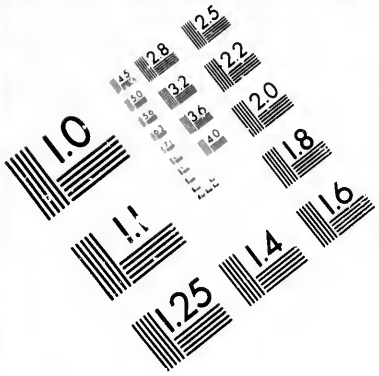


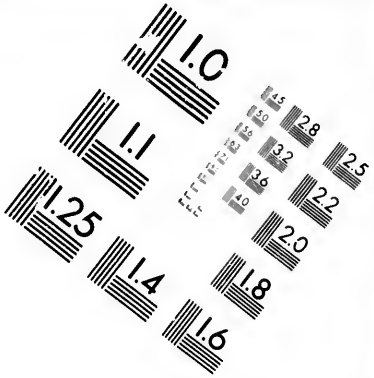
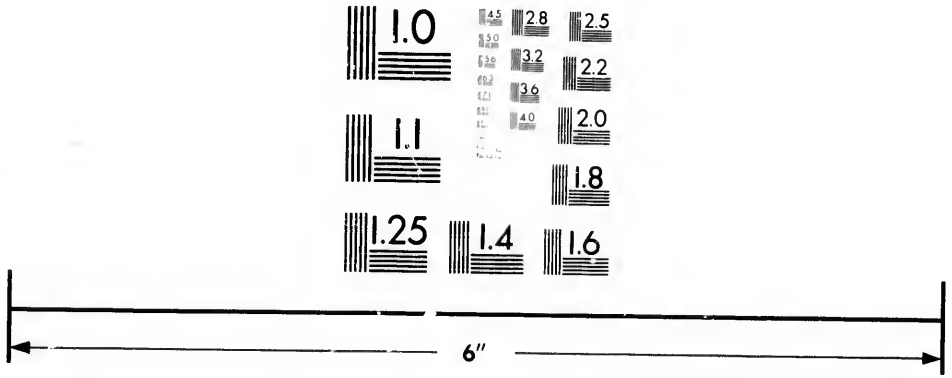
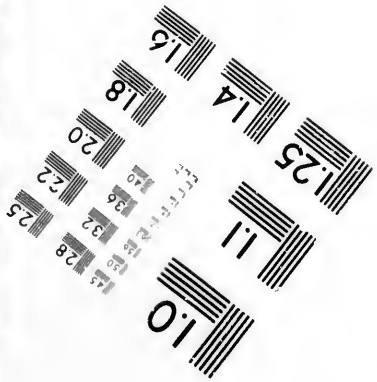
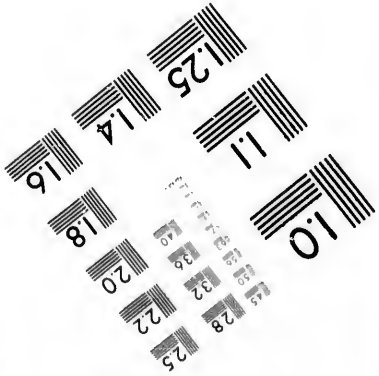


IMAGE EVALUATION TEST TARGET (MT-3)







Photographic Sciences Corporation

23 WEST MAIN STREET
WEBSTER, N.Y. 14580
(716) 872-4503

CIHM/ICMH Microfiche Series.

CIHM/ICMH Collection de microfiches.

Canadian Institute for Historical Microreproductions

Institut canadien de microreproductions historiques

1980

Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [x] Coloured covers/
  Couverture de couleur
- [ ] Covers damaged/
  Couverture endommagée
- [ ] Covers restored and/or laminated/
  Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/
  Le titre de couverture manque
- [ ] Coloured maps/
  Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/
  Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/
  Planches et/ou illustrations en couleur
- [ ] Bound with other material/
  Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/
  La reliure serrée peut causer de l'ombre ou de la distortion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/
  Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments:/
  Commentaires supplémentaires:

- [ ] Coloured pages/
  Pages de couleur
- [ ] Pages damaged/
  Pages endommagées
- [ ] Pages restored and/or laminated/
  Pages restaurées et/ou pelliculées
- [ ] Pages discoloured, stained or foxed/
  Pages décolorées, tachetées ou piquées
- [ ] Pages detached/
  Pages détachées
- [ ] Showthrough/
  Transparence
- [ ] Quality of print varies/
  Qualité inégale de l'impression
- [ ] Includes supplementary material/
  Comprend du matériel supplémentaire
- [ ] Only edition available/
  Seule édition disponible
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/
  Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

- [x] This item is filmed at the reduction ratio checked below/
  Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
					✓						

The copy filmed here has been reproduced thanks to the generosity of:

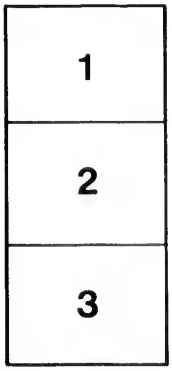
National Library of Canada

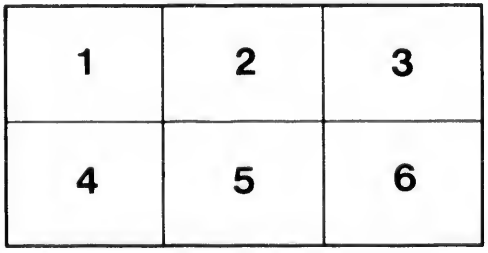
The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol → (meaning "CONTINUED"), or the symbol ▽ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:





L'exemplaire filmé fut reproduit grâce à la générosité de:

Bibliothèque nationale du Canada

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole → signifie "A SUIVRE", le symbole ▽ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

32X

THE

HISTORY OF SOME PRE-CAMBRIAN ROCKS IN AMERICA AND EUROPE.

