who flocked to this place for dance festivals in early years.

moderate swells the older masses have not been exposed, except where faulted. Much of the surface rock may be of Beekmantown or Upper Cambric age, the latter belonging to the upper dolomitic layers of the sediments of that epoch.

Structural features. The hiatus that is present between the Beekmantown and the Trenton within the Wappinger creek belt has its counterpart along the western margin of this limestone; but the failure to find any conglomerate farther east, such as usually represents the base of the Trenton, not only in the Wappinger creek belt and along the western margin, but also in the slates at the north, leaves much uncertainty as to the relative stratigraphic position of much of this Fishkill limestone. The presence of certain faults adds to the perplexity; while the general faulted position of the Fishkill limestone as a whole and the absence of the slates within it rather leaves the impression that it is made up chiefly of limestones older than the Trenton conglomerate, except where younger beds have been faulted in.

In spite of faults and thrusts the general folded arrangement of the Fishkill limestones can in some instances be made out with a fair degree of exactness.

In the hamlet of Wolcottville the limestone is in contact with the gneiss. In the town of Matteawan it first rests against the slates, which are almost certainly younger, and then on the gneiss, then on the quartzite and finally on the gneiss again. The quartzite contact may be normal. The gneiss contact may also be normal in places, but in such cases the gneiss is presumably the equivalent of the basal quartzite and represents an altered condition of the gneiss.

The fault on the west of the Glenham belt represents an early thrust which was succeeded and outstripped by the Bald hill thrust. The western break also bounds the Matteawan inliers at the west. Faults bound the Glenham belt on the south and the northern inlier of Matteawan on the north and between these the slates have apparently been dropped.

Numerous breaks may occur in Matteawan so that the limestone resting on the quartzite in that town may not be of the same age as that which rests against the slates. The limestone is traceable to the north across Fishkill creek and through Glenham and beyond. But as a rule not much can be made out about the structure.

At Wilsey's quarry on the Fishkill-Glenham road the arenaceous limestone strikes n. 35° e. and dips about 51° s.e. In the field just north the fossiliferous Beekmantown and interbedded limestones have a strike varying from n. 15° w. to n. s. and a dip of 35° e. One-half mile to the northeast the dip is gently away from the gneiss and the strike cuts across it at a small angle. This general relation holds to the Chelsea road.

The topography southeast of Fishkill Village is very flat. There are few outcrops north of the Fishkill-Glenham road, between it and the woods, until the farm of Albert Haight is reached and none to the south of it until Glenham is reached. Low ledges of limestone appear north of Fishkill Village. Between the Chelsea and Wappinger Falls roads and north of that road and the Cold Spring turnpike they are abundant.

Just north of the village on the west side of the road, to the south of the cemetery, the strike is n. 55° e. and the dip 35° s.e. (lettered B in section figure 23). Farther north on the roadside near the gneiss the strike is n. 15° e. and the dip 49° n.w. (lettered A). At the railroad crossing on the Cold Spring road the strike is n. 80° e. and the dip 46° n.w. (lettered C). Southeast of Fishkill creek and northeast of the Cold Spring road, from a point a short distance from the road as far as Milton Hustis's farm, the strike varies from 25° to 40° east of north and the dip is toward the mountain and according to readings taken varies from about 50° to 62° s. e. (lettered D). Along the road from Fishkill Village to Brinckerhoff, about one-half mile from Main street in Fishkill Village, the strike and dip are about the same as at the railroad crossing. Along the northwestern margin of the limestone to the northeast of the Wappinger Falls road the strike and dip are not easily followed. Along a section in a northwest-southeast direction from the Glenham belt through Fishkill Village to the northwestern base of the Honness spur, as shown on the map and the accompanying

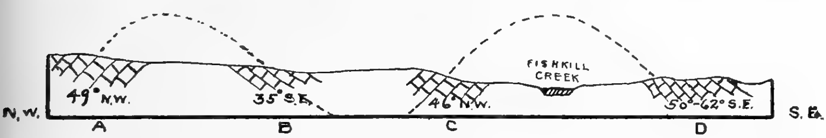

Fig. 23 Section across the Fishkill limestone along a northwest-southeast line through Fishkill Villagef rom the G'enham gneiss to the Mount Honness spur, to show the character of the folds Distance 2 miles

section (fif. 23), the limestone is in a series of northwest-southwest folds which have suffered great erosion and, at places, much disturbance. The latter is shown along the highway and in the railroad cuts southwest of Brinckerhoff, where the strike is only at a small angle to the east of north and at one place n. 50° w. with easterly dip. Northeast of Brinckerhoff the strike and dip return to the former general direction. In the railroad cut just north of the Johnsville road they are n. 30° e. and about 43° s.e., and one mile south of Hopewell Junction n. 44° e. and 45° s.e.

The western slope of Bonney hill has the appearance of a fault scarp and shows numerous outcrops of limestones dipping to the east. Along the road leading south from Bonney hill, at the north to the east of the road and at the south to the west of it is another scarp with easterly dips. South of Bonney hill a northeast-southwest break apparently intersects this fault and the limestones north of Johnsville lie in the angle between them.

The section (fig. 24) along the railroad cut east of Hopewell Junction shows some structural detail. Heavy erosion has obscured the larger features and has brought out the minor ones. Beginning at the west, the section is first through beds dipping gently eastward,

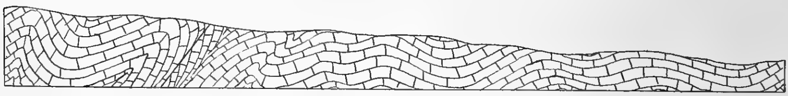

Fig. 24 Generalized section of the south wall of the railroad cut east of Hopewell Junction

and apparently bordered on the west by the northward continuation of the fault that follows the road southeast of Bonney hill. East of this it is through a symmetrical northward pitching anticlinal shown in plate 13, and complemental synclinal, then in a smaller anticline and syncline, and then through an irregular fold with its eastern limb pushed up. This is followed by a closely compressed syncline which is succeeded by a closely-folded overturned anticline (see plates 14 and 15); then two small folds which are cut off at the east by the fault shown on the map.

East from here along the railroad the sections are fragmentary. In the second cut east of the overhead bridge on the road from Gayhead to Gregory's mill, the limestones show an arrangement like that of figure 25. Just west of Stormville station the beds are isoclinal, dipping to the east, and show a considerable aggregate thickness.

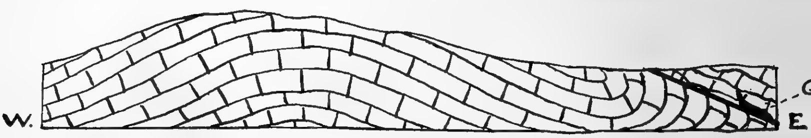

Fig. 25 Section just east of the overhead bridge on the railroad between Hopewell Junction and Stormville. Q, nest of quartz

The tendency to arrangement in somewhat gentle folds is shown by numerous observations. In some places the dip is east and at

Plate 13

Anticlinal fold in the limestones at the western end of the railroad cut east of Hopewell Junction. The axis pitches gently to the north

Plate 14

Compressed and overturned syncline in the railroad cut, one mile east of Hopewell Junction. Note the compression along the axial plane and the thrust along the overturned limb. The axial plane dips eastward

Plate 15

A view in the railroad cut about one mile east of Hopewell Junction, showing an overthrust on the left and a compressed syncline on the right marked by the hammer. The dip is eastward

others west. The strike remains practically unchanged for some distance in many instances for beds with the same general dip. The limestone differs from the slate at the north with its isoclinal arrangement over wide intervals.

The tendency to overthrust, shown in the section along the railroad, probably prevails over the entire area. Strike faults are most apparent. The regularity of the strike for long distances seems to indicate that horizontal offsetting has not been important. Two large breaks along the strike are shown on the map. They are shown in the field by long stretches of swampy lowland that may be followed for several miles across country. They seem to be the northward projection of faults in the Highlands. The presence of these large breaks and minor ones complicates the question of the age of the limestone. The displacement must have been a large one at places as, for example, along the fault line that bounds Shenandoah mountain on the east. Possibly beds of very different age lie in close proximity.

Metamorphism and alteration. Were it possible to trace continuously from west to east the beds now known to be present along the western margin of this limestone, more could be definitely determined about gradation in metamorphism to the eastward. Examination of the belt has shown that the rock usually displays greater crystallinity as one goes eastward. Banded limestones not very different from some seen in the Dover valley were noted near Gregory's mill. There is much evidence of crushing. Bunches and veinlets of calcite and quartz nests and stringers are abundant. These indicate hydrothermal activities. Organic remains have doubtless been obliterated by these as well as by crushng, shearing and pressure.

Summary. The Fishkill limestone, in its relations to the slates, stands essentially as a huge faulted block. Though less plainly shown, the same is true of its relations to the Highlands mass. This arrangement has produced a northwestward gradation by faulted blocks from older to young masses. These considerations afford further reason for believing that the Highlands owe their present elevation to the mountain-making processes that gave birth to the Green mountain system and that the younger rocks once had an extension much to the south of their present southern limit, thus giving an altogether different notion of the early relation of the Paleozoic sea to the Precambric land from that which the present topography might be assumed to show.

The northward projecting spurs of the Highlands indicate a tendency to fold with the younger series, but owing to their crystalline condition and high coefficient of elasticity the gneisses broke and were thrust up into the younger rocks, in some places carrying the latter with them, and in others overriding them. The West Hook series was apparently first thrust up and then dropped back and has thus been preserved.

The arrangement in echelon of transverse faults along the northwestern margin of this limestone belt seems to show the influence of the gneissic substratum on which it rests.

The northward pitch of the younger rocks, which is observable in places, may be as readily explained as the result of greater vertical movement at the south as of original inclination.

The Mount Honness spur is plainly faulted on the north and shows numerous transverse gaps (see plate 2).

The abnormal position of the Lower Cambric caused much confusion in early years and led to its assignment to the Potsdam on the basis of its apparent stratigraphic position.

The occurrence of numerous faults in the quadrangle suggests that the apparent absence of a Middle Cambric might thus be explained.

The evidence now in, although in great need of being supplemented, shows that the limestones of the Fishkill belt are, in part, the eastward representatives of those of the Wappinger creek belt.

THE "HUDSON RIVER" SLATE GROUP

The term "Hudson River" is used in this paper for the slates of the quadrangle because of the extensive section displayed in these rocks along the Hudson river and because the name is both widely known and locally followed by those who refer to the members of the slate formation. It is used only as the equivalent of other names employed in this paper and entirely without reference to the value of the term "Hudson River Group."

Distribution and general relations. Members of this formation underlie the major part of the quadrangle. At the present time there are no representatives of it within the Fishkill mountains or the Fishkill limestone of this quadrangle. Northwest of these rock masses the Hudson River rocks are the prevailing ones. The limestones of the Wappinger creek belt are faulted in with the slates. Northwest of this belt the slates entirely conceal the limestones. North of the Fishkill limestone block are several small patches of limestone within the slates which will be described with this formation.

Terranes present. Mather described the members of this formation under the headings, "Hudson River Group," "Utica Slate" and "Trenton Limestone Group."[1] He wrote of fossils being found in the "slates and slaty altered limestones that would not be recognized as limestones without close examination." The locality was about one and one-half miles north of Barnegate[2] and the fossils were recognized as belonging to the Trenton limestone.

