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BULLETIN

OF THE

New York State Museum

VOL. 3 No. 14

SEPTEMBER 1895

THE GEOLOGY OF MORIAH AND WESTPORT TOWNSHIPS, ESSEX COUNTY, N. Y.

WITH A GEOLOGICAL MAP

PREPARED UNDER THE DIRECTION OF

FREDERICK J. H. MERRILL, PH. D.

BY

JAMES FURMAN KEMP, E. M.

193677

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
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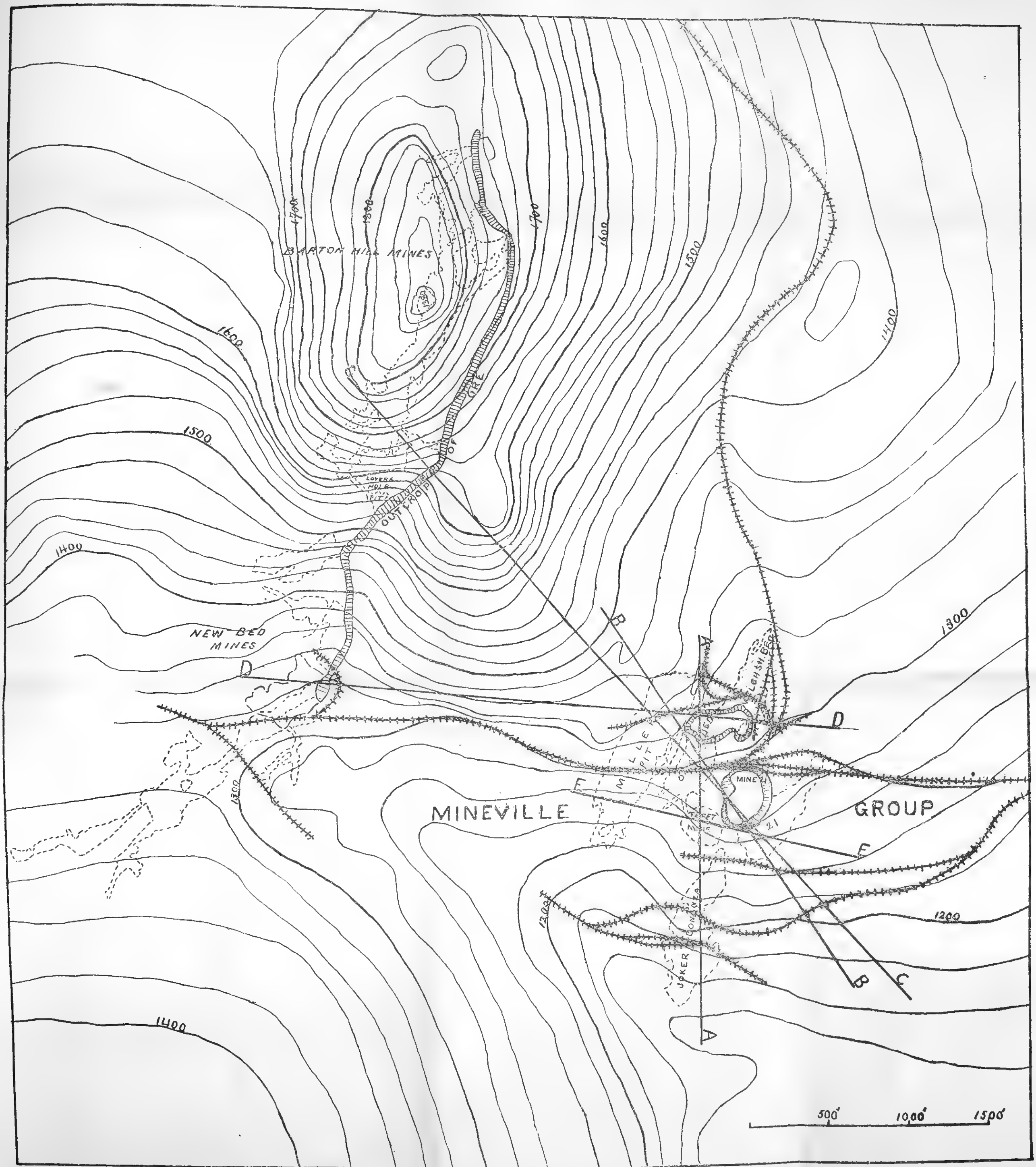

II. Map of the Mineville District, Essex Co. New York

Based on a Map by S. B. McKEE, Engineer of Witherbee, Sherman & Co. and the Port Henry Iron Ore Co.

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INTRODUCTION

The geology of the eastern Adirondacks presents many problems of interest. The townships along Lake Champlain contain within their borders the contacts of the labradorite rocks — (gabbros, norites and anorthosites) with the quartzose gneisses and crystalline limestones; and the later-formed unconformabilities of all these with the Potsdam sandstone of the Upper Cambrian. The crystalline rocks of the Archæan invite study of both igneous and metamorphosed forms, while along the old shore line are the Cambro-Silurian sediments, unchanged, not much disturbed and often rich in fossils. Remarkably little, detailed, field work upon the crystalline rocks has been done in the region since the early survey of Emmons and Hall, 1835–1840. What has been written is incomplete and the stratigraphical conclusions are drawn from too little recorded data. A general review of these papers has been given by the writer, in the Transactions of the New York Academy of Science, v. 12, p. 19, Nov. 1892. Emmons in his Final Report, 1842, devoted almost no attention to the relative stratigraphy of the crystalline rocks and not until 1876, is the question alluded to and then by James Hall only as regards the age of the serpentinous limestones (Amer. Jour. Sci. Oct. 1876) which are spoken of as being later than the Laurentian and earlier than the Potsdam. Dr A. R. Leeds' paper entitled "Notes on the Lithology of the Adirondacks" (Chemical News, Mar. 1877, 36th Annual Report, N. Y. State Cabinet 1877, p. 79) relates to the chemistry and petrography of the anorthosites and trap dikes only.

In 1879 C. E. Hall published a short condensation of what was apparently expected to be a longer contribution. It is entitled Laurentian Magnetite Iron Ore Deposits in Northern New York." (32nd Annual Report of the N. Y. State Cabinet — 1879, p. 133–140.) A brief outline is given of the township geology in the Eastern Adirondacks, and a colored map on a small scale (3 miles to the inch) accompanies the report. Mr Hall divides the Archean into the 1, Lower Laurentian Magnetic Ore Series. 2, Laurentian Sulphur Ore Series. 3, Crystalline Limestones. 4, Labrador Series or Upper Laurentian with Titaniferous Ores. The relations of 2 and 3 are said to be uncertain, but later, in a note, the limestone of 3 is stated to be later than 4. It is to be regretted that Mr Hall did not complete his paper, for too much attention could not have been given to proofs of these stratigraphical relations, and in the following pages, it will be shown that the conclusions reached in this paper favor his first arrangement. T. S. Hunt in the short description of the geology of Port Henry, (Canadian Naturalist, 2nd series, v. 10, p. 420,) regards the limestones near the town as a great, metamorphosed vein of calcite. C. R. Van Hise, in company with C. D. Walcott and R. Pumpelly, made an excursion in 1890 from Whitehall north along the Delaware and Hudson R. R. to Westport and thence into the mountains near Mt Marcy. They saw much that suggested the deposition of the limestones along an encroaching shoreline of gneiss, and remark also the extensive gabbro area of Westport. In December, 1893, J. F. Kemp read before the Geological Society of America, a paper on the Gabbros on the Western shore of Lake Champlain, (Bulletin V. 213–224) in which the petrography of these rocks is discussed. In December, 1894, the same writer read a subsequent paper on the Crystalline Limestones, Ophicalcites and Associated Schists of the Eastern Adirondacks, (Bulletin VI. 241–262) which treats both of petrography and stratigraphy.

All the other papers that have been written on the region, have small reference to these questions, but as bearing on petrographic points, some are important. Recently an account of the geology of Gouverneur township, on the western side, has appeared from the pen of Prof. C. H. Smyth, jr,* and many facts are adduced. The field work was undertaken in close association with the writer's work on the eastern side and with the general plan of keeping our investigations in harmony. Although no anorthosites are known there, basal gneiss was found practically like that near Lake Champlain and with it is associated igneous granite. Next in succession is crystalline limestone, with some black schists at its base, but serpentinous limestone is practically absent. Above all these is Potsdam sandstone. There is further, a great area of serpentine with red hematite, whose stratigraphic relations remain to be worked out.