BY

T. STERRY HUNT, LL.D., F.R.S.

Robt Bell.

THE HISTORY OF SOME PRE-CAMBRIAN ROCKS IN AMERICA AND EUROPE.

By T. Sterry Hunt, LL.D., F.R.S.

(Read before the American Association for the Advancement of Science, at Saratoga, September 1, 1879.)

I. Introduction.

One of the earliest distinctions in modern geology was that between the crystalline or so-called Primary strata, and those which are found in many cases to have been deposited upon them, and being in part made up of sediments derived from the disintegration of these, were designated Transition and Secondary rocks. While the past forty years have seen great progress in our knowledge of these younger rocks, and while their stratigraphy, the conditions of their deposition, and their geographical distribution and variations have been carefully investigated, the study of the older rocks has been comparatively neglected. This has been due in part to the inherent difficulties of the subject, arising from the general absence of organic remains, and from the highly disturbed condition of the older strata, but in a greater measure, perhaps, to certain theoretical views respecting the stratified crystalline rocks. In fact, the unlike teachings of two different and opposed schools lead to the common conclusion that the geognostical study of these rocks is unprofitable.

The first of these schools maintains that the rocks in question are, in great part at least, not subordinated to the same structural laws as the uncrystalline formations, but are portions of the original crust of the earth, and that their architecture is due not to aqueous deposition and subsequent mechanical movements,

but rather to agencies at work in a cooling igneous mass. The igneous origin of gneisses, petrosilex-porphyries, diorites, serpentines, and even of magnetic and specular iron-ores was held and taught almost universally by our geologists a generation since, and has still its avowed partizans; some maintaining that these various crystalline rocks are portions of the first-formed crust of the planet, while others imagine them to be volcanic matters extravasated at more recent date; in either case however, more or less modified by supposed metasomatic processes. By the term metasomatosis are conveniently designated those changes which are not simply internal (diagenesis), but are effected from without,—as a result of which the chemical elements of the original rock are supposed to be either wholly or in part replaced by others from external sources (epigenesis).

The other school, to which allusion has been made, and which, not less than the preceding, has helped to discourage, in the writer's opinion, the intelligent geognostical study of the crystalline stratiform rocks, is that which believes them to be, in great part at least, the result of chemical changes, often metasomatic in their nature, which have been effected in paleozoic and more recent sedimentary beds, obliterating their organic remains, and transforming them into crystalline strata. According to this view, feldspathic, hornblendic, and micaceous stratiform crystalline rocks having similar mineralogical and lithological characters, may belong to widely separated geological periods,—while the same geological series may, in one part of its distribution, consist of uncrystalline silicious, calcareous, and argillaceous fossiliferous sediments, and in another locality, not far remote, be found, as the result of subsequent changes effected in these strata, transformed into gneiss, hornblende-schist or mica-shist, by what is vaguely designated as metamorphism.

The recent history of geology abounds in striking illustrations of the fact that in a great number of cases these views have been based on misconceptions in stratigraphy, and without entering into the discussion of the question, it may be said that, in the writer's opinion, careful stratigraphical study will, in all cases, suffice to show the error, both of the plutonic and the metamorphic hypotheses of the origin of crystalline rocks. The former is supported chiefly by the lithological resemblances between certain stratified and unstratified rocks, and by the appearances of stratification occasionally found in these; while the latter is

sustained by the analogies offered in cases of local hydro-thermal action on sediments, and by the resemblances which recomposed materials frequently offer to their parent crystalline rocks. It is here maintained that the great formations of stratiform crystalline feldspathic, hornblendic and micaceous rocks, which, in various parts of the world, have been alternately described as plutonic masses, and as metamorphosed paleozoic, mesozoic or cenozoic strata are, in all cases, neptunean rocks, pre-Cambrian or pre-Silurian in age, and that we know of no uncrystalline sediments which are their stratigraphical equivalents.

We have then before us two schools, the one maintaining the secondary origin of a great, and, by them, undefined portion of the crystalline stratiform rocks, while assigning to certain older (pre-Cambrian) crystalline rocks (of which they admit the existence), either a neptunean or a plutonic origin. The other, or plutonist school, while asserting the plutonic derivation of the greater part of the crystalline formations, accepts, to some extent also, the notion of secondary and neptunean metamorphic schists. It is believed that the above concise statements cover the ground held by the hitherto prevailing neptunean and plutonist schools, neither of which, it is maintained, expresses correctly the present state of our knowledge. In opposition to both of these are the views taught for the last twenty years by the writer, and now accepted by many geologists, which may be thus defined:—

1*st*. All gneisses, petrosilexes, hornblendic and micaceous schists,* olivines, serpentines, and in short, all silicated crystalline stratified rocks, are of neptunean origin, and are not primarily due to metamorphosis or to metasomatosis either of ordinary aqueous sediments or of volcanic materials.