In 1878 T. Nelson Dale[3] discovered fossils in the slates near Vassar College and "on the Stormville road between Casper creek and the first limestone ridge." Mr Henry Booth, of Poughkeepsie, and students at the college found other fossils at the ledge near the observatory at Vassar. The writer has also found fossils there.

In company with Mr Booth, Mr Dale discovered other fossils on the west of the Hudson opposite Poughkeepsie. This locality is on the eastern slope of "Illinois mountain" southwest of Highland.[4]

The fossils discovered by Dale were identified by Hall as: Orthis (Dalmanella) testudinaria, Orthis pectinella, Leptaena (Plectambonites) sericea, Strophomena alternata, Bythotrephis subnodosa, Bellerophon bilobatus and crinoid stems. Specimens of the first five named are in the Vassar Institute Museum at Poughkeepsie and are labeled "Highland, N. Y." O. (D.) testudinaria and L. (P.) sericea were found on both sides of the river. Dale thought these fossils verified Mather's use of the term "Hudson River Group." Certainly these strata belonged to some member of the Trenton period.

The first three types mentioned have also been reported from Marlboro-on-the-Hudson about nine miles north of Newburgh. They have also been found in the slates at the northern end of the New Hamburg tunnel.[5] The writer has found fossils here, including O. pectinella, in the shales under the bank, back of the boathouse.

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[1] Geology of the First District. Part IV, p. 369, 390, 397.

[2] *loc. cit.* p. 401.

[3] Amer. Jour. Sci. Ser. 3. 17:56–59.

[4] Directions for reaching this locality were furnished by Mr Henry Booth. Take Modena road from Highland south one mile to cemetery, then wood road through cemetery to mountain. Fossiliferous ledges occur 150–200 yards up the mountainside.

[5] J. M. Clarke. Guide to the Fossiliferous Rocks of New York State. Handbook 15, p. 6.

Crinoid stems have also been found at Marlboro. L. (P.) sericea and O. (D.) testudinaria were found on both sides of the Hudson as rather abundant and characteristic.

The only other fossil locality in the slates which was found by the writer, and which appears to be new, is at Swartoutville. At the western edge of the large field across the road from the house of Irving Hitchcock is a ridge composed of fissile, gray sandy shales with interbedded, dense blue impure limestones.

The shales stand almost vertical, dipping slightly to the west and strike diagonally across the ridge, so that in going from south to north along the ridge one passes over probably older beds. The interbedded limestones are of dark blue color and carry numerous traces of organic remains. The fissile shales have yielded Plectambonites sericeus, and fragments of indeterminable fossils.

Relations are very obscure, but one or two small outcrops of limestone conglomerate were noted between these strata and the bluish-gray limestone a short distance to the east. In their structural relationships the fossiliferous shales probably belong with the limestones and are probably near the base of the slate formation. The slates at the west are younger. The amount of displacement between them is wholly problematical.

In 1883, during the construction of the railroad along the west bank of the Hudson, Messrs H. Booth and C. Lown of Poughkeepsie discovered graptolites in the newly-made cuts at two localities, one two miles south of Highland and the other about one mile north, near the place where the icehouses now stand. These graptolites were identified by Whitfield as follows [the correct names have been added in brackets]: Diplograptus pristis Hall; Climactograptus bicornis Hall; Dichograptus [Dicranograptus] furcatus Hall; D. [Dicellograptus] divaricatus Hall (?); Monograptus [Nemagraptus] gracilis Hall; M. [Didymograptus] sagittarius Hall; Diplograptus marcedus Hall. [Cryptograptus tricornis]. He considered them as of Utica age. A graptolite identified as Graptolithus [Amphigraptus] divergens was also reported from the slates one and one-half miles north of Poughkeepsie on the east bank of the Hudson river. This specimen is in the Vassar Institute Museum at Poughkeepsie.

Some of the slates within the quadrangle are shown by these discoveries to be younger in age than the so-called Trenton conglomerate of the area. Some may be contemporaneous and probably are;\ others are possibly much younger. The relations farther north, in Washington county, have shown that the Lower Cambric slates have been brought to the surface by faulting, but within this area it has not proved possible to determine this. On the whole, it does not seem probable.

The general problem of the slates is postponed until several features have been stated in detail.

Red slates. Red slates with green bands of varying thickness may be traced at intervals diagonally across the quadrangle, along the prevailing strike, from Matteawan to the northeastern corner of the area. Their regularity of recurrence indicates that an important stratum is involved in the folding. The main stratum of these red slates as shown in several places has a fairly uniform thickness. Thinner red bands have rarely been noted in the more common grayish-black members of this formation.

In the town of Matteawan red slates with green bands form thick masses along the banks and bed of Fishkill creek as far as the carpet mills at Wolcottville, and north of here at Glenham along the road from Matteawan to Fishkill Village, just west of the Glenham gneiss belt, ledges of these rocks are abundant. The red slates are locally called the "paint rock." Farther north along the strike they were noted north and south of the road from Fishkill Village to Chelsea and along the road from Swartoutville to Hughsonville. A thick band occurs along the New York Central Railroad track one-fifth of a mile south of Paye's clay pits and a similar band just north of the station at Chelsea. They were not noted farther north along the river section. The slates at Chelsea continue northeast along the strike and appear one mile north of New Hackensack along Wappinger creek, and again near Manchester Bridge and at Overlook; also frequently along the roads from Pleasant Valley to Moores Mill. At the north they appear oftener, chiefly because of the more frequent and larger outcrops of the slates and the thinner covering of surface material.

There are reasons for thinking that the slates form a synclinal fold west of Matteawan and possibly the red slates at Matteawan and south of Paye's pits respectively represent the east and west limbs, while those at Chelsea may represent the western limb of the succeeding anticline.

Associations of the red slates. Along both the north and south roads from Pleasant Valley to Moores Mill the red slates occur just to the west of small conglomeratic limestone patches that have plainly been brought up by faulting. There is no way of determining the amount of displacement, but it is reasonably clear that the red slates lie above the limestone and are younger and probably are not far from the base of the slate formation.

Along the New York Central tracks near Fishkill Landing station are heavy-bedded members of the slate formation, such as make up most of it northwest of the Wappinger creek limestone belt. Assuming that the slates west of the Glenham gneiss belt have synclinal structure, these heavy members can not be far from the axis of the fold and lie several hundred feet above the red slates in stratigraphic position. The reason for the gneiss being in contact with, or in proximity to, the red slates along the Glenham belt, while the limestone conglomerate has that position at the north, is clearly due to greater vertical movement of the older rocks at the south and west.

The red slates have not been noted within this quadrangle northwest of the Wappinger creek belt. According to the writer's observations, the companion members of the red slates southwest of that belt, although sometimes showing heavy beds and even fine conglomerates like those seen at the northwest, are prevailingly more fissile and splintery mud rocks of blackish-gray color. These also occur along the northwestern margin of the Wappinger belt, but farther northwest give way to beds of coarser sediments.

Quartzite near Rochdale. Along the road from Manchester Bridge to Pleasant Valley, east of Wappinger creek, between the farm of A. W. Sleight and that of George E. Smith at Rochdale, are prominent ledges of compact quartzite which rather strongly resembles some varieties of the basal quartzite. These ledges are portions of a continuous strip which can be traced from a ledge on the farm of A. W. Sleight just north of the Overlook road northward, roughly parallel with the Pleasant Valley road, to George E. Smith's house. Just south of here it crosses the road and ends at the bank of the creek west of the house. East of the road it ends just beyond the barn south of the brook shown on the map, which apparently occupies a fault between the quartzite and the slates to the north of it. This quartzite is bounded entirely by the slates, except where it disappears in the creek. Here it is only a short distance from the Trenton limestone at Rochdale. Along the eastern contact with the slates, about one-half mile south of Smith's house, the quartzite shows a strike of n. 20° e. and a dip of about 60° e. A mile and a half to the southeast, on the farm of Eugene Storm at Overlook, is a large block of compact whitish quartzite identical in character with that just described. This is cut off by a fault at the south against the slates. It can be traced only a short distance northward and disappears beneath the drift. This mass apparently belongs with the strip first described.

This quartzite is probably an interbedded member of the slate formation. Its exact equivalent has not been noted elsewhere within the quadrangle.

MISCELLANEOUS FAULTED LIMESTONES WITHIN THE HUDSON RIVER FORMATION

Arthursburg. Three small patches of limestone are faulted in with the slates at Arthursburg. One of these is near the Central New England Railroad station. The impure shaly limestone is exposed in the railroad cut and forms a conspicuous knoll, which is situated partly on the railroad property and partly on the estate of Obed Hewitt. It is bounded on all sides by the slates and is hardly more than one-fourth of an acre in extent. It occurs along the north ward projection of the line of faulting that farther south forms the western boundary of the angular portion of the Fishkill limestone north of Hopewell Junction. Its present position is due to this fault and marks its northward continuation. A careful search showed that the limestone does not occur in the neighborhood to the west of this fault.

A few hundred yards to the northeast of the station, on the road ascending the hill toward Beekman, conglomeratic limestone, with pebbles squeezed and elongated, outcrops along the road just north of the old schoolhouse.

One-fourth of a mile north of this outcrop on the farm of G. L. Wiley, just southeast of the private cemetery, the limestone is exposed on a knoll just north of the brook. Some bluish-gray beds, like those seen at Rochdale, are present. The conglomeratic facies is absent. The beds strike n. 10° w. and dip 55° e. The knoll is entirely surrounded by the slates. The topography suggests a fault more or less parallel with the brook at this place. The fault just referred to as projected north from the Fishkill limestone dies away to the northward.

An unmistakable fault passes southeastward from Arthursburg and intersects the strike fault that follows the line of the old Clove branch railroad bed.

The shaly beds near the station are probably younger than the conglomerate, while the latter is probably younger than the mass near the cemetery from which the conglomerate may have been eroded. These small masses are all separated from each other by the slates and no others could be found. They are clearly small faulted inliers of the older rocks lying near or at the intersection of two faults, one of which exactly parallels a similar break bounding the Fishkill limestone just south, while the other is the northward continuation of a fault between that limestone and the slate.

The fault features which mark the Highlands and the Fishkill limestone thus continue northward within the slate formation.

Moores Mill. On the farm of Mr Skidmore, about one mile west of Moores Mill station, is a larger mass of limestone resting against the slates. It extends up the hill on the northwest side of the road and for a short distance through the woods, but on the west, north and east gives way to slates. On the southeast it passes beneath the flood plain of Sprout creek. The entire patch does not exceed an acre or so in extent. In the orchard west of Skidmore's house the slate and limestone are mixed together. The limestone is of a gray color and somewhat crystalline and seamy, but has no distinctive character. No satisfactory readings could be obtained.

East of the creek, one-half mile from Skidmore's house, on the farm of Mr Houghtalin, is a small, precipitous ledge of limestone in place, apparently dipping to the east at a high angle. This ledge is in the angle formed by the two roads northeast of Houghtalin's house. The topography just south of the ledge is that of a scarp, which continues for one-third of a mile southwest. The scarp slope for this distance is uniformly abrupt, but outcrops are concealed south of Houghtalin's. The topography suggests a transverse break at the south along the line shown on the map. South of this break, along the base of the slope, outcrops are concealed by surface material for some distance, but farther on the slates outcrop in low-lying ledges and in some places lie close to the base of the slope.