*A Geological Reconnoissance in the Vicinity of Gouverneur, N. Y. Trans. N. Y. Acd. Sci. XII. 97, Feb. 23, 1893. A still more important paper by Dr Smyth on the Gabbro contacts in certain townships in St. Lawrence Co. appears in the Bulletin of the Geological Society of America VI. 263.

We hope year by year to add the geology of new townships to those already mapped, until the whole region has been carefully covered. The problems are not easy ones and the many questions require very thorough exploration.

The present contribution is only concerned with Moriah and Westport townships. The field work was done in the summer of 1892, but the writer has been making excursions into the mountains for five years past, and a general introduction is given, based on the data thus gathered.

In the field work efficient assistance was rendered by Mr W. D. Matthew, late Fellow in Geology, Columbia college, and acknowledgments for indispensable aid are here gladly given.

GENERAL TOPOGRAPHY AND GEOLOGY

The country along the western shores of Lake Champlain, is diversified in its contours. While the larger share of the water-front is formed of the later sedimentary strata, and while these do not reach in the townships here described, a height of much over 400 feet above the lake (this is not far from 500 feet above tide) they are either soon succeeded in the region south of Plattsburg, by the gneisses, serpentinous limestones, gabbros and anorthosites* as one goes inland, or else are cut by spurs of the latter which jut out in high ridges to the water itself. The heart of the Adirondacks is formed of the anorthosites and the highest peaks are dome-shaped masses of this rock. But the flanks on all sides consist largely of quartzose gneisses, and more or less of serpentinous limestones, which latter have interbedded with them black hornblendic and pyroxenic schists, and are heavily charged with bunches of silicates. The gneisses attain to less altitudes than the anorthosites, although in

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* The term anorthosite has been long in use among Canadian geologists, as a special name for the rocks of the Norian series, that consist almost entirely of plagioclase. It is derived from the old French word "anorthose," which is a collective term for the triclinic feldspars. While with New York geologists, norite is generally used for the labradorite rocks, yet increasing observation shows that true norites (i. e. containing plagioclase and orthorhombic pyroxene) are not so general as at first supposed, and as gabbro is a much wider term, embracing under it collectively, the gabbros proper, (plagioclase and monoclinic pyroxene), the norites and the anorthosites, it is here employed.

the region about the outlet of Lake George, these are by no means inconsiderable. The anorthosites occur in general throughout a broad belt, which extends from Port Kent and Saranac Lake, southwesterly 60 or 70 miles. The anorthosites do not form a solid belt, as is the general impression, but are found in ridges of northeasterly trend, with gneiss and crystalline limestone almost always appearing in the valleys. Still around Mt Marcy there is a great group of peaks and no gneiss or limestone has been found in between them.

The relief of the country is not entirely due to erosion, although this has been extensive both by water and ice. One can not resist the conviction when viewing the dome-shaped peaks or knobs, that they are in a large part due to block faulting, and the steep cliffs of Adirondack Pass, of Avalanche Pass and many others, confirm the impression. The remarkable shear-zone at Avalanche Lake* is also an additional proof. In the iron mines it has been a frequent experience to find the ore body cut off by a fault where it has been followed under a gulch. What is true for the small depressions is doubtless applicable on a large scale. The mountains repeatedly have a much steeper eastern face than western, as if presenting to the east, old, eroded, fault-scarps. Erosion both by water and ice has contributed its share in modifying contours, so that now the angles are largely rounded off.

Over the whole country is spread the drift, either sorted or unsorted, and no more striking exhibition of it is to be found in the United States, than in the Adirondacks. As a general thing, aside from the mountains, the country is extremely sandy, and often in the valleys shows unmistakable evidence of having once been lake-bottoms,† on whose shores the deltas still remain.

GENERAL STRATIGRAPHY

The stratigraphical relations of the Archean crystalline rocks are obscure as decisive evidence is not easy to procure. In the writer's opinion we have the same succession as in Canada, where the Ottawa Gneiss is the lowest member; the Grenville Series of more schistose rocks and limestones lies over it; and through both these are

*J. F. Kemp. The great Shear-zone at Avalanche Lake. Amer. Jour. Sci. Aug. 1892, p. 109.

†H. Ries. A Pleistocene Lake-bed at Elizabethtown, N. Y. Trans. N. Y Acad. Sci. Nov. 1893.

intruded the gabbros and anorthosites of the Norian. Purely lithological names are here chosen to indicate these and they are subsequently described in what is believed to be their stratigraphical succession. It would not be advisable to discuss at length this problem from the restricted area covered by this report. The difficulties in accurate determination and classification rise from the intrusive nature and vast extent of the Norian. Near the contacts of the undoubted gabbros and anorthosites with the gneisses there are all manner of intermediate types of rock, and even far out from the central masses, we find what are regarded as intrusive sheets of gabbroitic gneiss, which possess the characters of both the gneisses and the gabbros. It is hoped that by the close of the summer of 1894, that the whole of Essex co. will have been gone over once and that then these questions can be more intelligently discussed.

General character of the gneisses. The gneisses give little decisive evidence of their origin, whether they have been derived from sediments or from granitic rocks. Dr Smyth has shown the latter to be true in the township of Gouverneur on the west side, and the remarkable instances later described, by which the massive gabbros have become gneissic, lends much support to this view for many other regions. So far as they have been examined in the townships specially noted here, they are aggregates of quartz, normal orthoclase, microcline, pyroxene, biotite, hornblende and great quantities of microperthitic orthoclase. The last named is rather the most abundant component. It consists of orthoclase crystals so thickly set with blades of albite that at times they almost seem like crystals of banded plagioclase. Such structures are well known in both igneous granites and metamorphic gneisses. At times, specially near the Bessemer iron ores the gneiss becomes a nearly pure mixture of quartz and feldspar.

General characters of the crystalline limestones. The limestones are variable in structure and composition. They are in instances extremely pure carbonate of lime. The quarry opened for the Port Henry furnaces, a quarter of a mile north of Port Henry and east of the Treadway ophicalcite quarry was of this character. But here as elsewhere great bunches of silicates came in and necessitated much waste. It is rare that a bed of any size is met, which is not limited on either side by a black, hornblendic schist or gneiss. The exposed cross-sections show this alteration over and over. Frequently the limestone becomes more magnesian and is full of the altered pyroxene crystals, which give it the well-known green, serpentinous mottlings. This ophicalcite or ophiolite is widely familiar under the name "Moriah marble," by which trade designation it has been placed on the market as an ornamental stone. G. P. Merrill has shown that the serpentine has resulted from the alteration of a white pyroxene.* The limestones have undoubtedly been penetrated by igneous dikes before their metamorphism, for these show in broken fragments with the limestone in between. Whether all the interbedded, black schist was of this character is doubtful.

The limestone series rests on the gneiss and is later in age.

General characters of the rocks of the gabbro family. The gabbros are unquestionably true, igneous rocks of invariable plutonic habit when not rendered more or less gneissic by mountain-making disturbances. Passages of the one into the other can be traced. But even in the purely plutonic or granitoid structures the microscope shows widespread crushings and strainings, the results of dynamic disturbances. The typical anorthosites exhibit nearly pure feldspathic aggregates, specially in the interiors of the Norian mountain ridges. The darker, basic gabbros appear on the skirts of the latter or as more remote outliers. They consist of plagioclase, green monoclinic pyroxene, hypersthene, brown hornblende, titaniferous magnetite, almost invariable garnet and alteration products from all these. Olivine has been discovered but does not appear to be as abundant as in the analogous Canadian exposures described by F. D. Adams.

General characters of the Cambro-Silurian sediments. The earliest of the sediments is the Potsdam sandstone. It rests on all the members of the Laurentian in one place and another and sets up into them as embayments. It reaches a maximum altitude of 500 feet above tide at the first Y of the Mineville railway, out from Port Henry. None other of the sediments rises as high at this. Along the lake shore, the Potsdam is succeeded by the Calciferous Limestone, which appears just north of Port Henry and in Westport. In the latter town we find also the still higher Chazy and Trenton. Less attention was given to these than to the crystalline rocks, although later on some further details and lists of fossils are appended.