2*d*. The chemical and mechanical conditions under which these rocks were deposited and crystallized, whether in shallow waters, or in abyssal depths (where pressure greatly influences chemical

* It is a question how far the origin of such crystalline aluminous silicates as muscovite, margarodite, damourite, pyrophyllite, kyanite, fibrolite and andalusite is to be sought in a process of diagenesis in ordinary aqueous sediments holding the ruins of more or less completely decayed feldspars. Other aluminous rock-forming silicates, such as chlorites and magnesian micas, are however connected, through aluminiferous amphiboles, with the non-aluminous magnesian silicates, and to all of these various magnesian minerals a very different origin must be ascribed.

affinities) have not been reproduced to any great extent since the beginning of paleozoic time.

3*d*. The eruptive rocks, or at least a large part of them, are softened and displaced portions of these ancient neptunean rocks, of which they retain many of the mineralogical and lithological characters.

II. The History of pre-Cambrian Rocks in America.

Coming now to the history of our knowledge of American crystalline rocks, we find that the lithological characters of the Primary gneissic formation of northern New York were known to Maclure in 1817, and were clearly defined in 1832 by Eaton, who, under the name of the Macomb Mountains, described what have since been called the Adirondacks, and moreover distinguished them from the Primary rocks of New England. Emmons, in 1842, added much to our lithological knowledge of the crystalline rocks of northern New York, but regarded the gneisses, with their associated limestones, serpentines and iron-ores as all of plutonic origin. Nuttall, who had previously studied the similar rocks in the Highlands of southern New York and New Jersey, had however maintained, as early as 1822, that these had resulted from an alteration of the adjacent paleozoic graywackes and limestones, into which he supposed them to graduate. This view was, at the time, opposed by Vanuxem and Keating, but was again set forth in 1843, by Mather, who while admitting the existence of an older or Primary series of crystalline rocks, conceived a great part of these rocks in southern New York to be altered paleozoic, and distinguished them as Metamorphic rocks. To this latter class he referred all the crystalline stratified rocks of New England, and ended by doubting whether a great part of what he had described as Primary was not to be included in his Metamorphic class. The subsequent labors of Kitchell and of Cooke have however clearly established the views of Vanuxem and Keating as to the Primary age alike of the gneisses and the crystalline limestones of the Highlands.

The similar gneissic series in Canada, which was known to Bigsby and to Eaton as an extension of that of northern New York, was noticed by Murray in 1843, and by Logan in 1847, as pre-paleozoic, though apparently of sedimentary origin, and hence, according to them, entitled to be called Metamorphic rather than Primary. It was described by Logan in 1847, as

consisting of a lower group of hornblendic gneisses without limestones, and an upper group of similar gneisses, distinguished by interstratified crystalline limestones.

These rocks were found by Logan and by Murray to be overlaid, both on Lake Superior and in the valley of the upper Ottawa, by a series consisting of chloritic and epidotic schists, with bedded greenstones, and with conglomerates holding pebbles derived from the ancient gneiss below. The same overlying series had, as early as 1824, been described by Bigsby on Lake Superior, and by him distinguished from the Primary and classed with Transition rocks.

Labradoritic and hypersthenic rocks like those previously described by Emmons in the Primary region of northern New York, were, in 1853 and 1854, discovered and carefully studied in the Laurentide hills to the north of Montreal, when they were described as being gneissoid in structure, and as interstratified with true gneisses and with crystalline limestones. In 1854, the writer, in concert with Logan, proposed for the ancient crystalline rocks of the Laurentide Mountains, including the lower and upper gneissic groups already mentioned, and the succeeding labradoritic rocks (but excluding the chloritic and greenstone series), the name of Laurentian. In an essay by the writer, in 1855, the oldest gneisses of Scotland and Scandinavia were, on lithological and on stratigraphical grounds, referred to the Laurentian series, and at the same time the name of Huronian was proposed for the chloritic and greenstone series, which had been shown to overlie unconformably the Laurentian in Canada.

Previous to this, in 1851, Foster and Whitney had described the Laurentian and Huronian rocks of Lake Superior as constituting one Azoic system of Metamorphic rocks, with granites, porphyries and iron-ores of igneous origin; and in 1857, Whitney attacked the two-fold division adopted by the Canadian geological survey, maintaining that the stratified crystalline rocks of the region belong to a single series, with a granitic nucleus. The observations of Kimball in 1865, and the later studies of Credner, of Brooks and Pumpelly, and of Irving, have, however, all confirmed the views of the Canadian survey as to the relations of the Laurentian and Huronian in this region.

The primary age of the Highlands of southern New York, and their extension in what is called the South Mountain, as far as the Schuylkill, was now unquestioned, but the crystalline rocks

to the east of this range, while regarded by Eaton and by Emmons, as also forming a part of the Primary, were, by Mather, as we have already seen, supposed to be altered paleozoic strata. These rocks in New England, with the exception of the quartzites and limestones of the Taconic range, were by him assigned to a horizon above the Trenton limestone of the New York system, and portions of them were conjectured by other geologists, who adopted and extended the views of Mather, to be of Devonian age.

The characteristic crystalline schists of New England and southeastern New York, passing beneath the Mesozoic of New Jersey, re-appear in southeastern Pennsylvania, where they were studied and finally described by H. D. Rogers in 1858. According to him, these crystalline schists, while resting unconformably upon an ancient (Hypozoic) gneissic system, were themselves more ancient than the Scolithus-sandstone, which he regarded as the equivalent of the Potsdam. While he supposed these newer crystalline schists, called by him Azoic, to be connected stratigraphically with the base of the Paleozoic series, he nevertheless assigned them to a position below the base of the New York system; thus recognizing in Pennsylvania, beneath this horizon, two unconformable groups of crystalline rocks, corresponding stratigraphically as well as lithologically, with the Laurentian and the Huronian of the Lake Superior region.