The discovery of these two limestone patches aroused the suspicion that the valley of Sprout creek might be in the limestone, but careful search failed to show the limestone in any other outcrops with one doubtful exception. Along the bank of the creek, one mile northeast of Skidmore's farm, a mass of limestone about fifteen feet square was found between the road and the brook. At the base it is made up of coarse limestone conglomerate, which is followed by arenaceous limestone. This is succeeded by a finer-grained conglomerate. The apparent strike is n. 25° w. and the dip 34° n.e. This was regarded as a boulder. It strongly resembles similar beds found in place to the northwest. It hardly seems probable that this small ledge would have been preserved in its present position.

It is reasonably apparent that these two limestone patches have been brought to their present position by overthrust faulting, involving a horizontal displacement of at least one-half a mile. At Skidmore's the limestone has been eroded so as to expose the slates on which it has been thrust. The small ledge at Houghtalin's is only part of a scarp which is for the most part concealed.

The valley southwest of these two limestone patches is plainly in the slate. There is strong suggestion that it is along a line of strike faulting that extends from the Highlands northward beyond the limits of the quadrangle. The view which shows this best is that obtained from the western slope of the ridge southwest of Moores Mill. The conspicuous scarp on the west of the high hill west of Lagrangeville, which is seen so distinctly from Freedom Plains, lies along this line of faulting, while the northeastward continuation of the latter is marked by a hollow plainly visible at the elevation of the viewpoint just mentioned.

East of Pleasant Valley. Three limestone masses are faulted in with the slates east of Pleasant Valley. The largest of these is farthest east of the three and is shown on the map along the north road from Moores Mill to Pleasant Valley. A small ledge of the limestone outcrops among the slates one-fourth of a mile south of the fork in the roads near Ivy's house. This is separated from the main portion of the mass along the road by slates. East of Ivy's house, occupying practically all of the small triangle formed by the roads as shown on the map, and north of here for several hundred yards, are ledges of conglomeratic limestone interbedded with silicious limestones (silicicalcarenytes[1]) and limy shales. The dip is eastward. Low ledges of limestone outcrop on both sides of the road east of Ivy's. On the east side of the road the conglomeratic

[1] A name proposed by Professor A. W. Grabau for silicious limestones with sandy texture.

member forms a scarp for some distance. The pebbles of the conglomerate are squeezed out into a stringerlike appearance along the strike.

At the east this limestone patch gives way to the slates. At the south limestone and slate are somewhat mixed. At the west the patch evidently rests by overthrust on the slate formation. At the north relations are very obscure. It probably dies away along a strike fault.

Distinct fossil traces were not noted here. The silicious limestone often shows many rusty grains. The red slates outcrop less than one-fourth of a mile to the west.

Farther west, along this north road, about one and a half miles east of Pleasant Valley, as shown on the map, squeezed limestone conglomerate and interbedded silicious limestones form a knoll north of the brook and outcrop along the crossroad leading north. The limestone dies away at the north and is entirely surrounded by the slates. This block is along the line of thrust that brought up the third patch to the south of here along the south road to Moores Mill.

About two miles southeast of Pleasant Valley is another patch of limestone conglomerate with associated silicious limestone. The latter here is often weathered and shows a distinct clastic rock with fine quartz grains predominating. The weathered surface is pitted and the rock friable from loss of the lime constituent. This rock could be equally well designated as a calcareous quartzite. It is very similar to the rock overlying, or interbedded with, the conglomerate near Ivy's house farther east, but perhaps is a little more silicious. It carries the same rusty grains. The writer was interested to compare this rock with specimens collected from the Sprout brook limestone near Peekskill and was surprised to note the strong resemblance in texture, mineralogy and markings.

This patch lies back from the road, about 500 or 600 yards east of J. Fleet's house. It forms a distinct scarp which continues south in the slates along the road after the latter makes its southward turn just east of Fleet's house. A thick band of the red slates comes in between this scarp and Fleet's house and is crossed diagonally by the road. The conglomerate rests by overthrust on the slates at the west. This feature is shown at "Fox Hole," a local name for the precipitous scarp shown in plate 16 and figure 26.

Overthrust of the conglomerate on the slates east of J. Fleet's farm, southeast of Pleasant Valley

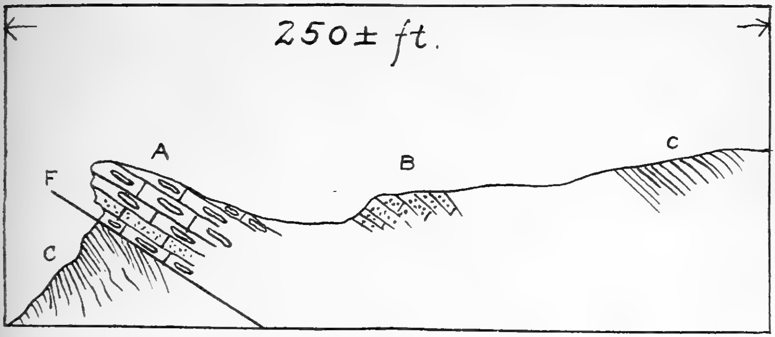


Fig. 26 Overthrust east of John Fleet's. *A*, limestone conglomerate; *B*, silicious limestone; *C*, slate; *F*, fault

When seen from above the conglomerate is coarse, but when examined along the edges of the eastwardly dipping beds the pebbles are seen to be squeezed out into stringers, so that the apparent coarseness can not represent the original condition. The dip is about 20° e. and the strike about n. 10° e. The calcareous quartzite was not seen in actual contact with the conglomerate, but is undoubtedly conformable. At the east the former is followed by the slates. Solenopora compacta, showing the characteristic very fine lines, was noted in the conglomerate. The quartzitic rock outcrops at intervals to the south for one-fourth to one-third of a mile, but gradually dies away. At the north the series ends more abruptly.

The conglomerate at the last mentioned locality of those which have just been described is undoubtedly the equivalent of that which at Pleasant Valley and Rochdale overlies the eroded Beekmantown, and there can be little doubt but that the conglomerate at the other localities is also the same. There is shown again the general tendency for the older rocks to be faulted up among the younger ones.

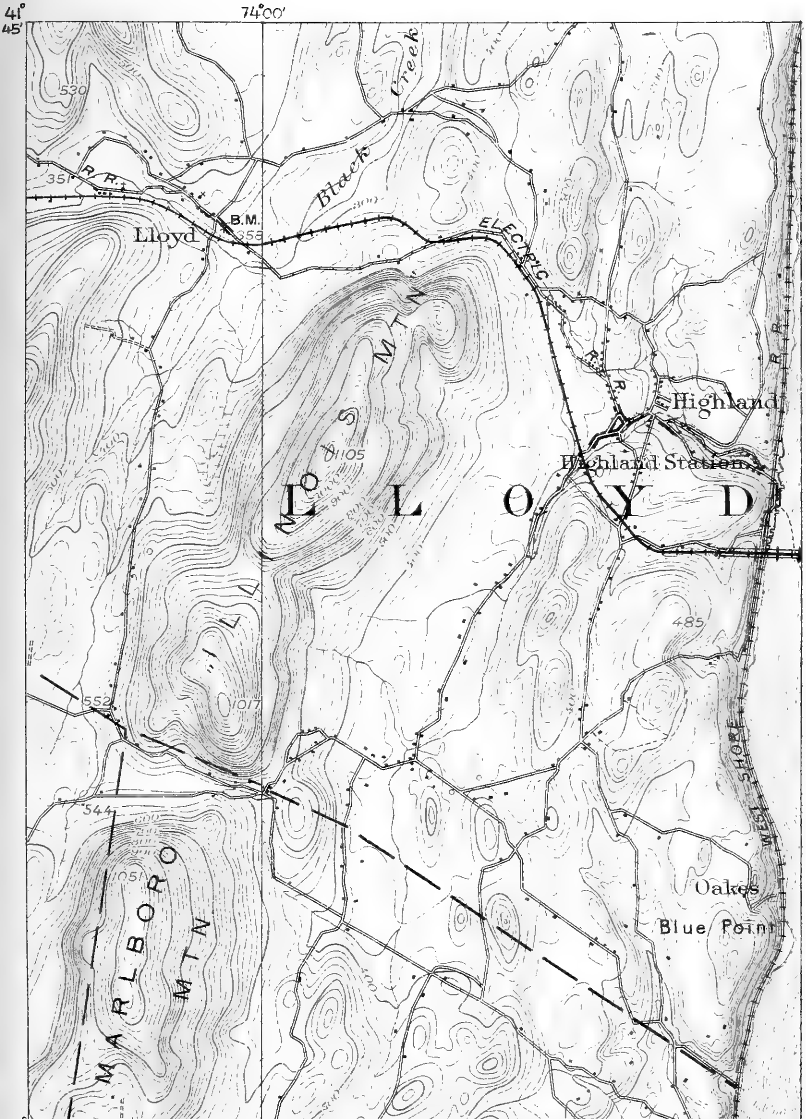
Summary of features shown by the conglomerate and associated rocks. At Pleasant Valley and at Rochdale the conglomerate and overlying or interbedded blue limestone resting on the eroded Beekmantown are prominently developed. At Rochdale the series is from 70 to 100 feet in thickness and at Pleasant Valley it is apparently about the same. At Sleight's quarry near Manchester Bridge the conglomerate and blue limestone is from 20 to 30 feet in thickness, but certain faulting here makes it unsafe to regard this change as marking a thinning of the limestone. Farther south along the Wappinger creek belt one can get no idea of the extent to which this basal series is represented. Along the western margin of the Fishkill limestone, as shown east of the Glenham belt, the conglomerate has plainly been eroded so extensively that no idea of its original thickness can be gained. At Swartoutville the conglomerate is apparently thin and passes quickly into a series of interbedded bluish limestones and gray limy shales. The impure shaly limestones along the railroad track west of Hopewell Junction, at the apex of the limestone angle and those near Arthursburg station, are probably near the base of the slate formation. At Arthursburg the conglomerate is present at a distance of a few hundred yards from the shaly limestones at the station. In the localities east of Pleasant Valley, which have been described, the conglomerate is interbedded with and followed by calcareous quartzite, the blue fossiliferous mud rock not being present.

At the east within this quadrangle the rocks associated with the conglomerate, though varying in texture from shaly rocks to quartzitic ones, tend to be more silicious than those farther west. Folding and faulting have doubtless brought the two into their present rather close proximity.

Other varieties within the slates. This formation shows many varieties of more or less altered clastic rocks, ranging from muds to fairly coarse conglomerates. While folding and faulting have produced the greatest confusion, it seems possible to make out the general sequence. The writer's observations favor the idea that the calcareous conglomerate and overlying quartzitic limestone represent an eastwardly overlapping sea. These were quickly followed in some cases by limy mud rocks and in others by argillaceous cnes. These were both succeeded by a clastic series of both argillaceous and calcareous nature with one and sometimes the other element in excess and occasionally with so much lime as to form an impure lime rock. The varieties varied in texture and followed each other irregularly. Impure argillaceous muds predominate, and are interbedded with limy muds and grits of varying thickness, but often attaining several feet. Grits often reaching conglomeratic texture are frequent. In these, the larger particles range from the size of a pin head through that of a pea to that of a walnut and larger.