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* Proc. U. S. Nat'l Mus. XII, 595, 1890.

Brief description of the map. The accompanying map has been roughly reproduced from advance sheets of the U. S. Geological Survey and from the County Atlas of Essex Co. Only the 100 foot contours are given, to avoid confusion of lines. While not claiming to be more than a general picture of the topography, it does show the elevations with all the accuracy needed for a first draft and as such has been employed. In the subdivision it has been the endeavor to show the areas occupied by the gneiss, the crystalline limestones, the outlying gabbros, the main anorthosite masses, the Potsdam sandstone and the Lower Silurian limestones. Where all rocks are concealed by drift, this has its appropriate sign. Practically all the roads were traversed in Moriah and Westport and a corner of Elizabethtown. The only omitted area is a small one in the extreme northwest of Moriah.* But it is recognized that some outlying gabbro areas may have been overlooked, although all accessible hills were climbed. On many the forest growth and smaller vegetation conceal all exposures. Some gneissoid forms of anorthosites may be included in the areas drawn as gneiss, for as already remarked the intermediate varieties are extremely hard to classify, even when the prominent types are readily recognized. The geological sections will serve to indicate the stratigraphical relations in several places.

OUTLINE OF THE GEOLOGY OF MORIAH

An examination of the accompanying map will show that the gneisses with iron ores make up the greater part of Moriah. There is also a belt of crystalline limestone and black schist in Port Henry and another east of Ensign Pond. Along the Lake Champlain front the Potsdam sandstone is well developed, and the Calciferous shows in one small spot just north of Port Henry. The later sediments although present in the townships on the north and south are absent in Moriah. The anorthosites appear in the southwest and form one especially high hill, Harris Hill, and several others, hardly inferior.

Outlying masses of gabbros are frequent and often strongly gneissoid. A great sheet of gabbro has been cut by drill cores near Mt Bob, Mineville, and an enormous mass of it underlies the Cheever Mine, outcropping all along the lake. Another great sheet, at least 250 ft thick forms the middle (horizontal) third of Bald Peak. Several diabase dikes have also been met. Geological sections accompany the map.

*Since filled from observations made in 1894.

OUTLINE OF THE GEOLOGY OF WESTPORT

The southern part of Westport is mainly gneiss, but the northern is is all anorthosite and gabbro. The anorthosites have an extended development in Split Rock Mountain, and also appear in the southeast. The gabbro is especially important in the central portion. The sedimentary rocks mark the southeastern lake shore. The Potsdam, Calciferous, Chazy and Trenton are all well shown.

PETROGRAPHY

Petrography of the gneisses. There are several varieties of gneiss as shown by the thin sections. These occur, forming the larger portion of what is regarded as the basal series. Gneisses are also found as immediate associates with the undoubted anorthosites, and such are doubtful forms for stratigraphic classification. The endeavor has been made to differentiate the certain and well marked varieties in each series from the intermediate or doubtful ones.

The most characteristic gneiss in the undoubted exposures of the basal series, is formed by an aggregate of quartz and microperthitic orthoclase in largest amount, with which are orthoclase, plagioclase and brown biotite in less degree. The rock shows no features at all remarkable among gneisses. The accompanying figure (Fig. 1)

FIG. 1.—Common biotite-gneiss, Bulwagga Mountain, Moriah. O is orthoclase; M, microperthite; Q, quartz; B, biotite; P, plagioclase.

gives a fair illustration. Occasionally a little garnet is seen, but it is a very light colored or quite colorless one, in contrast with the deeper pink variety of the anorthosite derivatives. It shows also no tendency to characterize the contacts between the dark silicate and the feldspar, as is the case with the anorthosites. It contains quartz inclusions and is thus doubtless a result of metamorphism and of late formation in the history of the rock. A few minute zircons are also seen, and a few grains of magnetite. The gneisses do not show wide spread evidence of dynamic disturbances. While one or two exposures, exhibit the operations of crushing forces, the others from the main ridges are quite without such effects. These latter are far more widely shown by the anorthosites in which they seldom fail. Prof. Smyth after examination of the writer's slides of gneisses states that dynamic effects are much more widely shown by the gneisses on the western side of the mountain.

Along the lake front just above the Cheever dock, and near the great gabbro mass, are several exposures of brecciated gneiss. This seems to have been a micaceous variety originally, but the dark silicate is now altered beyond recognition. Even in the outcrop the rock is visibly crushed into small angular fragments, now recemented, and in the slides this comes out in a still more marked way. Strained fragments of quartz, microperthite and chlorite fill the field. The crush was apparently caused by the intrusion of the neighboring gabbro. A less common variety of gneiss contains, instead of biotite, dirty green hornblende, but all the other features are essentially like the micaceous ones.

In the walls of the non-bessemer ore bodies the gneisses appear to become somewhat richer in dark silicates as the ore is approached. Near the ore the slides show chiefly plagioclase, with abundant green hornblende, green augite, scattered magnetite and titanite.

The lean ore is chiefly mixed with pyroxene, black in the hand specimens, but of a beautiful, emerald green in the sections.

Much black hornblende is also met. Diamond drill cores near Mt Bob, Mineville, have shown as the wall rock of the Bessemer ores a very feldspathic gneiss, with scarcely a trace of a dark silicate. The lean ore is mixed with quartz and feldspar. There is some reason for thinking that this contrast of wall rock may often show itself. Gneisses are also met, practically like those cited as most typical and characteristic; except that they contain green monoclinic pyroxene instead of either hornblende or biotite, or else this in association with hornblende. Their acid character, possessing as they often do, much quartz, causes them to depart from the gabbro types. Especially towards the great masses of gabbro and anorthosite, gneissoid rocks appear that are difficult to classify in their stratigraphical relations. They contain abundant plagioclase, augite, hornblende and deep pink garnets and are probably gneissoid forms of gabbro. Still the relations are much confused. Towards the contacts, pegmatite masses are also met at times of great size, but they are better shown in adjoining towns.

Petrography of the limestones and associated black schists. In thin sections the pure white limestones show little of interest. They contain flakes of graphite, small scales of phlogopite, an occasional apatite crystal and little else. Such occur at the furnace quarry on the ridge just north of Port Henry; below this along the lake shore; and south of the Pilfershire Mine.

The limestone afforded is a very pure calcium carbonate at the first mentioned locality. It has yielded some unique crystals of calcite. Often closely associated with this latter is the mottled serpentinous limestone or ophicalcite. Its best exposures are in the belt along the ridge from a point north of the Cheever Mine and thence southward to the Lee Mine. Quarries have been opened at several points. It outcrops again west of Moriah Center, on the present road to North Hudson, and also on the old and now abandoned highway, nearly due north of Ensign Pond. The rock is a dolomitic marble with copious green mottlings of serpentine. At times these are evenly distributed and a quarter inch across as a maximum, and then the stone is very beautiful, when polished, but such pieces can seldom be obtained of large size or of even texture. The masses of serpentine too often form great blotches, up to several inches across, and mar the appearance of the stone. Small bunches of silicates also appear and afford white pyroxene, brown tourmaline, rose quartz, beautiful crystals of brown hornblende, titanite, etc., as later set forth. Similar serpentinous marbles have in Warren county afforded specimens thought to be Eozoon, as described by A. M. Edwards (Proc. Lyceum Nat. Hist. N. Y., 1870, p. 96). G. P. Merrill has also written of them and is able to show in many cases that the serpentine is secondary after pyroxene, but some forms of serpentine seemed to him not to be referable to this original. In my slides, the core of pyroxene is usually present and the process of alteration is graphically shown. The total effect resembles an altered olivine crystal most closely. In one instance the core proved isotropic and showed no trace of an optic axis. It would appear to be an isometric mineral of quite high index.

The limestone series is accompanied by masses of silicates of all sizes from small bunches up to large lenses. There are also beds of dark schistose rocks that are an inseparable associate, and no extended section was met devoid of them. The small bunches are especially numerous near the contacts with gabbros, and in the Delaware and Hudson railway cuts, two miles and less above Port Henry, along the lake they are very numerous. They assume very fantastic shapes, from the small foldings and stretching of the limestone, and specially resemble snakes. These are here regarded as due in part to the metamorphism of siliceous portions of the original limestone, but still more often to bunches of minerals formed by contact action along the intruded gabbro. They have been afterwards stretched in the general dynamic disturbances which have given rise to such extended foliation. The limestone everywhere gives evidence of being very plastic under these conditions and has wound itself around the inclusions and followed them in many intricate curves.