The existence among these newer crystalline schists of Pennsylvania, of a series distinct from the Huronian, and representing the White Mountain or Montalban rocks (the Philadelphia and Manhattan gneissic group), had not been then recognized. Rogers at this time taught the igneous origin of the magnetic iron ores, the quartz-veins, the serpentines and their associated greenstones in this region. The belief entertained by Rogers of an intimate connection between his upper or Azoic series and the Paleozoic, had its origin, apparently, in the fact of the existence in this region of still another and a newer crystalline series, the Lower Taconic of Emmons, or the Itacolumite group of Lieber, which I have designated Taconian, and propose to consider in detail in a future paper. In it are included the iron-ores of Reading, Cornwall and Dillsburg, in Pennsylvania.

The views of H. D. Rogers with regard to the crystalline schists of the Atlantic belt were thus, in effect, if not in terms, a return to those held by Eaton and by Emmons, but were in direct opposition to that maintained by Mather, which had been adopted

by Logan, and by the present writer. The belt of micaceous, chloritic, talcose and epidotic schists, with greenstones and serpentines, the extension of a part of the Azoic of Rogers, which, through western New England, is traced into Canada, (where it has been known as the Green Mountain range), was previous to 1862 called by the geological survey of Canada, Altered Hudson-River group. It was subsequently referred to the Upper Taconic of Emmons, to which Logan, at that date, gave the name of the Quebec group, assigning it, as had long before been done by Emmons (in 1846) to a horizon between the Potsdam and the Trenton of the New York system.

In 1862 and 1863 appeared, independently, two important papers bearing on the question before us as to the age of these rocks. The first of these was by Thomas Macfarlane, who, after a personal examination of the three regions, compared the Huronian of Lake Huron and the Green Mountain range of Canada, with portions of the Urschiefer or Primitive schists which, in Norway, intervene between the ancient gneisses and the oldest Paleozoic (Lower Cambrian) strata. The second paper was by Bigsby, who was, as we have seen, the earliest student of the Huronian in the northwest, pointing out that these rocks could not in any sense be called Cambrian, but were the equivalents of the Norwegian Urschiefer. The conclusions of Macfarlane were noticed in connection with the views of Keilhau on these rocks of Norway in "The Geology of Canada" in 1863, with farther comparisons between the New England crystalline schists and the Huronian, but official reasons then, and for some years after, prevented the writer from expressing any dissent from the views of the director of the geological survey of Canada.

Meanwhile, the existence of an equivalent series of crystalline schists was being made known in southern New Brunswick, where they were described by G. F. Matthews in 1863, under the name Coldbrook group, which included a lower and an upper division. In a joint report of Matthews and Bailey in 1865, these rocks were declared to be overlaid unconformably by the slates in which Hartt had made known a Lower Cambrian (Menevian) fauna, and were compared with the Huronian of Canada. The lower division of the Coldbrook was then described as including a large amount of pink feldspathic quartzite and of bluish and reddish porphyritic slates. In the same report was described, under the name of the Bloomsbury group, a series lithologically

similar to the Coldbrook, but apparently resting on the Menevian, and overlaid by fossiliferous Upper Devonian beds, into which it was supposed to graduate. The Bloomsbury group was therefore regarded as altered Upper Devonian, and its similarity to the pre-Cambrian Coldbrook was explained by supposing both groups to consist in large part of volcanic rocks.

In 1869 and 1870, however, the writer, in company with the gentlemen just named, devoted many weeks to a careful study of these rocks in southern New Brunswick, when it was made apparent that the Bloomsbury group was but a repetition of the Coldbrook on the opposite side of a closely folded synclinal holding Menevian sediments. These two areas of pre-Cambrian rocks were accordingly described by Messrs. Matthews and Bailey in their report to the geological survey of Canada in 1871, as Huronian, in which were also included the similar crystalline rocks belonging to two other areas, which had been previously described by the same observers under the names of the Kingston and Coastal groups, and by them regarded as respectively altered Silurian and Devonian.

After studying the Huronian rocks in southern New Brunswick, and their continuation along the eastern coast of New England, especially in Massachusetts (where, also, they are overlaid by Menevian sediments), the writer in 1870, announced his conclusion that the crystalline schists of these regions are lithologically and stratigraphically equivalent to those of the Green Mountain range of western New England and eastern Canada. These, he further declared, in 1871, to be a prolongation of the newer crystalline or Azoic schists of Rogers in Pennsylvania, and the equivalents of the Huronian of the northwest. The pre-Cambrian age of these crystalline schists in eastern Canada has now been clearly proved by the presence of their fragments in the fossiliferous Cambrian strata in many localities along the northwestern border of the Green Mountain belt, and farther by the recent stratigraphical studies of Selwyn, as announced by him in 1878.