On the whole, the finer-textured members are more characteristic of the basal portions of the series and the coarser and gritty layers of a higher horizon. Such a series as has just been described is folded in between the red slates of Matteawan and those south of the clay pits at Paye's brickyard, and the members are exposed at

Plate 17



West side of Hudson river showing location of Marlboro and "Illinois" mountains

many points between or along the strike to the north and south, and along the New York Central Railroad track. The coarser, gritty members, or conglomerates, were noted about midway between the strikes of the two bands of red slates.

The red slates suggest that they were formed under conditions of regular exposure to the atmospheric influences, perhaps on extensive tidal flats or river deltas. It is probable that these rocks were formed on a gently subsiding sea floor which occasionally allowed for partial nonmarine conditions of sedimentation. The relative horizon of the red slates is indeterminate, but is probably not far from the base of this formation. This is indicated by the geographical associations with the conglomerate and their absence northwest of the Wappinger creek limestone.

North of Camelot, along the railroad track, almost to Poughkeepsie, crushing has affected all members much the same, producing coarsely splintered slates. The great confusion exhibited by the slates about Poughkeepsie and on the west of the river north and south of Highland seems to have been due very largely to the effect of heavy beds interbedded with thinner ones.

Along the western bank of the Hudson from Marlboro to a point two miles or so north of Highland, the rocks are quite similar to those along the east bank. Westward from the Hudson the rocks grow prevailingly coarser. The section along the Central New England track between Highland and Lloyd shows thick masses of quartzitic rocks interstratified with coarse grits and conglomerates. The latter form relatively thin beds, perhaps from six to eight feet in thickness, often with pebbles from two to four inches in their longest diameters, embedded in a matrix of finer conglomerate; while in the grits are scattered pebbles ranging from the size of a walnut to that of a man's head. These coarser types prevail along the track west of Highland station and are particularly well shown just east and west of the overhead trolley bridge on the New Paltz road and at the foot of the mountain along the road just south. These rocks appear to be the northward continuation of the rocks of "Illinois mountain." That some of the strata were deposited under marine conditions is indicated by the fossils that have been discovered on the eastern slope of "Illinois mountain" and on Marlboro mountain farther south. While this is true, there appears to have been a gradual coarsening of sediments westward which suggests changed conditions in the source of supply, lying to the eastward, as though terrigenous sediments gradually encroached westward and contended with marine deposits. This idea would seem to fall in line with what we know of the record of closing Ordovicic time in eastern North America.

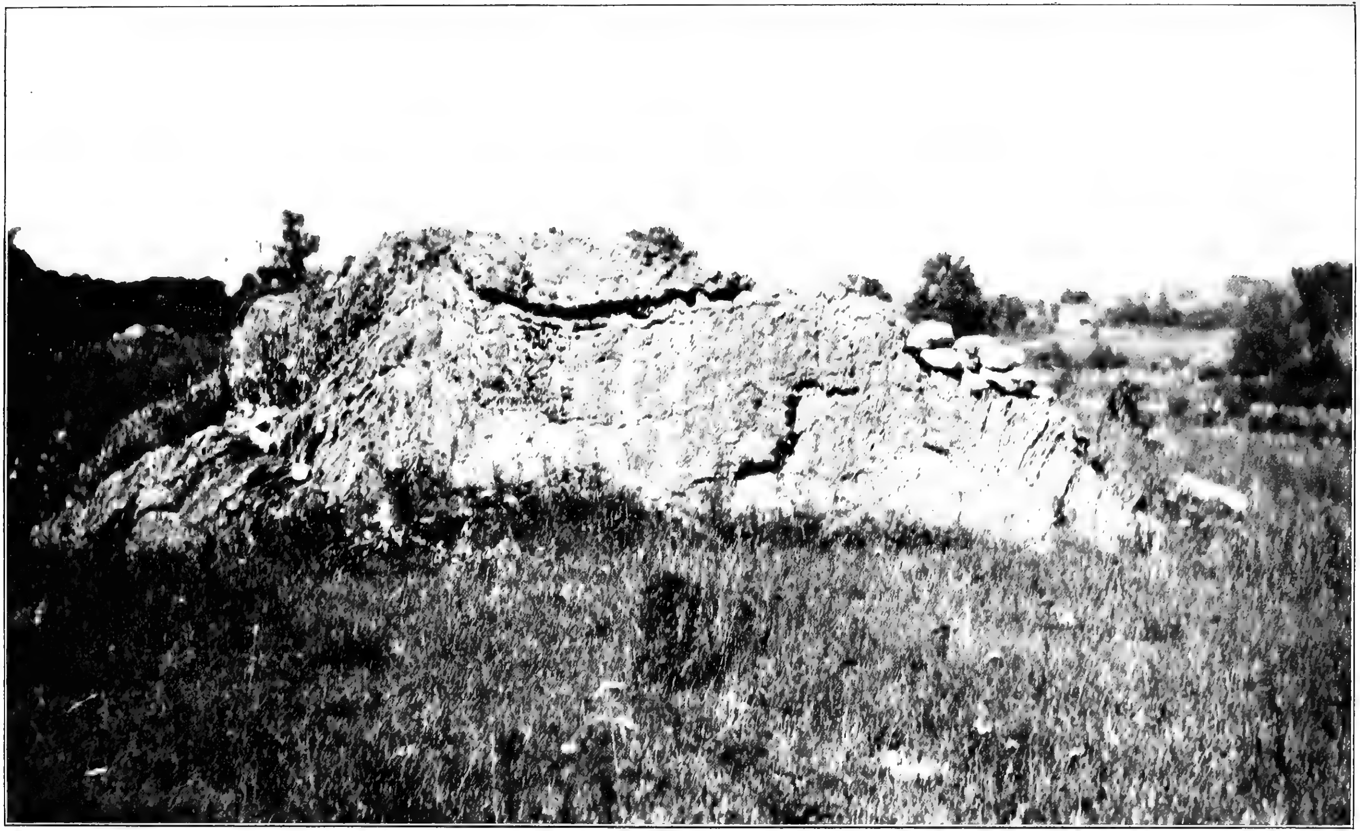
Some of the members of the slate formation on the west of the Wappinger limestone belt may be much younger than those on the east of it. They may be thought of as having been preserved partly on account of their occupying, in general, a downthrow position with reference to a tendency to thrust and reversed faulting to the eastward, as well as on account of being west of the axis of maximum folding.

About two miles north of Poughkeepsie are strata of black, somewhat carbonaceous slates in which graptolites have been found. They indicate changed conditions of sedimentation from those which chiefly prevailed during the accumulation of these rocks. These black slates have been thought to be of Utica age.

Structural features. Where the stratification dip has been determined on what is plainly the limb of a fold, it is chiefly eastward. Judging from the conditions shown in the Fishkill limestone, the structure is that of minor folds within a system of larger ones with a tendency to overturning. The presence of strong cleavage usually obscures everything in surface outcrops.

The dimensions of the larger folds seem to be smaller at the north and northeast than at the southwest, and the folds seem to be more open at the north. The slate ridge just east of Freedom Plains, which ends abruptly at the south at a point due east from that hamlet, has synclinal structure of a rather open character. At various points along the southern portion of its eastern slope it shows the slates dipping to the west into the hill. To the north, along the south road from Moores Mill to Pleasant Valley, the red slates come up on the western limb of this syncline and about three-fourths of a mile farther northwest they appear again apparently on the western limb of the succeeding anticline.

There was a tendency to form irregular folds. This is shown on a small scale in plate 18, in which we have a small overturned and compressed syncline on the right of the picture, followed by an irregular anticline, which becomes compressed and pushed up at the west, and then another compressed syncline not distinct in the photograph but similar to the first. In this instance, it is seen that the production of anticline and syncline in the middle part of the ledge has been incomplete. With similar tendencies prevailing in the larger folds, it is easy to see how, along the western portion of the irregular anticline, there would have been a tendency to overthrust. Crumpling is not uncommon. The wrinkles vary from



Folds in the slates on Ivy's farm, three miles east of Pleasant Valley

minute size to the dimensions shown in plate 19. These features are more common at the east.

Cleavage is so prominent in surface outcrops that the stratification dip is usually obscured. The prevailing eastward dip indicates a common eastward inclination for the cleavage. The presumption is that stratification and cleavage often coincide or approximate each other very closely. Where the cleavage is not dominant to the exclusion of the stratification, this fact is often observed.

Jointing is well displayed in Matteawan along the Newburgh, Dutchess and Connecticut track. A prominent set of joints shown here has a general strike of n. 20° e. and a dip of 80° w.

Some of the faults within the slates have been alluded to in describing the limestone patches within this formation.

Extending in a northwest direction approximately parallel with the road from Brush to Arthursburg, as shown on the map, is a clear transverse fault. This break is best seen from the southeast near the old railroad bed. This break intersects a line of strike faulting at Arthursburg, and probably ends at that point. The strike fault just mentioned dies away to the northward. Continued south, it bounds the limestone triangle north of Hopewell Junction on the west.

The high hill northwest of Lagrangeville is bounded by a fault scarp on the west. This scarp is a conspicuous cliff east of the road from Lagrangeville to Freedom Plains. The high hill northwest of Billings is bounded on the south by an east–west fault whose scarp is very conspicuous.

The other lines of fracture shown on the map have already been referred to.

A long line of swampy lowland, beginning two miles north of Freedom Plains and running northward toward Pleasant Valley, appears to mark a line of crustal weakness similar to that which extends from Hopewell Junction to Manchester Bridge.

The fault which bounds the western strip of the Wappinger creek limestone on the north may extend across the Hudson and bound "Illinois mountain" on the north.

Metamorphism and alteration. The members of the slate formation show an appreciable increase in metamorphism toward the east within the quadrangle, passing into slaty phyllites and graywackes. These rocks do not develop into perfect schists like those occurring a few miles to the eastward, but pellets of decomposed ferruginous particles, suggesting former garnets, were noted in the phyllites east of Arthursburg. Veins, veinlets and nests of quartz are most abundant in the northeastern part of the area. Sandstones have been changed into quartzites.

Summary. There is no evidence at hand that any slates of the quadrangle are older than the limestone conglomerate that has been discussed, either as overlying the Beekmantown or as isolated inliers within the slates. The slate formation was ushered in by this basal conglomeratic layer. The area of deposition of the latter may have been much more extensive than is indicated by its present faulted outcrops. The period of its formation was of short duration.

The most that can be said of the slate series is that it began in some horizon of the Trenton and perhaps ranges upward an indefinite distance into the Cincinnatian. Probably a large portion is of Trenton age.

The Utica may be present, although the graptolite beds that have been so called more probably represent an early invasion of the Utica fauna in Trenton time in what is known as the Normanskill subepoch. Some of the slates may be contemporaneous with the Utica as developed elsewhere to the north, and possibly even younger; or they may all be of Trenton age.