The inclusions exhibit in thin section, plagioclase and hornblende in greatest amount, and with these phlogopite, scapolite, pyroxene, quartz and probably orthoclase. In larger ones fine crystals of brown tourmaline and light brown hornblende, titanite and rather rudely bounded pyrrhotite appear. All these show characteristic forms. Very similar mixtures are met at Van Artsdalen's quarry near Philadelphia, Penn. as has been cited by the writer (Trans. N. Y. Acad. Sci. Vol. XII. p. 74, Jan. 23, 1893) where they are referred to the contact action of gabbro. They are practically duplicated in the bunches of silicates contained in the marbles on the contact with the hornblende granite of Mount Adam and Eve, Orange co. N. Y. A very complicated and interesting mass of silicates occurs in the cut on the railway from Port Henry to Mineville, just at the grade crossing of the northeastern highway in O8, of the map. Garnet, quartz, tourmaline, phlogopite, and magnetite can be readily recognized, while in the slides, scapolite is abundant and small masses of titanite are everywhere through the somewhat altered phlogopite. Pyrite and apatite also appear. It is an unusually complex bunch of silicates in the limestone series. The dark schistose rocks that penetrate the limestones in instances apparently parallel to the foliation are shown by the thin sections to consist of brown hornblende, rather scarce brown biotite, plagioclase, some pyroxene and magnetite. Either hornblende or augite may fail. The rocks are at times quite gneissic or even massive, as in the great sheet just over the limestone of the abandoned Pease Quarry in the outskirts of Port Henry. In thin sections these more massive sheets bear the strongest resemblance to the metamorposed dikes from the Hudson River shore above West Point, described by the writer in the American Naturalist for August 1888. There is much that leads one to regard them as intruded dikes and sheets, doubtless contemporary with the gabbro, and offshoots from its magma, that have afterwards become foliated by metamorphism. Such a dike from the limestone quarry near the Pilfershire Mine is shown in the accompanying reproduction of a photograph. It is clearly a broken dike, between whose separated fragments the limestone has been forced. The mineralogy and structure of this is precisely like the gneissic ones above referred to, but less certainty is felt that the more schistose ones may not be metamorphosed sediments. Very similar beds occur in the limestones of Gouverneur, St Lawrence co. where they are regarded by C. H. Smyth, jr as altered sediments, (Trans. N. Y. Acad. Sci. XII p. 102 Feb. 23, 1893) and where they are far west of any exposure of gabbro. Their noticeable parallel arrangement in the limestone makes it seem extraordinary that dikes should have been so regular unless the apparent bedding of schists and limestones is due to mountain making processes. One or two beds of light grey gneiss with graphite and sillimanite were met with in the limestone series. One occurs along the highway south of the Pilfershire mine, N8 on the general map. It may represent a silicious bed, deposited in with the limestones.

Petrography of the gabbros and anorthosites. In the high knobs of Mount Harris, in the western portion of Moriah, near Ensign Pond, and also in the northern part of Westport, the

Plate I — View in a quarry of white crystalline limest ne, near the Pilfershire Mine, Moriah Township The limestone has been penetrated by a dark dike of gabbro which has been subsequently broken by dynamic disturbance. The limestone has been forced in between the sundered ends of the dike. The view is intended to illustrate the plasticity of limestone under pressure.

anorthosites make up the country. The most massive variety consists of large, bluish labradorite crystals, up to an inch and a half in length, with almost no traces of dark silicates. The rock is nearly pure feldspar, but it has been subjected to powerful dynamic disturbances and now exhibits a mass of larger nucleal fragments, often of considerable size, surrounded by fine breccias of the same. The specific gravity of the large pieces, free from garnets, lies between 2.65 and 2.71, proving them to be labradorite. The thin sections bring out the crushed condition still more strongly. Even small brecciated cracks penetrate the larger pieces. The comminuted feldspar is more or less altered, and often presents a fibrous or scaly mass of sericite. Other darker varieties from this western border of Moriah, contain bisilicates and tend to assume gneissoid forms, from the alignment of these, in continuous bands. The plagioclase is much smaller than in the first mentioned variety. The dark silicates are green monoclinic pyroxene, deep brown, almost opaque hornblende, and less common hypersthene, in about this order of abundance. There is also more or less titaniferous magnetite. The two pyroxenes are evidently original minerals and much of the brown hornblende is also, but there are cases, later described where it forms one of the zones in the reactionary rims, which give the impression, that some of it may be secondary. Deep pink garnets are universal and often associated in a most intimate way with the pyroxene. The same cracks pierce both minerals, and though the line of demarcation is sharp, it makes the observer suspect that the garnet has resulted from the pyroxene. The reactionary rims of garnet give some added ground for this suspicion. But garnet often appears alone with no bisilicate near it, and in such cases it is probably an original mineral, as garnet often occurs in this relation in plutonic rocks. A microscopic drawing of a typical anorthosite is given by the author in a paper in the Amer. Jour. Sci. for Aug. 1892, p. 111, Fig. 2.

Generally outlying from the main exposures of anorthosites and separated from them by intervening gneiss are the areas of rocks, marked gabbro on the map. The gabbros exhibit massive, coarsely banded and very thinly laminated forms, and in several places the unbroken transition can be followed from one into the other.

In general, the massive gabbro makes the impression of a dark rock upon the observer and this is due to the abundance of magnetite grains and dark silicates. The minerals present are plagioclase, green monoclinic augite, brown hornblende, hypersthene, garnet, titaniferous magnetite and titanite. The more important ones of these are shown in the accompanying figure (Fig. 2) which is a little

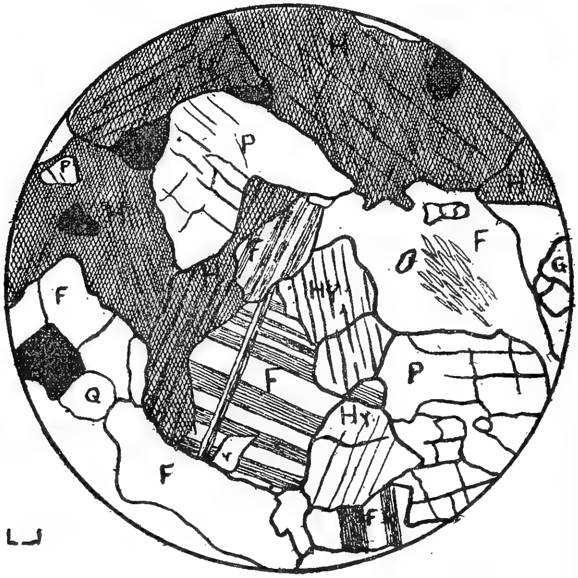

FIG. 2.—Gabbro without reaction rims—near Ensign Pond, Moriah. F is labradorite; P, augite; Hy, hypersthene; H, hornblende; Q, quartz; G, garnet; M, magnetite.

richer in hornblende than the average. The rock is blotched with light green from the altered feldspar, and has faint, pink streaks running through it, due to the garnets. These latter give it a peculiar reddish cast that is very characteristic. The feldspars are now largely altered to saussuritic matter, but when not too far gone they have a broad, lath-shaped outline, more or less idiomorphic, and are rather coarsely twinned. At times they are filled with minute dots or crystals of brightly polarizing character which are so small as not to be easily recognized, but they are probably pyroxene. Less commonly, polygonal scales of a brown color and in geometrical arrangement are to be seen. These latter are generally regarded when seen in other exposures as a micaceous variety of ilmenite. The successive zones of grains of garnet and brown hornblende between the dark silicates and the feldspar, or surrounding the magnetite are extremely interesting. They have been described and figured by the writer in the Bulletin of the Geol. Soc. of Amer.—V. 218, and are regarded as due to the reaction of the bisilicate or other basic mineral and the feldspar on each other. Olivine is found in the gabbros on the lake shore north of Port Henry, and in the walls of the Split Rock Mine—on Split Rock Mountain, Westport.

In the gneissoid varieties of gabbro, hornblende appears in notable preponderance, and in the extreme cases, of very thin lamination it is the only dark silicate present. It is quite certainly of secondary origin.