In close association with these Huronian strata in eastern Massachusetts is found a great development of petrosilex rocks, generally either jaspery or porphyritic in character, and sometimes fissile, which, by Edward Hitchcock were regarded as igneous. These were found to be identical with the rocks designated by Matthews and Bailey, feldspathic quartzites and

siliceous and porphyritic slates, which form the chief part of the Lower Coldbrook or inferior division of the Huronian series in New Brunswick. The petrosilexes of Massachusetts were, after careful examination by the writer, described by him in 1870, and in 1871, as indigenous stratified rocks forming a part of the Huronian series. He subsequently, in 1871, studied the similar rocks in south-eastern Missouri, and, in 1872, on the north shore of Lake Superior, but was unable to find them in the Green Mountain belt, or in its southward continuation, until, in 1875, he detected them occupying a considerable area in the South Mountain range in southern Pennsylvania. The stratified petrosilex rocks of all these regions were described in a communication to this Association, in 1876, as apparently corresponding to the *hälleflinta* rocks of Sweden, and, having in view their stratigraphical position both in that country and in New Brunswick, they were then "provisionally referred" "to a position near the base of the Huronian series." Their absence in the Huronian belt in western New England, and in the province of Quebec, as well as at several observed points of contact between Laurentian and the well-defined Huronian in the nothwest, led to the suspicion that these hälleflintas might belong to an intermediate series.

C. H. Hitchcock has pointed out that the characteristic Huronian rocks do not form the higher parts of the Green Mountain range in Vermont, which he conceives to belong to an older gneissic series, a conclusion which the writer regards as premature. Hitchcock, however, in his final report on the geology of New Hampshire, in 1877, adopts the name of Huronian for the crystalline rocks of the Altered Quebec group of Logan, which makes up the chief part of the Green Mountain range in Quebec, is largely developed along it in Vermont, and appears in a parallel range farther east, which extends southward into New Hampshire. In his tabular view of the geognostical groups in this State, Hitchcock assigns to these rocks a thickness of over 12,000 feet, with the name of Upper Huronian; while he designates as Lower Huronian the petrosilex series of eastern Massachusetts, already noticed, where these rocks are of great, though undetermined, thickness. The similar petrosilex or hälleflinta rocks in Wisconsin, where they have lately been described by Irving as Huronian, have according to this observer, a thickness, in a single section, of 3,200 feet. They here sometimes become

schistose, and are interbedded with unctuous schists, and rest in apparent conformity upon a great mass of quartzite. The general high inclination both of this series and of the typical Huronian, renders the determination of their thickness difficult. The maximum thickness of the Huronian (excluding the petrosilex series) to the south of Lake Superior, may, according to Major Brooks, exceed 12,000 feet, while the estimates of Credner and Murray, respectively, for this region, and for the north shore of Lake Huron, are 20,000 and 18,000 feet.

As regards the Laurentian, there exists a certain confusion of nomenclature which requires explanation. As originally described, it includes, as already said, a basal granitoid gneiss, without limestones, which the writer has elsewhere designated the Ottawa gneiss, and of which the thickness is necessarily uncertain. Succeeding this is the Grenville series of Logan, having for its base a great mass of crystalline limestone, and consisting in addition to this of gneisses, generally hornblendic, and quartzites, interstratified with similar limestones. To this series, as displayed north of the Ottawa, Logan assigned an aggregate thickness of over 17,000 feet, though the later measurements of Vennor, in the region south of the Ottawa, give to it a much greater volume. The geographical distribution of this limestone-bearing Grenville series gives probability to the suggestion of Vennor that it rests uncomformably upon the basal Ottawa gneiss.

Thes two divisions constitute what was designated by Logan, in his Geological Atlas, in 1865, the Lower Laurentian,—the name of Upper Laurentian or Labradorian being then, for the first time given by him to a series supposed to overlie unconformably the former, of which it had hitherto been regarded as constituting a part. This third division has already been referred to as characterized by the predominance of great bodies of gneissoid or granitoid rocks, composed chiefly of labradorite or related anorthic feldspars, and apparently identical with the norites of Scandinavia. With these basic rocks are interstratified crystalline limestones, quartzites and gneisses, all of which resemble those of the Grenville series. This upper group, for which the writer in 1871 proposed the name of Norian, was supposed by Logan to be not less than 10,000 feet thick.

For farther details of the history of these various groups of pre-Cambrian rocks, and their distribution in North America,

the reader is referred to a volume published in 1878 by the Second Geological Survey of Pennsylvania, being Part I of the writer's report on Azoic Rocks, intended as an historical introduction to the subject.

III.—The History of Pre-Cambrian Rocks in Great Britain.

In an address before this Association in 1871, in which the writer maintained the Huronian age of a portion of the crystalline schists of New England and Quebec, he further expressed the opinion, based in part upon his examinations at Holyhead in 1867, and in part upon the study of collections in London, that certain crystalline schists in North Wales would be found to belong to the Huronian series. The rocks in question were by Sedgwick, in 1838, separated from the base of the Cambrian, as belonging to an older series, but were subsequently, by Delabeche, Murchison and Ramsay, described and mapped as altered Cambrian strata, with associated intrusive syenites and feldspar-porphyries.

In South Wales, at St. David's in Pembrokeshire, is another area of crystalline rocks, which the geological survey of Great Britain had mapped as intrusive syenite, granite and felstone (petrosilex-porphyry) having Cambrian strata converted into crystalline schists on one side, and unaltered fossiliferous Cambrian beds on the other. So long ago as 1864, Messrs. Hicks and Salter were led to regard these granitoid and porphyritic rocks as pre-Cambrian, and in 1866 concluded that they were not eruptive but stratified crystalline or metamorphic rocks. After farther study, Hicks, in connection with Harkness, published in 1867, additional proofs of the bedded character of these ancient crystalline rocks, and in 1877 the first named observer announced the conclusion that they belong to two distinct and unconformable series. Of these, the older consisted of the granitoid and porphyritic felstone rocks, and the younger of greenish crystalline schists, the so-called Altered Cambrian of the official geologists; both of these being overlaid by the undoubted Lower Cambrian (Harlech and Menevian) of the region, which holds their ruins in its conglomerates. To the lower of these pre-Cambrian groups, Hicks gave the name of Dimetian, and to the upper that of Pebidian. The last, with a measured thickness of 8000 feet, he supposed to be the equivalent of the

Huronian, and compared the Dimetian with the Upper Laurentian of Logan.