PREGLACIAL HISTORY OF THE DRAINAGE

Old valleys of the Tertiary cycle. During the erosion cycle inaugurated by the Postcretacic uplift, the Hudson river then, as now, must have been the dominant factor in the drainage of this and adjacent areas. A broad valley region was formed and the tributaries of the master river steadily pushed their valleys eastward. The early Tertiary valley of the Hudson itself is now represented by old rock terraces preserved at different points back from the river's edge. Near Poughkeepsie they have an elevation of about 200 feet.

The rock valleys of the present tributary streams are in most cases out of proportion to the present size of those streams. During the time the Hudson river occupied the valley now marked by the terraces that have just been alluded to, its tributaries widened their own valleys a good deal and acquired their present open character. These branches formed a drainage system of the second order within the broad valley region of the main river and a somewhat advanced stage of mature topography was attained. During this time the various lines of crustal weakness became marked off into their present prominence, without necessarily becoming prominent lines of drainage; simply responding in a logical way, on

Crumpled slates east of Freedom Plains

account of reduced resistance, to the base-leveling forces of the time.

Late Tertiary uplift. Late in the Tertiary cycle, probably during the latter part of Pliocene time, it seems probable that an elevation occurred which rejuvenated the whole river system. The Hudson began the construction of its present gorge and its tributaries began to deepen their valleys within their former confines. It has been suggested that the temporary shifting of the St Lawrence drainage through the valley of the Mohawk gave the main stream a tremendous advantage. It was able to sink its channel at a very rapid rate. The larger tributaries were able to deepen their gorges near their mouths and for some distance back from the Hudson before the glacier invaded the land.

Buried river channels. Borings have been made at different points across the Hudson river and its tributaries in connection with the location of the aqueduct of the great metropolitan reservoir in the Catskill mountains. These have yielded important data regarding the preglacial channels of these streams. Professor Kemp has summarized and discussed these data in an interesting paper.[1]

Borings across the Hudson have been made at Pegg's Point, at a point one-half of a mile north of that place, at New Hamburg and at Danskammer within this quadrangle, and at Storm King just south of Newburgh.

The most northerly line of borings is known as the "Tuff crossing." From this, only wash borings were secured. The river here is only 2200 feet wide.

At Pegg's Point the river narrows still more. A diamond drill was sunk 720 feet from the west shore and reached the slate at 223 feet below sea level. Another sunk 440 feet from the east bank reached the limestone at 92 feet. The distance separating these two borings is 1040 feet. Professor Kemp believes that a deep and relatively narrow gorge lies between. Several lines of wash borings at this place gave depths to supposed bed rock varying from 139.5 feet to 256 feet in what would perhaps be thought of as the deepest part of the river.

At New Hamburg the river is 2300 feet wide. Drill borings on each bank found the slate beneath the limestone. At the point of boring on the east bank it was reached at 220 feet; on the west at 351 feet. Only wash borings were made in the river bottom. These ranged from 130 feet to 263.5 feet below tide.

[1] Buried Channels beneath the Hudson and its Tributaries. Amer. Jour. Sci. Ser. 4. 26:301–23.

At Danskammer the stream is about 3500 feet wide. The results of wash borings gave a range in depths from 133.2 feet to 268.5 feet to supposed rock bottom, but the evident irregularity and variability would seem to indicate a bed of loose material at these depths at this crossing.

At the Storm King crossing the drill brought up from a depth of 617.4 feet a core of granite just like that on the east bank of the river, which it had penetrated to a distance of 8.8 feet. The drill was thought to have reached rock bottom at this point at a depth of 608.6 feet not far from 750 feet from the east bank.

Casper creek was tested near its mouth by wash borings. The lowest point thus reached was 67 feet below tide.

Fig. 28 The Casper creek crossing. (After Kemp)

In Wappinger creek one wash boring below the falls reached a depth of 50 feet below tide. Of three core borings, the maximum was 39 feet.

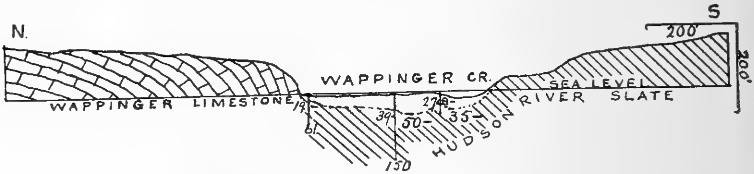


Fig. 29 The Wappinger creek crossing. (After Kemp)

A proposed line of the aqueduct crossed Fishkill creek near the village of Fishkill. Everything is beneath the drift at this point. Of two core holes, the deeper reached the limestone at 40 feet below tide. After penetrating 8 feet of limestone, the drill encountered fine yellow sand in which it continued for 60 feet, when the hole was abandoned. This crossing is about five miles back from the Hudson.

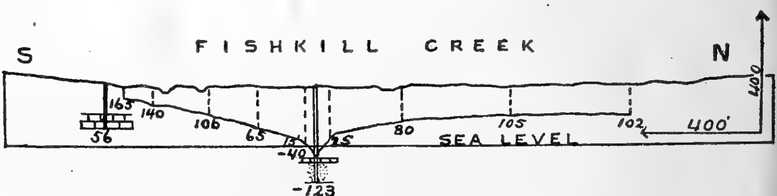


Fig. 30 The Fishkill creek crossing. (After Kemp)

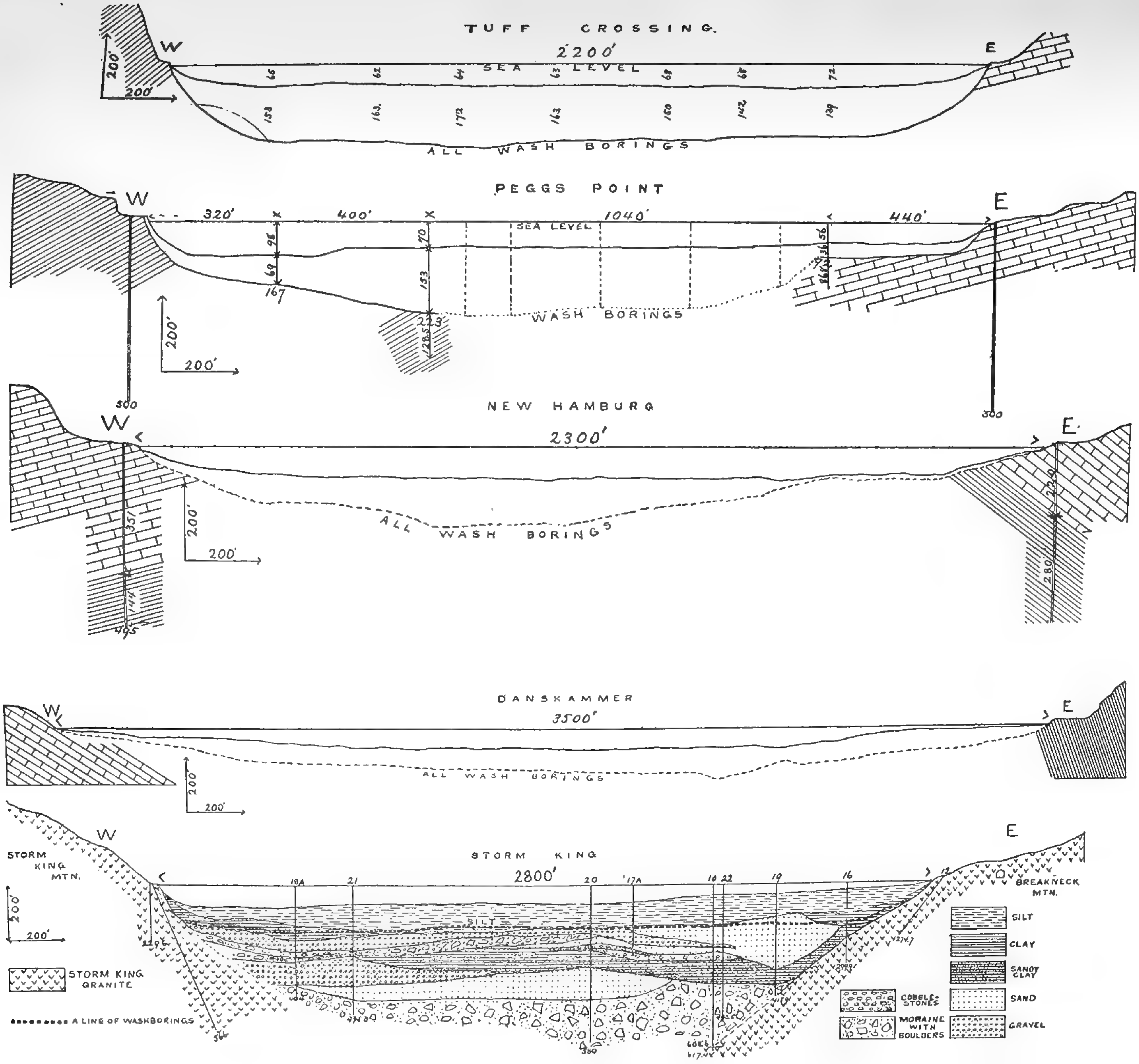


Fig. 27 Sections showing borings across the Hudson river at Tuff crossing, Peggs Point, New Hamburg, Danskammer and Storm King (after Kemp)


TUFF CROSSING.

The above-given numerals and description were taken from Professor Kemp's paper. The general conclusions to be drawn from these facts to which Professor Kemp has called attention, are that the Hudson river occupied a deep gorge at the close of the Tertiary period and that its tributaries emptied into it from hanging valleys. Unless a deep gorge exists at the Pegg's Point crossing, as discussed above, a rather large gradient between this point and Storm King would have to be assumed.

The borings south of Fishkill Village suggest that this creek deepened its gorge some distance back from the Hudson during late Tertiary time. The other tributaries probably did the same to an extent commensurate with their size and erosive power. All the tributaries, however, occupied hanging valleys with reference to the bed of the main stream.

The boring records also show that much glacial stuff now lies in these buried channels.

GLACIAL GEOLOGY

Erosion. The elevation of the land at the close of the Tertiary is believed by many to have ushered in the glacial epoch. The passage of the ice sheet over this region is marked by grooves and striae and characteristic deposits of surface material. The ice sheet may have assisted in gouging out the channel of the Hudson.

The following is a summary of observations by the writer on the direction of glacial striae and grooves in different parts of the quadrangle. West of the Hudson about two miles northwest of Highland, along the road to Lloyd, a deep glacial groove was noted with bearing true s. 15° w. One and a half miles west of Milton another fine groove gave a reading of true s. 9° w. Fine *roches moutonnees* occur to the west of "Illinois mountain" south of Lloyd.

East of the Hudson in the eastern part of the city of Poughkeepsie, near the driving park, striae were noted with bearing true s. about 14° w. and farther east, just west of the central strip of the Wappinger belt along the Hackensack road, a reading of true s. 1° w. was taken. Near the Central New England Railroad at Poughkeepsie the striae had a bearing of true s. about 26° w.; north of Poughkeepsie near quadrangle boundary, east of Fallkill creek, true s. 11° w.; one mile north of New Hackensack, n. 21° w.; near the Hudson, north of Fishkill Landing, true s. 33° w.

Some of the strike fault scarps, as, for instance, those of Bald hill, Mount Honness and Shenandoah mountain of the Highland spurs, and the fault east of Freedom Plains, appear to show the effects of glacial plucking.