Petrography of the palaeozoic sediments. The microscope yields little in addition to the macroscopic examination. The Potsdam sandstone shows considerable calcite, in small rhombs mingled with the quartz grains. The Calciferous cherty limestone consists of fine grained calcite crystals and the chert is devoid of fossil organisms of any sort. The others were not ground in sections.

Dikes. These two townships are not as prolific in dikes as others to the north. Several have been noted recently by Kemp and Marsters* and determined with the microscope. They are all diabase or closely related types. There is a bunch of dikes on Mill brook, just west of the lake in Port Henry. One or two cut the ore beds at Mineville. A fine one is in a hill a short distance northeast of Moriah Corners, (No. 56 in O5 of map) where it has been mined out for an ore body. Several others are exposed along the lake shore a mile or two north of Westport,—and others appear in the old iron mines on the west side of the Split Rock ridge. Porphyries, tho' known in the next township north, have not been met.

GENERAL CONCLUSIONS

The two older series of rocks, the gneisses and the crystalline limestones were formed before the intrusion of the anorthosites and gabbros. These latter came up as great plutonic masses and as offsetting sheets penetrating the older rocks, and contributing to their metamorphism. Much faulting and folding ensued, by which the latest intrusions became involved in the earlier rocks in very

* The trap dikes of the Lake Champlain Valley. Bulletin 107, U. S. Geol. Survey.

puzzling ways, and by which they received brecciated and gneissoid structures. This metamorphosing process then ceased in pre-Cambrian time and on the flanks of the old crystallines were laid down the Potsdam sandstone and the Silurian shales and limestones, all of which show comparatively unaltered forms and not greatly disturbed positions. Their dips are low, mostly to the north, and beyond comparatively slight faulting they have not been participants in heavy movements. What disturbance appears is probably to be attributed to the upheaval of the Green Mountains.

There is evidence in neighboring townships which indicates that the Cambro-Silurian sediments formerly reached well up into the valleys, at least in the case of the Potsdam, but that they have been since extensively eroded.

IRON ORES

The ores are all magnetite, but as already outlined are of two varieties. The one that is useful and merchantable to-day is practically free from titanium. Variable amounts of phosphorus and sulphur, occasionally reaching high percentages are present. These ores seem to be uniformly associated with the older gneisses. The second variety contains titanium, often in very considerable amount. The limestones are devoid of ore in these townships. In Moriah there are the following mines, all of which have been practically worked except the last named. They are all non-titaniferous. The Mineville Group; the Barton Hill Group; the Cheever Group; the Pilfershire and Pease Pits; the Lee Mine; and the Coot Hill Mine. In Westport there are the following which are all titaniferous, except perhaps the first named. The Nichols Pond Mines; the Split Rock Mines; and the Ledge Hill Mines. None of these latter have been worked in years.

The general merchantable ore in Moriah is non-bessemer, for only the mines on Barton Hill furnish bessemer ores. The following table illustrates their composition. The Lee mine is quite sulphurous. The Pilfershire and Pease pits have been long abandoned. The Coot Hill mines have no serious showing of ore and were an ill-advised enterprise; and the mine put down on the county atlas as occurring north of Crowfoot pond is purely imaginary. The outcrop of gabbro or gabbro-gneiss near Mr J. Lewis's house, Moriah,

PLATE II

PANORAMA OF MINEVILLE, N. Y.
Looking southeast. Lake Champlain in the distance.

and near some prospects that he has opened make it seem probable that the ore will prove titaniferous, but no analyses are available. The Barton Hill mines and their prolongation, the Fisher Hill and Burt Lot openings are bessemer, and some lots have been found surprisingly low in phosphorus. They occur at a higher horizon in the gneisses than the Mineville group as will be later shown by sections.

TABLE OF ANALYSES

	Bessemer Ores—		Non-Bessemer Ores—				
Mine	Barton Hill.	Fisher Hill	Welch Shaft	Miller.	Old Bed.	"21"	Cook Shaft
Authority	Birkinbine.	Tenth Census.	do	do	do	do	do
Fe	65 12	46.96	57.71	60.54	62.64	62 10	62.80
P	0 0289	0.03	1.266	0.830	0.908	1.198	0 870
TiO_2	....	present.	present.	present	present	present	present.

			Titaniferous Ore.			
Mine	Cheever.	Lee.	Split Rock	do	do	Cook Shaft—Humbug Vein—
Authority	Tenth Census.	do.	....	....	...	F. S. Witherbee.
Fe	63.86	45 01	44 77	32 59	40 42	
P	0 680	0 047	....			
TiO_2	present.	Absent	13.15	14.70	16 37	Circa 20.

In the octahedral ore of the Lovers Hole Mine, T. R. Woodbridge found with iron 68.58 and phosphorus .004, titanic oxide .147. Thus where found in these ores it is in very minute amount.

The beds are often disturbed by small faults and very frequently these are occasioned by the intrusion of a trap dike. In fact hardly a mine has failed to reveal these. Profounder faults may also intervene and cut off the ore entirely as at the Cheever mine.

The ores in the richest forms are granular. They have for a gangue, pyroxene as a general thing, and in the thin sections of lean ores this is seen to be of a brilliant emerald green hue, though black in the thicker masses. Grains of apatite are at times very abundant, and are present in most of the mines. Pyrite is notable in a few. Bessemer ores are afforded by several very large openings.

GENERAL FEATURES OF THE TITANIFEROUS ORES.

The titaniferous ores are in true igneous gabbro, which has been more or less metamorphosed and to which a foliation or banding has been imparted by pressure. The ore-bodies are thus flattened parallel to the banding, but their general shape, if indeed they have any uniformity, is far less clearly understood than that of the ores in gneiss as they have not yet been much mined.

GENERAL FEATURES OF THE NON-TITANIFEROUS MAGNETITE ORE-BODIES

The common form assumed by non-titaniferous ore bodies, and the one usually associated with gneisses for wall-rock, is that of a bed or flattened lense, or pod, which lies parallel to the general foliation. They show no traces of having filled a cavity, but unless regarded as segregated veins, i. e. as having gathered along the bedding by the concentration of iron oxide from the walls, after the manner of a concretion on a grand scale, they must be considered true beds. For the smaller ore bodies in the two towns here described, these general relations and shapes hold good but for the great ore-bodies at Mineville, it is difficult to see how any folding and contortion of simple beds can explain the peculiar and irregular shapes which are later illustrated. They are decidedly abnormal. In the writer's estimation no segregative agency strictly so called could have occasioned them and some other method of origin must be invoked. The true lenses pinch, swell and feather out at the boundaries. They often fork when wedge-shaped masses of the walls come in. They are often distributed along a general horizon in the gneiss, although at times several beds, one over the other are afforded. The long axis of the ore-body does not run straight down on the dip, but diagonally, and this inclination is called the pitch in distinction to the true dip. The rule already formulated in New Jersey also holds good in the Adirondacks, that with a westerly dip the pitch is to the southwest, and with an easterly dip the pitch is northeast.

DETAILED GEOLOGY OF THE IRON ORES

The Mineville and Barton Hill Groups. The topography of this district may be seen from the accompanying map. As already stated the Barton Hill group occurs at a higher horizon in the gneisses than the Mineville group, but just what it is in feet is hard to say, for there is a fold or crumpling between. As shown by the table the ores are contrasted in composition, the lower series being much higher in phosphorus. Almost no sulphur occurs in either, and titanium is insignificant.