The similar crystalline rocks of North Wales, already noticed, were now studied by Professor T. McKenny Hughes of Cambridge, who described them in 1878. These include in Carnarvonshire and Anglesey the greenish crystalline schists which the writer in 1871 referred to the Huronian (pre-Cambrian of Sedgwick, and Altered Cambrian of the geological survey), certain granitoid rocks formerly described as intrusive syenite, and also a reddish feldspar-porphyry which forms two great ridges in Carnarvonshire. This latter was by Professor Sedgwick regarded as intrusive, and is moreover mapped as such by the geological survey, though described in Ramsay's memoir on the geology of North Wales as probably the result of an extreme metamorphism of the lower beds of the Cambrian. The pre-Cambrian age of all these rocks was clearly shown by Hughes, who however considered that the whole might belong to one great stratified series; while Hicks, from an examination of the same region, regarded them as identical with the Dimetian and Pebidian of South Wales.

Dr. Hicks continued his studies in both of these regions in 1878,—being at times accompanied by Dr. Torell of Sweden, Professor Hughes and Mr. Tawney of Cambridge, and the writer—and was led to conclude that beside the chloritic schists and greenstones (diorites) of the Pebidian, and the older granitoid and gneissic rocks, there exists, both in North and South Wales, a third independent and intermediate series, to which belong the stratified petrosilex or quartziferous porphyries already noticed. These are sometimes wanting at the base of the Pebidian, and at other times form masses some thousands of feet in thickness. At one locality, near St. David's, a great body of breccia or conglomerate, consisting of fragments of the petrosilex united by a crystalline dioritic cement, forms the base of the Pebidian. For this intermediate series, which constitutes the quartziferous-porphyry ridges of Carnarvonshire, Dr. Hicks and his friends proposed the name of Arvonia, from Arvonia the Roman name of the region.

This important conclusion was announced by Dr. Hicks at the meeting of the British Association for the Advancement of Science at Dublin, in August, 1878. The writer, previous to attending this meeting, had the good fortune to examine these

various pre-Cambrian rocks in parts of Carnarvonshire and Anglesey with Messrs. Hicks, Torell and Tawney. He subsequently, in company with Dr. Hicks, visited the region in South Wales where these older rocks had been studied, and was enabled to satisfy himself of the correctness both of the observations and conclusions of Dr. Hicks, and of the complete parallelism in stratigraphy and in mineral composition between these pre-Cambrian rocks on the two sides of the Atlantic. It may here be mentioned that Dr. Torell, who, during his visit to America in 1876, had an opportunity of studying, with the writer, the petrosilexes of New England and Pennsylvania, which he regarded as identical with the hälleflinta of Sweden, at once recognized them in the Arvonian series of North Wales.

Of the many areas of these various pre-Cambrian rocks which the writer was enabled to examine in company with Dr. Hicks, may be mentioned the granitoid mass of Twt Hill in the town of Carnarvon, and the succeeding Arvonian to Port Dinorwic, followed, across the Menai strait, by the Pebidian on the island of Anglesey, near the Menai bridge. Farther on, the Pebidian was again met with near the railway station of Ty Croes, in the southwest part of the island, succeeded by a large body of Arvonian petrosilex, and a ridge of granitoid gneiss, fragments of which make up a breccia at the base of the Arvonian series. The Pebidian is again well displayed at Holyhead.

In South Wales, the similar rocks were examined by him at St. David's, where three small bands of an impure coarsely crystalline limestone are included in the Dimetian granitoid rock, which is here often exceedingly quartzose. It may be remarked that the Dimetian, as originally defined at this, its first recognized locality, included a great mass of Arvonian petrosilex, the two forming a ridge which extends for some miles in a northeast direction, flanked by Pebidian rocks, which are sometimes in contact with the one and sometimes with the other series. At Clegyr bridge was seen the base of the Pebidian, already mentioned as consisting of a conglomerate of Arvonian fragments. Another belt of the same crystalline rocks was also visited, a few miles to the eastward of the last, and not far from Haverfordwest, forming, according to Hicks, a ridge several miles in length and about a mile wide. Where seen, at Roch Castle, it was found to consist of Arvonian petrosilex, with some granitoid rock near by. The ridge is flanked on the northwest

side by Pebidian and Cambrian, and on the southeast by Silurian strata, let down by a fault.

On the shore of Llyn Padarn, near the foot of Snowdon in North Wales, the porphyritic petrosilex of the Arvonian is again well displayed, while in contact with it, and at the base of the Llanberris (Lower Cambrian) slates, is a conglomerate made up almost wholly of the petrosilex. This locality was supposed by Prof. Ramsay and others to show that the petrosilex is the result of a metamorphosis of the lower portion of the Cambrian, the conglomerates being regarded as beds of passage. The writer, after a careful examination of the locality, agrees with Messrs. Hicks, Hughes and Bonney that there is no ground for such an opinion, but that the conglomerate marks the base of the Cambrian, which here reposes on Arvonian rocks, and is chiefly made up of their ruins. In like manner, according to Prof. Hughes, the Cambrian in other parts of this region includes beds made of the *débris* of adjacent granitoid rocks.