The Highland crests were buried by the glacier. Some places along the northern slopes show polishing effects (see plate 6). The excavation of the valleys between the northern spurs of the Highlands was probably materially assisted by the ice.

Deposits during the advance. Drumlins, or drumlinoid masses of till, are rather numerous in the quadrangle and often are conspicuous features of the topography. They seem to be deposits of the advancing ice sheet which molded them by pressure into their usual elongated domelike shapes. These masses greatly obscure the structural relationships over much of the area. They are the most conspicuous features of the ground moraine. The larger part of the veneer of till, which is very plentiful, probably dates from the advance of the glacier. About 200 feet of boulders and sand, which rest on the bottom of the Hudson gorge, probably are a part of the ground moraine.

RETREAT OF THE ICE SHEET

It is generally held that accompanying and following the retreat of the Wisconsin ice sheet from this region there was a slow subsidence of the land. At this time a large body of water filled the old valley of the Hudson within this area. It would appear that the subsidence went on gradually and that during the earlier stages much sand, gravel and sandy clay was deposited on the earlier boulder material that covered the bed of the gorge to a depth of 200 feet, and then a thin layer of boulders representing a probable flood of floating ice, and then typical river deposits.[1] Finally, it would appear that the subsidence may have brought in estuarine conditions, at which time the Hudson river clays were laid down. These considerations assume an open gorge and postulate the probable deposition of the clays entirely across it, their present condition having been brought about by later dissection. It is proper to state that there are exceptions to this idea. Professor Woodworth, from a study of the entire Hudson and Champlain valleys, holds the opinion or belief that, during the deposition of these clays, the Hudson gorge was filled with a long tongue of ice against which were standing bodies of water at a higher level than water could have assumed in the open gorge. He cites many observations to

[1] See J. F. Kemp. Buried Channels beneath the Hudson and its Tributaries. Amer. Jour. Sci. Ser. 4. 1908. 26:322.

show that the clays, and overlying sands and gravels are best explained as depositions under such conditions.[1] Woodworth's hypothesis does not call for so great a subsidence of the land as the other, and logically explains the present bisected character of the clays as their original condition. The proximity of the ice during the deposition of the so-called Champlain deposits is shown in several ways. It seems quite reasonable, however, to explain the upward more or less perfect passage from coarse to finer detritus in the Hudson gorge as due to gradual deepening, and a passage from fluviatile to estuarine conditions which would furnish the conditions for the accumulation of the finer material.

Terraces. The finer material in question takes the form of stratified deposits of clay, capped with sand and gravel, which occur in the form of terraces at various places along the Hudson gorge. A number of these are in this quadrangle.

Such a terrace begins somewhat over a mile north of Fishkill Landing and extends for a mile north of that point, varying in width from about one-fifth to three-fourths of a mile. It is about 100 feet high at the outer edge and a few feet higher at the inner edge. It is followed on the north by a lower terrace varying from 30 to 40 feet in height, with varying depths of clay and covered with coarse gravel. On the west bank of the Hudson at Roseton and at Danskammer gravel-covered terraces also occur. These are somewhat higher than the north terrace on the east bank. Terrace deposits also occur at Marlboro.

At New Hamburg the deposits are a good deal coarser and have a terrace delta form. The coarse sands and gravels of this terrace and their general relations, as well as the Roseton and Danskammer terraces, are thought by Woodworth to "compel the belief" that they were deposited against the ice. In the case of the Roseton terrace, he states that there are signs of inthrusting of drift from ice movement (*loc. cit.* p. 119) and further that the terrace can not be attributed to a river pouring into an estuary after the disappearance of the ice.

The diminishing altitude of the terraces northward has been interpreted as favoring the idea of their formation against the ice in glacial lakes. The coarser material overlying the clays has been attributed to the retreat of the ice front beyond the mouths of tributary stream valleys, allowing an influx of coarser sediments.

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[1] Ancient Water Levels of the Champlain and Hudson Valleys. N. Y. State Mus. Bul. 84, 1905, p. 66–265.

By others, the lower level at the north has been attributed to erosion accompanying elevation, and the coarser sediments to the same cause.

C. E. Peet[1] has made the observation that, if the valley between the low terrace just south and north of Carthage Landing and the slightly higher one on the west of the river at Roseton and Danskammer were filled with ice, the latter was stagnant, and may have stood on the lower terrace at the east. He also admits the possibility that the terraces may have been continuous and that the lower one on the east is the product of the erosion of higher deposits.

Later, in discussing the history of the " Hudson water body and the successive positions of the ice as it retreated through the Hudson valley, Peet[2] states that the ice front appears to have assumed two distinct phases in different parts of the valley. In some parts, notably the narrower ones, it is believed that the ice protruded down the valley and that accumulations took place at the edge of this ice-tongue, or between it and the valley wall. The deposits at Carthage Landing and New Hamburg might represent such conditions, but the valley ice was probably not an active contributor, although at the latter place waters from the valley ice may have been active in the early stages of the plateau building. In the broader parts of the valley the deposits were probably deposited in an embayment of the ice front.

Peet cites many facts to show that the Hudson water body may have been a lake made by a barrier at the south, or a succession of lakes made by a succession of barriers or by a migrating barrier, and, on the whole, leans toward the lake hypothesis as against a salt water body. The reader is referred to the original paper (see *loc. cit.* p. 640–56).

It is probable that a series of glacial lacustrine basins at the south would have allowed both for open water and the many characteristic glacial phenomena in connection with the deposition of this material.

On the submergence hypothesis an elevation of between 100 and 150 feet was necessary for the bisection of the delta at New Hamburg, and at this time the deposits in the gorge of the Hudson may have been dissected, although to a greater extent in the case of the main river. The moot point seems to be the extent to which the gorge was submerged by the sea.

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1 Journal of Geology. 12:445.

2 *loc. cit.*, p. 618–21.

A portion of the high-level terrace of Wappinger creek near Tompkins's farm, east of the road from Poughkeepsie to Pleasant Valley

Well-preserved sand and gravel erosion terraces occur at frequent intervals along Wappinger creek. These are best shown in the open portion of the valley of this stream in the neighborhood of Manchester Bridge and between that hamlet and Rochdale. The road from Manchester Bridge to Rochdale for a mile north of the former place closely follows the edge of a fine terrace that drops with uniform slope from the 160 foot level to the present flood plain of the creek. The cemetery at Manchester Bridge is built on a projecting tongue of this fine terrace which is broken by the limestone knoll on which Mr George Byer's house stands. North of here it may be followed for a short distance.

South of Rochdale, to the east of the Pleasant Valley road, on the west side of the creek, the present flood plain makes a large embayment to the west, north of Frank De Garmo's house. This embayment is fringed by a fine terrace, a portion of which is shown in plate 20. Other terrace remnants may be followed southward along the creek.

These dissected deposits clearly belong to an epoch when the creek valley was flooded and the creek was able to aggrade its valley floor to the level of these terraces, at least. It was probably during this time that the delta deposits were making at the mouth of the creek, whatever the conditions there may have been. These features would appear to have been intimately connected with the retreat of the ice sheet which, as it melted, would have furnished both the floods and the material. This material is in the form of sand and gravel. A good deal of finer detritus must have been carried out into the Hudson gorge.

To allow for this accumulation of sand and gravel in the old valley of the creek, either there must have been a body of standing water in the Hudson gorge nearly 200 feet higher than now, or the land must have been much lower than now.

Fishkill creek and its tributaries were also able to aggrade their valley floors. Gravel deposits belonging to a former higher level form imperfect terraces at different points. In some places, the gravels look like outwash plains during a short halting of the ice, as in the vicinity of Hopewell Junction. The Newburgh, Dutchess & Connecticut Railroad apparently cuts a series of terrace remnants from Hopewell to Brinckerhoff. Fishkill Village is located on a terrace at the 200 foot level which extends southwest to Glenham. Small, but perfect, terrace levels along brooks tributary to Fishkill creek, belonging to a stage in the subsidence of the water corresponding to the rock barrier over which the main stream flowed at Glenham, are preserved near Johnsville.

Kame deposits. These are prominently developed in places along the northern margin of the Fishkill mountains. A conspicuous group occurs along the Cold Spring road south of Fishkill Village, near the quadrangle boundary.

Kame moraine deposits are prominently developed south of Johnsville along the eastern base of Mount Honness, and still farther south along the western road from West Fishkill Hook into the mountains.

The brook flowing north from the mountains, through the hollow of East Fishkill Hook, cuts through similar masses.

Kames are noticeable features along the road from East Fishkill Hook to Shenandoah. Northeast and east of that hamlet they are pronounced topographic forms guarding the approach to Shenandoah hollow (see plate 21).

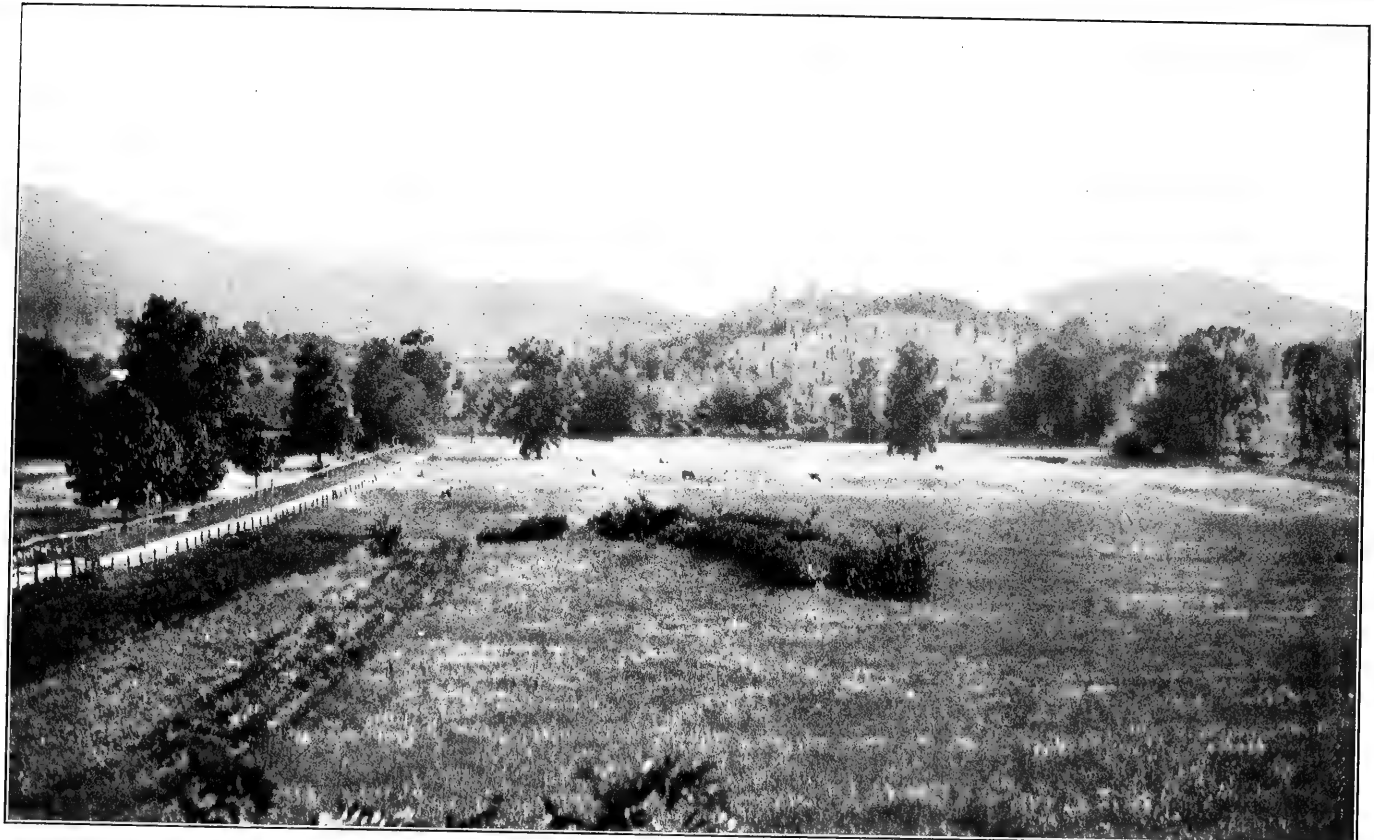
Kames also occur along Casper creek between the Hudson river and the Poughkeepsie road (see plate 22), and near Camelot.