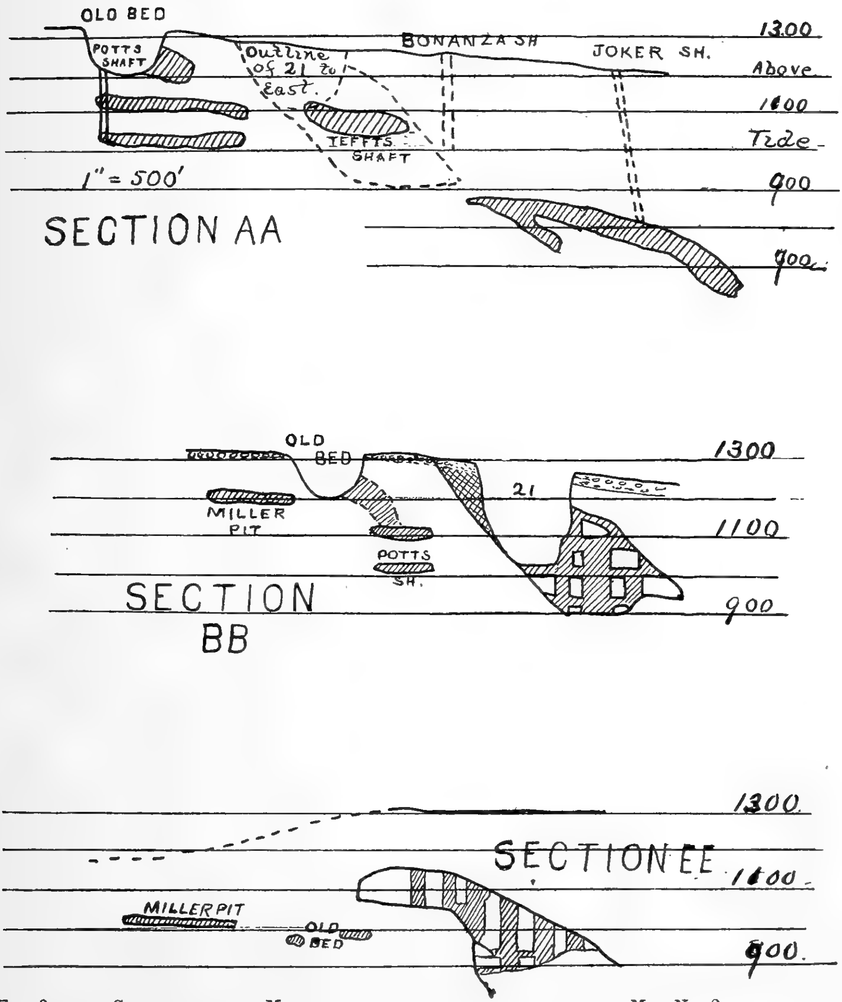

FIG. 3. SECTIONS OF THE MINEVILLE ORE-BODIES CORRESPONDING TO MAP NO. 2.

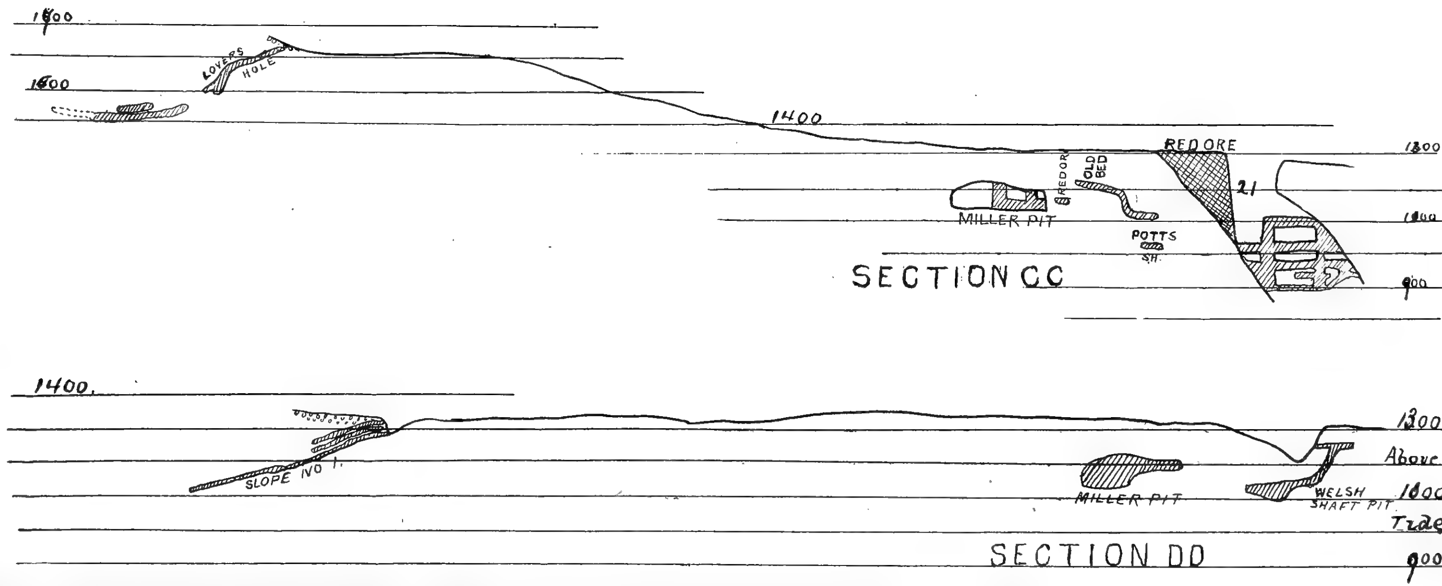

Fig. 4. Sections of Mineville ore-bodies corresponding to Map No. 2.

The relations of the Mineville ore bodies have always proved confusing, but it is hoped that the accompanying sections may help to throw some light on them. Referring to the plan of the workings as shown on the map, it will be seen that the axial direction of all the ore bodies is southwest and that they lie in two or three parallel ranges. There are irregularities entering in that upset the uniformity of this somewhat, but in general it holds. There are five distinct mines. One is based on the bed, tapped by the Brinsmade and Welch shafts, and is generally called the Welch shaft bed. This dips westward at a varying angle that is nearly vertical at the north end and about 45° at the Welch shaft. In its southern part it runs in under the Old Bed (called in earlier days the Sanford) but a drift has been run through the intervening rock. The widest breast is about 50′ from wall to wall but at the northern end it pinches to an unworkable thinness. This bed appears in Section DD.

Lying over the last but also extending further south is the Old Bed. Old Bed has an axis that runs about S. 30 W. The pitch is quite flat being but 20°. The dip in the eastern workings is much more southerly than the Welch Shaft bed and on the western side it becomes more westerly. The Old Bed is quite complex in form and structure. It starts from the surface with a low dip, as already mentioned, but soon rolls over more and more steeply until it connects with a lower lying ore-body, which sets back under its upper portion, and is called the Potts Shaft bed, because opened by a shaft of that name. This same shaft tapped a still lower lying and parallel bed with which Old Bed also connects down the pitch. They are shown in Sections AA, BB, and CC. The structure can be best summed up, perhaps, as a triple forking of an original bed. The Old Bed, as do also the Miller and "21," thickens very much from a comparatively thin outcrop to a much greater section lower down. The mining has shown breasts varying from 20 to 125 feet. Mr Putnam of the Tenth Census referred this to the buckling of a sigmoid fold. He makes however no mention of the lower Potts shaft Bed and when this is included, the forking original seems more probable. The ore next the footwall in both Old Bed and 21 is specially charged with apatite. Indeed the workings in 1852 on the former were begun in order to procure phosphates for fertilizers. (W. P. Blake, Trans. Amer. Inst. Min. Eng. Balto. Meeting 1892.) Considerable quantities have 10% or more of this mineral. This variety is called "red ore" and is of course avoided. This especial richness in apatite is interesting when compared with the investigations of D. H. Browne, on the distribution of phosphorus in the Ludington mine, Menominee District, Mich. (Trans. Amer. Inst. Min. Eng. XVII 616). Between the Old Bed and the Miller, there is a long pod of this red ore, which is separated from the Miller by a trap dike for its greatest part, but which runs into the Miller at its northern end.

The Miller bed has an axis that runs about S. 30 W, but it pitches at a higher angle than the Old Bed and in the northerly portion has a quite steep westerly dip, corresponding closely with the Welch Shaft bed. The inclination of the skipway is about 40°. To the southwest along the line of the axis it lies quite flat from east to west, but it has one notably steep drop on the pitch. This is indicated by the different altitudes of the several sections of this bed. Thus from DD to EE, it has pitched 200 feet, and a large part of this is in the one roll just mentioned. The breasts varied from 10 to 100 feet.

Mine 21 is the largest of all and has a magnificent ore body, 200–300 feet perpendicularly between walls. It has the general northwest course for its axis, while the pitch is not to be easily, if at all, determined. The dip varies from being nearly south and very flat in the Tefft shaft extension to an increasing steepness around to the eastward and to an increasingly eastward dip. The skipways, which are nearly parallel to the footwall, run down at about 60°. The ore body seems to lie on the southeast side of a doming anticline.