These petrosilex-conglomerates of Llyn Padarn are indistinguishable from those found at Marblehead and other localities near Boston, Massachusetts, which have been in like manner interpreted as evidences of the secondary origin of the adjacent petrosilex beds, into which they have been supposed to graduate. The writer has, however, always held, in opposition to this view, that these conglomerates are really newer rocks made up of the ruins of the ancient petrosilex. He has found similar petrosilex-conglomerates at various points on the Atlantic coast of New Brunswick, of Lower Cambrian, Silurian and Lower Carboniferous ages, all of which have, in their turn, been by others regarded as formed by the alteration of strata of these geological periods. The evidence now furnished in South Wales of still older (Huronian) beds of petrosilex-conglomerate should be noted by students of North-American geology. From observations near Boston, made by one of my former students, I have for some time suspected the existence of petrosilex conglomerates of Pre Cambrian age.

To the eastward of the localities already mentioned in Wales, are some other small areas of crystalline rocks, including those of the Malverns, and the Wrekin and other hills in Shropshire, all of which appear as islands among Cambrian strata; also those of Charnwood Forest, in Leicestershire, which rise in like manner among Triassic rocks. The Wrekin, regarded by Murchison as

a post-Cambrian intrusion, has been shown by Callaway to be unconformably overlaid by Lower Cambrian strata, and consists in part of bedded greenstones, and in part of banded reddish petrosilex-porphyries, closely resembling the Arvonian of North Wales and the corresponding rocks of North America. The geology of Charnwood has within the past two years been carefully studied by Messrs. Hill and Bonney. The ancient rocks of this region are in part crystalline schists (embracing in the opinion of Dr. Hicks and of the writer—who have seen collections of them—representatives both of the Pebidian and the Arvonian of Wales) and in part eruptive masses, including the granitic rocks of Mount Sorrel.

There is not, so far as known, in the British localities already mentioned, any representative either of the Taconian or Itacolumite group, or of the white micaceous gneisses with micaceous and hornblendic schists, which I have designated the Montalban series. I have, however, found the latter well displayed in Ireland, in the Dublin and Wicklow Hills. The probable presence both of this series and of the Huronian in the northwest of Ireland was pointed out by me in 1871. I have there lately seen the Huronian on Lough Foyle, and also in Scotland in various parts of Argyleshire and Perthshire, as along the Crinan Canal and in the vicinity of Loch Etive and Loch Awe. From collections sent me by Mr. James Thomson of Glasgow, it appears that both Huronian and Laurentian rocks occur in the island of Islay.

The crystalline schists of Charnwood offer, as was pointed out by Messrs. Hill and Bonney, many resemblances with parts of the Ardennian series of Dumont in France and Belgium. These, which have been in turn regarded as altered Devonian, Silurian and Lower Cambrian, were, as shown by Gosselet, islands of crystalline rock in the Devonian sea, and in one part include argillites with impressions of *Oldhamia* and an undetermined graptolite. These rocks have lately been described in detail in the admirable memoir of de la Vallée Poussin and Renard. The writer had the good fortune, in 1878, to visit this region, and in company with Gosselet and Renard to examine the section along the valley of the Meuse. The crystalline rocks here displayed greatly resemble those of the American Huronian, in which may be found most of the types described by the authors of the memoir just mentioned. It would be easy to extend

farther this review of late advances made in the study of the ancient crystalline rocks, but the writer has preferred to confine himself to those regions which he has lately examined.

Conclusions.

1. The Pebidian of Hicks has both the lithological characters and the stratigraphical position of the Huronian of North America, to which he has already referred it.

2. The Arvonian is, in like manner, identical with the Hälleflinta group of Sweden and with the Petrosilex group of North America, which the writer had provisionally included in the lower part of the Huronian, and which Hitchcock subsequently called Lower Huronian. The fact that there is in Wales a stratigraphical break between it and the overlying Huronian, will help to explain the frequent absence of the Arvonian at the base of Huronian in many of its American localities.

3. The Dimetian, including the granitoid and gneissic rocks with limestone bands, so far as can be seen in the limited outcrops, is indistinguishable from parts of the Laurentian of North America. It was from a misconception that Dr. Hicks in 1878 provisionally referred the Dimetian to the Upper Laurentian—a name at one time used by the geological survey of Canada to designate the Norian series, which in some parts of North America overlies unconformably the Laurentian. Hicks at the same time designated as Lower Laurentian the gneiss of the Hebrides (Lewisian of Murchison), which he believed to be distinct from and older than the Dimetian. These two apparently correspond to the Ottawa and Grenville divisions of the proper Laurentian in Canada, and perhaps to the Bojian and Hercynian gneisses of Gümbel, in Bavaria.

[The following is a partial list of publications relating to the rocks noticed in part III. of this paper:

In the Quar. Jour. Geol. Soc. of London are the following papers on these rocks in Wales: Hicks, May, 1877, p. 230; Hicks & Davies, Feb. 1878, p. 147, and May 1878, p. 153; Hughes & Bonney, Feb. 1878, p. 137; Hicks & Davies, May 1879, p. 285; Hicks & Bonney, ibid, p. 295; Bonney, ibid, p. 309; Bonney & Houghton, ibid, p. 821; Hughes, Nov. 1879, p 682; Maw, Aug. 1878, p. 764; also Hicks, rocks of Rossshire, Nov. 1878, p. 811. Tawney, Older Rocks of St. Davids: Proc. Bristol Naturalists' Society, vol. II, part 2, p. 110.