POSTGLACIAL EROSION

After the retreat of the glacier either the land, which probably was at a higher level than now, remained stationary, while the water level in the gorge subsided, or it was elevated. The tributary streams, now greatly reduced in volume, meandered over their old floor plains and began the vertical and lateral dissection recorded in part by the terraces described or alluded to above. Wappinger creek, in seeking an outlet to the Hudson, was confined near its mouth between narrower rock walls and began the bisection of its old delta of the flood period. It readily found its old preglacial channel, which it tumbles into at Wappinger Falls. The precipice at this place forms a local base-level to which the stream is slowly reducing its bed at various places along its course at the north.

Fishkill creek is off its old preglacial channel for some distance in Glenham, and between that hamlet and Matteawan. When the stream was superposed on its former flood plain it was obliged to make a wide detour at Glenham round the huge drumlin on which the cemetery of Matteawan stands. It eventually found bed rock and finally the contact between the limestone and the gneiss of the Glenham belt, and has made the gorge shown in plate 23. At the northeast end of the carpet mill the creek crosses a fault between

Plate 21



Kames northeast of Shenandoah at the northern opening of Shenandoah hollow. Shenandoah mountain may be seen in the background on the right of the picture

Plate 22

Kames along Casper creek west of the road from Wappinger Falls to Poughkeepsie

Postglacial gorge of Fishkill creek below the railroad bridge at Glenham. Gneiss forms the right wall and limestone the left

the limestone and the slate and from this point on cascades over the slates until its own delta is reached. It is probably along or very near its preglacial channel from Wolcott avenue southward. The preglacial channel north of here is probably to the southeast of the present course of the stream.

It may be that during this time of erosion the Hudson cut its present gorge and that the gravel-covered, laminated clays are erosion terraces instead of benches laid down against the ice.

THE PRESENT DEPRESSION

Following the bisection of the Wappinger creek delta, the valley of the Hudson suffered the depression that produced the present estuary and the later channel of Wappinger creek was submerged (see plate 24). Fishkill creek filled up its gorge to tide level and produced its present delta.

OTHER DRAINAGE FEATURES AND ADJUSTMENTS

Near Gregory's mill at Old Hopewell, Fishkill creek was deflected by the drift and imposed on the limestone through which it has cut a gorge.

The rock valley of Casper creek, at points north of the Hopewell branch of the Central New England Railroad, suggests a once more powerful stream which may have drained a larger area to the north of this quadrangle along the valley of the brook that rises in the swamp east of Van Wagner, and now flows north to join a southward flowing stream of considerable size, and which reaches Wappinger creek by making an abrupt turn to the east-northeast.

The course of the Fallkill near Poughkeepsie suggests that this stream has utilized certain fault features. Fishkill creek, along its course within the quadrangle, makes a number of bends to the northeast that are in line with the fault features of the Fishkill limestone.

LAND FORMS

These are apparently of two fundamental types: those produced by a sort of block faulting and those produced by folding, accompanied by faulting. Each is distinct, but is modified by the other. Both apparently date from the time of the Green mountain revolution.

At the close of Cretacic time this region was a peneplain. A re-elevation introduced the history of the present topographic aspect of the quadrangle and subsequent erosion presents the striking discordance between the present topography and relations and those of Precambric and early Paleozoic time.

The Precambric gneissic floor appears to have behaved in a measure as though it had no load. It was twisted and broken into blocks like a piece of glass and thrust up into the overlying formations, the force of the shove diminishing to the northwest. The plateau type of the Highlands is primarily the result of upward thrust as a mass and secondarily the effect of the resistant quality of the Precambric rocks when subjected to erosion. The present topographic level of the Fishkill limestone would appear to indicate a normal position for the limestone now. Primarily, however, it is a faulted up thrust block; erosion has exposed the older stratigraphic series which were thrust up into the overlying slates.

The northern valleys of the Highlands represent down-faulted masses of the younger rocks which later erosion cycles discovered and removed.

As superstructures on these basal features are forms connected with folding and breaks along the strike and dip.

Influence of the petrographic character of the rock. The low average level of the Hudson valley is attributable to the ease with which the slates are broken up and removed. The relatively low topographic level of the Fishkill limestone, corresponding with its lower stratigraphic position, is deceptive. In this case, the removal of the slates and the erosion of the limestone obscures the structural position brought about by faulting.

The present altitude of the high ridge forming "Illinois mountain" is due in part to the resistant character of its grits.

The resistant quality of the metamorphosed rocks in the eastern part of the quadrangle has been a factor in producing their present relief.

ECONOMIC GEOLOGY

The agricultural industry. The agricultural interests are chiefly those of fruit growing and dairy farming. The former is conducted on an intensive plan on the hilly land west of the Hudson where well-drained hills of tilted slates, covered with a veneer of till and coarse gravel, afford highly suitable soil conditions for growing fruit of excellent quality. Large consignments of peaches, apples, pears and small fruit are sent to New York city and New England markets and some growers find a highly profitable business for fancy fruit in the markets of England. Grapes are also a successful and important crop.

Drowned gorge of the Hudson as seen two miles south of New Hamburg, looking north

Fruit growing is also practised east of the Hudson. Nearly every large farm has its apple orchard, some of which are of large size. Peaches are also successfully grown and apparently are growing in popularity as an investment. Some fine fruit is grown in small orchards along the northern slopes of the Fishkill mountains. The Hudson river affords favorable temperature conditions for the budding season and insures good crops. The ravages of the coddling moth and other injurious insects are, however, sometimes extensive.

The importance of the climatic influence of the Hudson river as a successful factor in fruit growing is clearly recognized. Fruit is not so successfully grown out of reach of this influence, even on soils of the same character and with similar drainage.

Dairying is perhaps the largest farming industry and the one most widely practised. The area enjoys unusual facilities for transportation of farm products.

Soils. The glacial ice, as shown above, moved in a course generally roughly parallel with the longer axes of the rock ridges. This fact seems to have had an influence on the character of the soil along these ridges. It is noticeable that the upland soils have a definite relation to the underlying rock.

Lower levels, which mark the flood epoch of the waning ice sheet, have sandy and gravelly soils, with clayey subsoils, and are often of terrace form or in kamelike masses. In addition to these are the drumlinoid masses of somewhat more compacted character, often attaining or approximating boulder till. Finally, there are the alluviums of the river bottoms.

The limestone areas are considered the finest grass lands, but all the upland soils yield good grass crops. The gravelly river bottoms are usually good corn soils. The more sandy terrace soils are suitable for garden truck or early fruit. The slaty hill sides usually give good apple-growing soils when not too clayey.

The finest farms are in the limestone areas, but the slaty uplands of moderate elevation are highly valued for both of the principal farming pursuits of the present day.

Clays. All the important clays of this area are of sedimentary character and belong to Pleistocene time.

A number of important brick industries are located within the quadrangle. The laminated clays that have been briefly described as forming the terraces along the Hudson, between Fishkill Landing and New Hamburg, and on the west bank at Roseton and Danskammer, are worked on extensive scales (see plates 25 and 26).

These beds form only a part, but are perhaps as important as any, of the valued clays of the Hudson valley.

These deposits are very similar in appearance. The lower portions are usually bluish and the upper yellowish in color. The laminated character is best shown in the upper layers. Thin laminae of sand occasionally appear, in some places forming such proportion of the masses as to require no admixtures of that material in the process of brick manufacture. The coarser sandy material overlying the clay, when screened, furnishes sufficient quantities of sand when that is required, which is usually the case on account of the purity of the clay.

The chemical composition of the clay at Roseton is given from the following analysis:[1]

SiO_2	55.00
Al_2O_3 } Fe_2O_3 }	34.54
CaO	5.33
MgO	3.43
K_2O } Na_2O }	0.48
Combined H_2O } Moisture }	1.22
	100.00

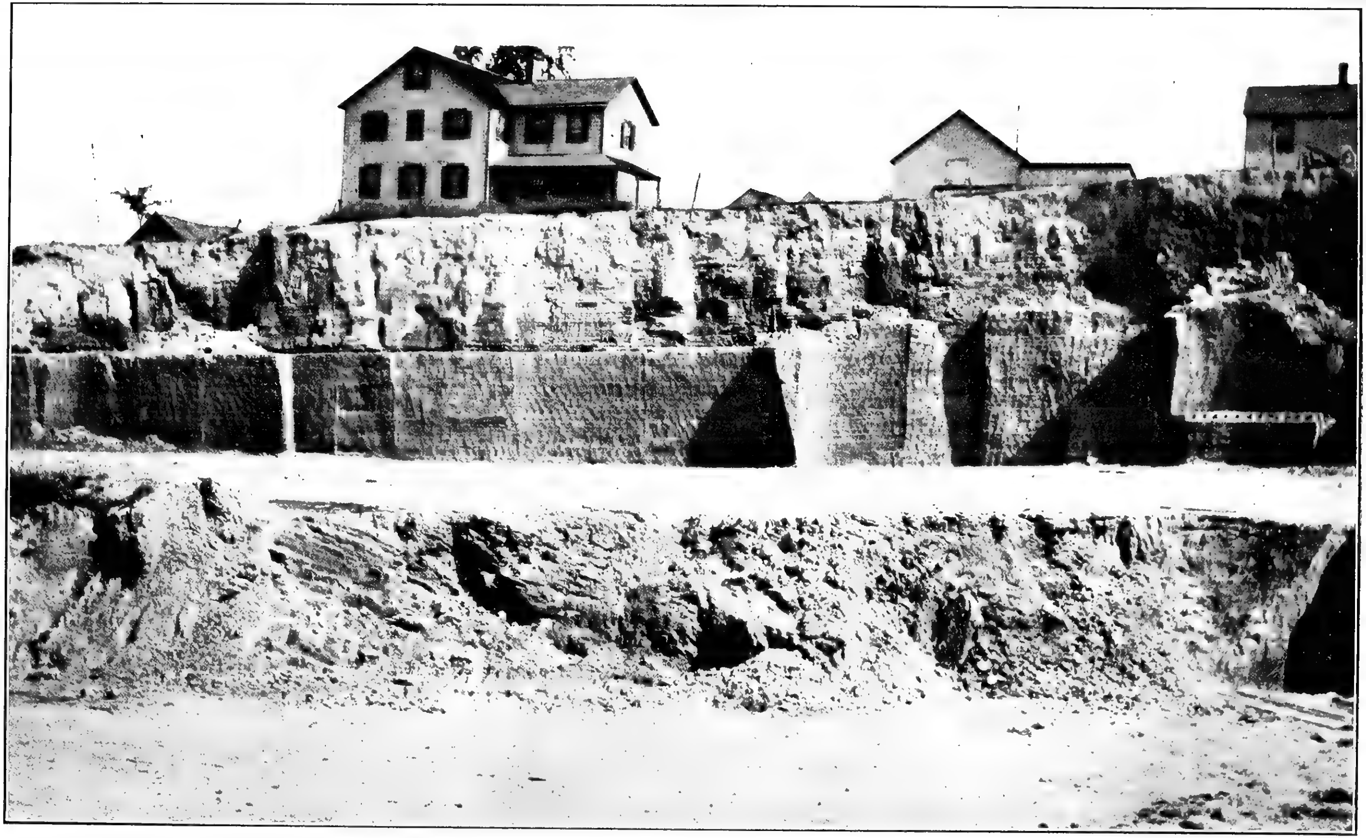
Both the blue and yellow clays are calcareous and effervesce with acid. They have been used as marls on account of their lime content. The yellow color is due to oxidation. The clays are used entirely for brick.