The fifth bed or mine is the Bonanza-Joker, lying south of the others, and not outcropping. It is an extension of "21," for the workings are now approaching each other and a hole has been bored through. (Section AA.) The axis of the Bonanza runs southwest as do the others. The bed is a double one, as it splits between the Bonanza and Joker shafts into two, over and under. A great horse of rock comes in, but each portion forms a noble ore body, the upper being 100′ thick and the lower 65′ as mined.

Still another thin ore body has been lately shown by the diamond drill south of the Joker, and a hole in the footwall of the Joker has revealed a vast additional thickness lying lower. The map with

Plate III

Skipway into Mine 21, Mineville, N. Y.

PLATE IV.

BURT LOT MINES NORTH OF BARTON HILL.
The two beds of ore are indicated by the skipways.

the outlines of the workings which are reduced from the surveys of Mr McKee, the engineer of the two companies, gives a clearer idea of the relations in plan than any description could and also of the surface topography. The sections will further afford a picture of the relation in elevation. They have been compiled from the most recent mine surveys (1893), but aid has been obtained from the drawings of Mr. Putnam (10th Census, v. 10, plate 27, p. 108) and from personal notes on the surface and underground. The important structural features are these: The westerly dip of the north ends of Welch shaft and Miller beds; the flat and more southerly dip of the Old Bed, of its several divisions and of the Miller; the southerly and easterly dip of "21." These facts indicate an anticline with a doming development in the easterly extension of "21." The forking of the bed makes it possible to have several of them one over the other. The Bonanza-Joker bed lies not far from the axis of this anticline on its southerly pitching crest, as does also Old Bed. The general southwest and somewhat parallel arrangement of all the beds or lenses is strongly shown in the map. Before the folding took place they doubtless all formed horizontal and parallel-tending, pod-shaped masses, and were afterwards heaved into their present position with some attendant faulting. The wall rock of "21," and some distance from the pit, is a light colored gneiss, consisting of microperthitic orthoclase, green augite, a little quartz and magnetite. The same rock also forms the summit of Barton Hill. It may be mentioned that the usual gneiss of the oldest formation contains biotite and some quartz but near the ores it becomes augitic. Microperthite is present in both. The strike of the gneiss is very irregular. Between the Miller Pit and Barton Hill readings were obtained varying from N. 10 E. to N. 85 E. with in one case N 60 W. The general average is about northeast. Section CC is drawn nearly across this strike. As indicated in the section the dip toward the Miller Pit is westerly but it changes to easterly and again toward the Barton Hill to the normal westerly.

In variety of minerals the mines are not prolific. Many years ago James Hall obtained from the Old Bed (called also the Sanford Bed) an unusually fine crystal of allanite which has been figured and described by E. S. Dana, (Amer. Jour. Sci. June 1884. 479).

In the office of Witherbee, Sherman & Co., at Mineville, there are slabs with calcite, and one superb octahedron of magnetite, that is nearly symmetrical and perfect. A few quartz crystals also occur. The Barton Hill mines as later noted yield a greater variety.

The Barton Hill Group. The highest outcrop of ore at Barton Hill is as much as 400′ above the highest of the Mineville Group. Measured across the strike (Section CC) it is about 300′ between corresponding points, and there is at least 500′ of rock section in the interval. The dips show a fold to intervene, and allowing for this the distance 500′ is given. It is also possible that there is faulting and this is suggested by the steep slope of Barton Hill, resembling as it does a fault-scarp. The outcrop of the beds at Barton Hill is long, being over $\frac{3}{4}$ of a mile. It is shaded in on the map. The general southeasterly pitch for the axes of the lenses is also well shown by the map and is notably parallel to those of the Mineville group.

This belt has been exploited over nearly the whole of the outcrop but all the output is not equally good. The deepest workings are at the New Bed where the slope has followed the chute down over 2000 ft. The beds are not as thick as in the Mineville Group. They range about 8′, with 20′ as a maximum, and are quite irregular. In places three beds have been met, as at the New Bed. The Lovers Hole exposed but two but one was very thin, (See Figure in paper by Mr John Birkinbine, Crystalline Magnetite in Port Henry Mines, Trans. Amer. Inst. Min. Eng. Feb. 190. Vol. XVIII), and the other thickened to a large body of extraordinarily pure and rich ore. 40,000 tons of the run of the mine gave 68.6 Fe. As the map shows, the workings are quite irregular all along the belt and much exploration is necessary to keep them well in hand. The continuation to the north appears to be broken beyond the Little Orchard Slope, and a barren piece comes in. The ore, doubtless from the same belt, reappears in the Fisher Hill Mines and their northerly extension, the Burt Lot. In the last named there are two beds separated by about 50 ft. vertical thickness of rock, although much more across the surface from slope to slope, as the dips are flat. The dip at Fisher Hill is about 25° southwest as measured on the skipway. This flattens out in the northerly openings to 22°.

In the Burt Lot Mines the dip is about 25°. These latter are in Elizabethtown. The break between Barton Hill and Fisher Hill may be due to a fault or eroded fold, but the lack of outcrops pre-

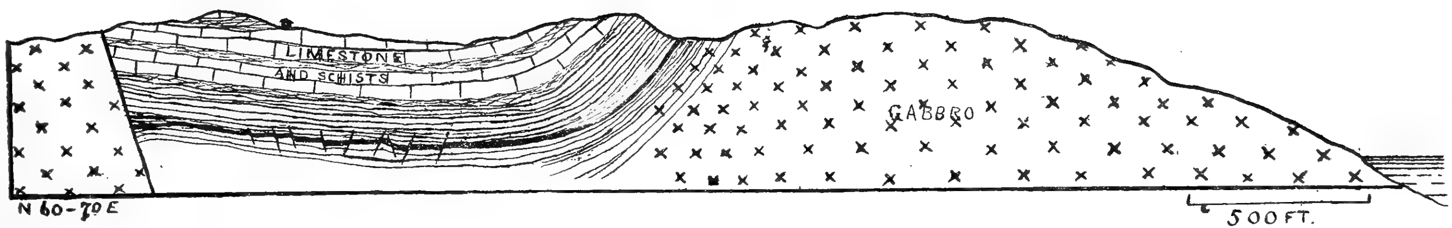

FIG. 5. CROSS-SECTION OF THE CHEEVER. MINE

vents observation. The belt continues beyond the New Bed to the south, as recent drilling has tapped it.

In this section, the wall rock near the ore at the Lovers Hole, is seen to contain plagioclase and orthoclase, brown biotite, green hornblende, titanite, zircon and magnetite and is an ordinary quartzless gneiss. A specimen from the top of Barton Hill was shown by the same form of examination to contain quartz, microperthitic orthoclase in great amount, diallage and hornblende, being very like the rock mentioned above as occurring near "21." These rocks are all gneisses that often but not always become more basic toward the ore body. Sections from the wall rock at Fisher Hill and the Burt Lot mines are practically the same.

Along with the ore or near it in the wall rock, are at times masses of very hornblendic rock. When cracked open these occasionally show small zircons, apatites and very fair titanite crystals.

At the South Pit some excellent red garnets up to 1″ in diameter have been brought to light, in talcose or chloritic material. They were very brittle and crumbled with slight rubbing.

The Lovers Hole pit has also yielded considerable fluorite, which, of white, red and green colors, gave rather fine specimens. It had more or less magnetite disseminated through it. It was probably from a small vein-filling or in part a replacement of the gneiss.

Fine cleavage pieces of plagioclase are also to be had on the dumps. The beautifully striated surfaces contain at times several square inches.

The Pilfershire and Pease Pits. These are now abandoned. They lie along the westerly foot of the range of gneissic hills that separate Mineville and Moriah Center from the lake. Both mines are now full of water. They strike a little west of north and dip 50° to 60° west. The gneiss just to the south of them contains quartz, microcline, orthoclase, very little plagioclase, emerald green pyroxene, and a little magnetite. The lean ore in thin section exhibits magnetite, light green pyroxene and apatite. As elsewhere the gneiss is more basic near the ore.

The Lee Mine. This is just back of Port Henry and in gneiss immediately west of the ophicalcite exposures. The outcrop of ore is in a small steep hill on the west side of the fault figured on the map. The strike at the main opening is west of north and the dip at the skipway is 19° W. Mr Putnam (10th Census Vol. X. p. 115) states that the ore is cut off on the north by a trap dike. The ore is pyritous and is no longer mined. The breast was 8–10 ft. The hanging wall is gneiss and contains microperthitic orthoclase, quartz, green biotite, magnetite and pyrite.