On these rocks in Shropshire, in the same Journal, Allport, Aug. 1877, p. 449; Callaway, Nov. 1877, p. 653, and Aug. 1878, p. 754; Callaway & Bonney, Nov. 1879, p. 643.

On these rocks in Charnwood Forest, in the same Journal, Hill & Bonney, Nov. 1887, p. 753, and May, 1878, p. 199.

See farther, Hunt, Chemical and Geological Essays, pp. 34, 269, 270, 272, 278, 383; also his Azoic Rocks, part I (Second Geol. Survey of Penn., 1878), pp. 187, 188.

For the rocks of the Ardennes see Memoir sur les Roches dites Plutoniques, etc. (4to, pp. 264), by de la Vallée Poussin and Renard, from Memoires de l'Acad. Royale de la Belgique for 1876; Memoire sur la Comp. Minéralogique du Coticule, by Renard, from the same for 1877; and The Mineralogical and Microscopical Characters of the Belgian Whetstones, by Renard, Monthly Microscopical Journal for 1877, Vol. xvii. p. 269. Also Gosselet and Malaise, Terrain Silurian des Ardennes, Bull. Acad. Roy. de la Belgique (2) No. 7, 1868; Dewalque, Terrain Cambrien des Ardennes, Ann. Soc. Géol. de la Belgique, tom. I, p. 63; and farther, Hunt, Chem. and Geol. Essays, p. 270.]

Appendix.

Since the above paper was read the author has received (November, 1879) a private communication from Prof. L. W. Bailey, giving his latest results as to the pre-Cambrian rocks of southern New Brunswick, which confirm what has already been said about that region. Bailey separates the Huronian into a lower division, for which he reserves the name of Coldbrook, consisting chiefly of petrosilex rocks, and an upper division, the typical Huronian, called by him the Coastal group. He adds that there is between the two a marked physical break, which is indicated by a stratigraphical discordance, and by the presence in the lower part of the Coastal group of coarse conglomerates made up from the ruins of the Coldbrook or underlying division. This correspond to the break between the similar Arvonian and Huronian in South Wales.

At the meeting of the British Association for the Advancement of Science at Sheffield in August, 1879, Dr. Hicks read a paper on the Classification of the British Pre-Cambrian Rocks, which is published in the Geological Magazine for October, 1879. He concludes that the Pebidian is "a group of enormous thickness, which is largely distributed over Great Britain, where it has a prevailing strike of N.N.E. and S.S.W., or from this to N.E. and S.W." In addition to the localities which we have already mentioned in Great Britain, he notes its occurrence in Shropshire and in Charnwood Forest, and also in the northwest of Scotland, where, as elsewhere, it enters largely

into the Lower Cambrian conglomerates. The group is concisely described by him as consisting "for the most part of chloritic, talcose, feldspathic and micaceous schistose rocks, alternating with slaty and massive greenstones, dolomitic limestones, serpentines, lava-flows, porcellanites, breccias and conglomerates. It is also traversed frequently by dykes of granite, dolerite, etc."

The conglomerates at the base of the Huronian in Wales are largely make up of the masses derived from the Arvonian, with which "it is undoubtedly, at most of the points examined, unconformable." This Arvonian series, Hicks regards as identical with the great Hälleflinta group of the Swedish geologists and with the Petrosilex series which the writer has made known in America. In addition to the localities already mentioned of it in the British Isles, Hicks notes its occurrence in the Harlech Mountains and the Orkneys, and probably also in the Western Islands, and in the Grampians of Scotland. Its strike in the regions examined by him is generally about N. and S.

As regards the gneissic Dimetian group, the strike of which is N.W. and S.E., or from this to N. and S., Hicks adds to the localities in Wales, already noticed, its occurrence in the Malvern chain, especially in the Worcester Beacon, and cites Dr. Callaway as authority for its existence in Shropshire. Hicks further notes its presence in several points in the northwest Highlands of Scotland. From this series of light colored gneisses, often very quartzose, with limestone bands, he separates, as we have seen, under the name of Lewisian, proposed by Murchison for the ancient gneisses of Lewis and others of the Hebrides Isles, these, and similar reddish and dark-colored hornblendic gneisses which are found in parts of the Malvern chain, in the northwest of Ireland, and possibly also in Anglesey. This series, according to Hicks, is unconformably overlaid by the Dimetian, brecciated beds in which hold fragments of the older Lewisian gneiss. The strike in these older gneisses "is usually E. and W., or some point between that and N.W and S.E."

Dr. Hicks concludes the above paper by remarking that the chief part of these ancient rocks in Great Britain "were until recently supposed to be either intrusive masses, or altered sediments belonging to tolerably recent times," and adds, "it is becoming more and more an acknowledged fact that the metamorphism of great groups of rocks does not take place so readily

as was formerly supposed, but that some special conditions, such as do not appear to have prevailed over this area since pre-Cambrian times, were necessary to produce so great a result."

The reader in this connection is referred to the abstract of a memoir communicated by the writer to the British Association at Dublin in August, 1878, on The Origin and the Succession of the Crystalline Rocks of North America, which will be found in the Geological Magazine for that year (page 466), as well as in Nature, vol. xviii, page 443.

Montreal, February, 1880.