Clay deposits also occur at Arlington, a mile east of Poughkeepsie, and are used for brick. The clay which is fairly abundant along the banks of Casper creek in the neighborhood of Arlington is covered with some sod, but is easily exposed by stripping this off. Yellow clay is underlain by blue clay.

It seems possible that the deposits at Arlington were accumulated in lacustrine waters, perhaps impounded by stagnant ice at the mouth of Casper creek. The kames (see plate 21) that now lie near the mouth of the creek may have been left by the melting of such a mass of ice.

Limestone quarries. Quarries have been opened at places in the limestone strips of the Wappinger creek belt. The largest of these is Stoneco quarry, operated by the Clinton Point Stone Com-

[1] Ries, N. Y. State Mus. Bul. 35, 1906, p. 381.



Laminated clays in the pits at J. Paye's brickyard, north of Fishkill Landing. The photograph also shows joint structure in the clays

Plate 26

Showing the laminated clays and overlying gravel in the pits at Roseton

pany. The rock is somewhat silicious and dolomitic, as the following analysis[1] shows:

Lime	29.07
Magnesia	16.29
Carbonic acid	40.76
Alumina	2.33
Ferric oxid	.47
Silica	10.17

Another quarry has been opened on the west bank of the Hudson in the southwestern extension of the western strip of the Wappinger creek belt, about three-quarters of a mile south of Marlboro station. This is commonly known as Kerr's quarry. A considerable enterprise was apparently projected and was in active operation up to the season of 1909. During that season work was suspended.

The limestone near New Hamburg was burned for lime in earlier years. Its silica and magnesia content would necessitate lean returns.

At Ruppert's quarry near Poughkeepsie the Potsdam is burned for lime for private use.

The Fishkill limestones were used for lime in earlier days, and also as a flux in the operation of the Hopewell furnace a generation ago.

Limonite deposits. Limonite, or brown hematite, beds belonging to a fairly well-defined belt of these deposits occur two miles south of Fishkill Village and near Shenandoah. A small quantity of ore was taken from the former in 1885. The Shenandoah mine was abandoned in 1879 on account of the small quantity of ore.

The question of the origin of these deposits was discussed by Professor Dana.[1] According to his view, during the transition from the limestone-making epoch to that of terrigenous sediments, iron-bearing waters were washed into restricted basins and in the course of time the calcareous and magnesian material became changed to ferriferous rock. In some cases pure iron carbonate was probably formed. The general magnesian character of the limestone was taken as good evidence of the confined character of the basins receiving the additions of iron-bearing solutions.

Kaolin. A residual deposit of kaolinite derived from the disintegration of a feldspathic rock occurs near Shenandoah, and

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[1] N. Y. State Mus. 51st Rep't 2:434; also N. Y. State Mus. Bul. 44, p. 779.

[2] Amer. Jour. Sci., Ser. 3. 1884. 28:398–400.

is known as Fowler's kaolin mine. The material at present is taken out on a small scale and sold principally for stove cement.

Molding sands. Molding sand is dug in large quantities a short distance back from the Hudson, near the mouth of Casper creek and two miles north of that place, and is hauled to docks at these places for shipment.

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1910 **Gordon, C. E.** Further Report on the Geology of the Poughkeepsie Quadrangle. N. Y. State Mus. Bul. 140. p. 16–20.

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New York State Education Department

New York State Museum

JOHN M. CLARKE, Director

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These reports are made up of the reports of the Director, Geologist, Paleontologist, Botanist and Entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Director's annual reports 1904–date.

1904. 138p. 20c.
1905. 102p. 23pl. 30c.
1906. 186p. 41pl. 35c.
1907. 212p. 63pl. 50c.
1908. 234p. 39pl. map. 40c.
1909. 230p. 41pl. 2 maps, 4 charts. *Out of print.*

These reports cover the reports of the State Geologist and of the State Paleontologist. Bound also with the museum reports of which they form a part.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, 8vo; 2, 14–16, 4to.

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899–1903. The two departments were reunited in 1904, and are now reported in the Director's report.

The annual reports of the original Natural History Survey, 1837–41, are out of print.

Reports 1–4, 1881–84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

Report	*Price*	*Report*	*Price*	*Report*	*Price*
12 (1892)	$.50	17	$.75	21	$.40
14	.75	18	.75	22	.40
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16	1	20	.50	[*See* Director's annual reports]	

Paleontologist's annual reports 1899–date.

See first note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Those for 1901–3 were issued as bulletins. In 1904 combined with the Director's report.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

Reports 3–20 bound also with museum reports 40–46, 48–58 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3–4, 17 are out of print, other reports with prices are:

Report	*Price*	*Report*	*Price*	*Report*	*Price*
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5	.25	13	*Free*	21 (" 104)	.25
6	.15	14 (Bul. 23)	.20	22 (" 110)	.25
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Botanist's annual reports 1867–date.

Bound also with museum reports 21–date of which they form a part; the first Botanist's report appeared in the 21st museum report and is numbered 21. Reports 21–24, 29, 31–41 were not published separately.

Separate reports for 1871–74, 1876, 1888–98 are out of print. Report for 1899 may be had for 20c; 1900 for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have also been published in volumes 1 and 3 of the 48th (1894) museum report and in volume 1 of the 49th (1895), 51st (1897), 52d (1898), 54th (1900), 55th (1901), in volume 4 of the 56th (1902), in volume 2 of the 57th (1903), in volume 4 of the 58th (1904), in volume 2 of the 59th (1905), in volume 1 of the 60th (1906), in volume 2 of the 61st (1907), 62d (1908), 63d (1909) reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum Memoir 4.

Museum bulletins 1887–date. 8vo. *To advance subscribers, $2 a year or $1 a year for division (1) geology, economic geology, paleontology, mineralogy; 50c each for division (2) general zoology, archeology, miscellaneous, (3) botany, (4) entomology.*

Bulletins are grouped in the list on the following pages according to divisions.

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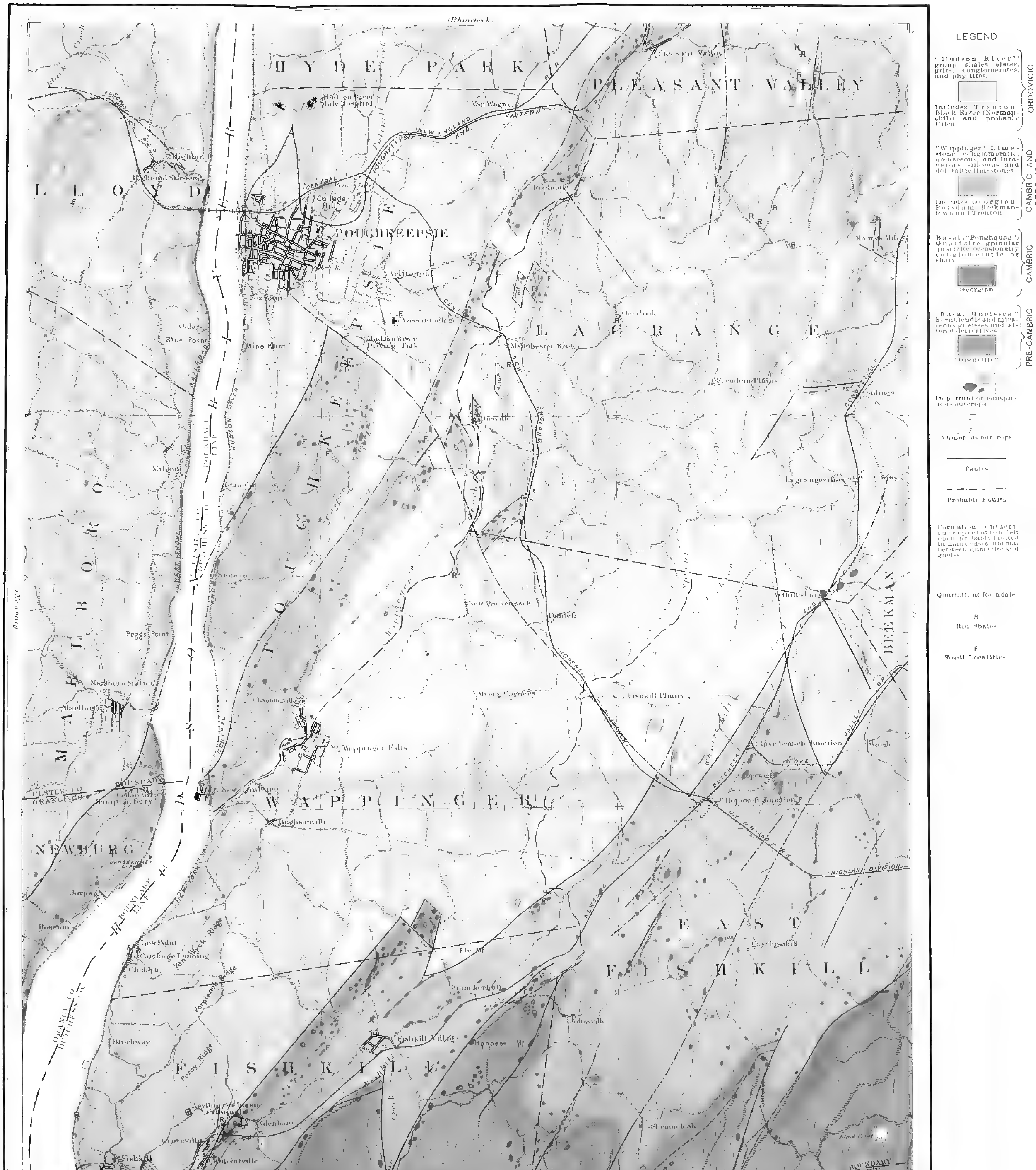

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