The Cheever Mine. A general section of the Cheever ore body is here given. The mine is situated about two miles north of Port Henry, but the ore belt is prolonged about a mile further in a northerly direction, the Goff mine being in this portion. The Cheever is one of the most interesting of all in its geology, and for this reason the geological section has been prepared based on the outline of the ore body given by Mr Putnam (10th Census Vol. X. p. 113). The upper topography is reproduced from the 20 ft. contour map of the U. S. Geol. Survey and from sketches made on the ground. The section shows that the ore has over it gray feldspathic gneiss 25′ containing green pyroxene, plagioclase, quartz and orthoclase. The lean ore consists of magnetite with some green pyroxene and some plagioclase.

The next 15′ is hornblendic gneiss, containing quartz, microperthite, plagioclase, orthoclase, brown hornblende, green pyroxene, garnet and apatite. Fifty yards from the ore is gray gneiss again, with quartz, microperthitic orthoclase, brown biotite, very little plagioclase, and magnetite. Over this lies black hornblendic schist and white crystalline limestone. Under the ore is gneiss again but 50 feet east of the ore body, foliated gabbro appears consisting of bastite, brown hornblende, and plagioclase represented by a saussuritic alteration product. The bastite is a light yellow, feebly pleochroic, brightly polarizing mineral, very fibrous and with extinctions parallel to the fibres. In the longitudinal sections it shows the trace of a biaxial figure, but in one transverse section a rectangular cleavage still remained with diagonal extinctions. This would suggest diallage as the original of it. A few garnets are also present. A little further the gabbro becomes massive, and contains hypersthene, brown hornblende, magnetite, much garnet and shattered and saussuritic plagioclase. The gabbro extends to the lake. To the west the ore is cut off by a fault, the underlying gabbro being heaved up along the west side. The ore is also cut by several trap dikes all of the diabase type, which upset it short distances. The ore body is not one single continuous bed, but splits at times into two from incoming horses.

It is much narrower than long, and has the usual lenticular cross-section forming a great pod or elongated lense, with its axis running about S. 60 W, thus showing the invariable southwest pitch with a westerly dip. Two cross sections are given by Putnam, who made them underground. At my visit the mine was full of water. Borings across the gulch to the south have shown a thin bed at 300′ depth. The geology of this ore body presents points of interest not shown by others. At first sight it might appear like a great contact deposit near the junction of gabbro and limestone, but so much gneiss intervenes that difficulties are in the way of this view, and the shape, structure, associates and character of the ore all connect it with the usual lenses in the gneiss. It lies however in the gneiss near the overlying limestone, and also near the intruded gabbro. It differs from the ores in the gabbro by having but slight traces of titanic oxide. The general composition is very much like that of the Mineville ores.

Other Mines in Moriah

The county atlas mentions an opening near the house of James Lewis, and inquiry of Mr Lewis elicited the fact that he believes that he has opened a large ore body. I did not visit the openings, but specimens gathered from the hill in the rear of his house are gneissoid gabbro, and if in these rocks the ore would prove titaniferous. There is also an old series of prospect holes two miles or so south of Lewis's. These show traces of ore but nothing serious. The wall is gneiss and consists of orthoclase, green pyroxene, much titanite and a little hornblende. A small prospect has been ill-advisedly run in on a fine diabase dike, on the east side of a hill a mile west of Moriah Center. A considerable plant has been set up at the Coat Hill Mines, on Bullwagga Mtn. Both walls and ore consist of crushed quartzes, chloritic matter, rotten feldspar and scattered magnetite grains. There are no surface indications of any ore body of serious moment.

General Remarks. The present state of the iron business and the small prices at which Lake Superior ores are now sold in the east offer slight encouragement to new ventures. The productive ones do however occur along common lines of strike, and any prospecting would best be done with these as ranges. Disturbances of strike and dip should however be looked for with care, as in such a broken region, they are common and might throw one off the track. As already mentioned cross gulches are often caused by faults.

Iron Mines of Westport. There are at present no producing mines in Westport, and such as have been opened have been idle for many years. Except perhaps the second bed at Nichols Pond all that we visited were clearly in the gabbro series and gave thus every reason to infer that they are titaniferous and such analyses as have been available, have carried out this impression.

The Nichols Pond Mines. These are situated high up on a mountainous ridge, above Lake Champlain, and just north of Nichols Pond. There are two beds ; the southerly one is in gneissic gabbro, and is about 9′ thick. It strikes nearly East and West, and dips south about 80°. The ore is magnetite mixed with hornblende and is lean. The second bed lies more to the north, and shows the following section, with a strike and dip like the last. 1, Hanging wall gneiss. 2, Ore 12′–15′, shot ore consisting of magnetite and quartz. 3, Lean Ore not worth separating 20′, but of same general character as 2. 4, Compact feldspathic rock, 15′. 5, Lean shot ore and quartz same character as 2, not worked. 6 Foot wall coarse gneiss. There was a large separator in operation some 25 years ago at Nichols Pond, and a tramway ballasted with tailings runs down to the highway to the eastward. As stated by Professor Smock, (Bull. N. Y. State Mus. No. 7. p. 36) these mines are in lots 166 and 168 of the Iron Ore Tract and on Campbell Hill.

The Ledge Hill Mines. This name may not be the most common or correct one, but it is the one given us in Westport. The mines are near the summit of a hill, two miles west of Westport and are several hundred feet above Lake Champlain. They are in gabbro of a gneissic habit, but at times quite massive at points not far from the ore. There are two ore bodies. The ore is richest in the middle and becomes lean towards the walls, with abundant hornblende and garnets. In the lowest opening there are 4′–6′ of richest ore. Fifty feet higher up there is another opening on the same ore. The strike is east of north and the dip is high to the west. A little to the east is a second ore body, opened by a cut about 6′ feet wide at the bottom. The walls are gabbro. The mines are in lot 163 of the Iron Ore Tract.

The Split Rock Mines. These are opened in Split Rock

Mtn., about 100 feet above Lake Champlain, and show very considerable excavations, which are practically dry, as the situation for mining is very convenient. The ore is 10′ thick, strikes N. 70–80° E. and dips 50° south. Gabbro forms the walls right up to the ore on both sides. It is the metamorphosed variety with the copious reaction runs of garnets. The writer was told that there is another opening to the south. There is a separator on a level with the lake, and above the mines, in a terrace in a break in the hills, are the old boarding houses. From this terrace there is a most superb view of the lake and the Green Mountains. The mine is just across from Fort Cassin. The analysis of the ores given in the opening table shows that they contain from 13–16 TiO_2 with 32.5 to 44.7 Fe.

GENERAL REMARKS

There seems little if any prospect of profitable mines in Westport in the future. Those ores that are reasonably near the lake are certainly titaniferous and cannot be used under the present calculation of blast furnace slags and mixtures. The non-titaniferous ores which may be in the western limits of the town, are extremely inaccessible if indeed in any quantity.

In their scientific relations the titaniferous ores are of great interest. They invariably occur in dark, basic gabbros and in such relations as to make the inference unavoidable, that they are excessively ferruginous or basic, portions of the original igneous magma. There is no sharp line of demarcation between ore and wall but a gradual passage of one into the other, although in a short space. We are coming to recognize titaniferous magnetites in these relations in many parts of the world, and Wadsworth* in this country, Derby† in Brazil, and Vogt‡ in Sweden have already called attention to such.

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* M. E. Wadsworth. The Iron Ore or Peridotite of Mine Hill, Cumberland, R. I. Bull. Min. Comp. Zool. 1880. VII.

† O. A. Derby. Magnetite Ore Districts of Jacupiranga and Ipanema. Sao Paulo, Brazil. Amer. Jour. Sci., April, 1891. 311.

‡ J. H. L. Vogt. Bildung von Erzlagerstätten durch Differentiations-processe in basischen Eruptivmagmata; Zeitschrift für praktische Geologie, I. pp 4, 125, 257. This paper appears in its completest and latest form in the reference given, although the conclusions had been previously published elsewhere.

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BY J. F. KEMP

New York State Museum

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