

ambulacral line, and on either side is found a projecting triangular ossicle, whose cast is well preserved. These are thus arranged in closely opposed pairs in the interambulacral line (see Fig. 4). The features of the ventral side of the rays are not well preserved; but in four places at least the casts of the pair of ambulacral ossicles are seen, and they are of the same shape as in the new specimen (see Fig. 3). The somewhat separated rows of interambulacral ossicles are preserved as grooves, in the base of which are seen the pits which indicate the spines. The larger ones at the ends are also marked by the marginal pits, and the casts of the spines themselves are seen diverging from them. Towards the margin of the central aperture is seen the madreporiform tubercle which, with the exception of the casts of a few ossicles, is the only relic of the dorsal surface that is preserved. This is beautifully shown, it is of the ordinary type with radiating pores, and it is about $\frac{1}{16}$ inch in diameter (see Fig. 5).

It is thus seen that in all comparable points the two specimens agree, while each contributes something special to the description, which between them is rendered about as complete as we can well expect in the case of such an ancient relic of the group. The new specimen is now one of the ornaments of the Kendal Museum, whose development the discoverer has done so much to promote.

DESCRIPTION OF PLATE XV.

- FIG. 1. New specimen of *Solaster Murchisoni*, in the Kendal Museum. Found by Rev. G. Crewdson in the Capricornus beds of Huntcliff. Natural size.
 ,, 2. Portion of a ray of the same restored. Enlarged.
 ,, 3. Ambulacral ossicles of the type specimen. Enlarged.
 ,, 4. Angle plates at the inner ends of the rays of the type specimen.
 ,, 5. Madreporiform tubercle of the type specimen. Enlarged.

II.—GASTALDI ON ITALIAN GEOLOGY AND THE CRYSTALLINE ROCKS.¹

By T. STERRY HUNT, M.A., D.Sc., LL.D., F.R.S.

THE present writer in 1883 reviewed the history of the rocks of the Alps and the Apennines with especial reference to the geological relations of serpentine and its associates, in a paper which appeared in the first volume of the Transactions of the Royal Society of Canada, and is reprinted, revised and with some additions, as the tenth chapter of his volume entitled "Mineral Physiology and Physiography" (Boston, 1886). Therein he gave a somewhat detailed account of the labours in Italian geology of the late Professor Bartolomeo Gastaldi, of Turin, a list of whose publications on that subject from 1871 to 1878, so far as known to the writer, will there be found, including his letter to Quintino Sella, in 1878, on the general results of explorations made in 1877 (*loc. cit.*, 458). In doing this the present writer said, "I feel that I am both rendering a veritable service to science and paying a tribute to the memory of my honoured friend and correspondent of many years," stating at the

¹ Read before the British Association for the Advancement of Science, Section C, Manchester, Sept. 4, 1887.

same time that "the work of Gastaldi, interrupted by his death in 1878, was unfortunately left incomplete." This statement was not quite exact in one particular, since he survived till January 5, 1879, when there passed away, universally honoured and beloved, one who brought to the study of geology, with a spirit of complete devotion, a rare genius and a breadth of view which will assure him a first place among the geologists of our time.

In the chapter above mentioned the writer proceeded to consider the history of the so-called Tertiary serpentines of Monte Ferrato in Prato (Tuscany), and those of parts of the Ligurian Apennines which he had personally examined, and, in opposition to the opinion of most Italian geologists, and some others who have studied them, maintained that they were really but portions of the ancient *pietre verdi* zone, identical with that of the Alps, underlying, in the regions in question, the beds of Eocene age; which latter, by subsequent terrestrial movements, have been disturbed, broken and even inverted, so as to seem to pass beneath the serpentinic rocks. The indigenous and neptunian character of serpentine, maintained on stratigraphical evidence in North America by E. Emmons, by Logan, and by the present writer, was not only held by Gastaldi and Delesse, but is maintained by Stapff, by Lotti, and by Dieulefait. The hypothesis of a plutonic origin has moreover been so much modified by recent Italian geologists, as Taramelli, Capacci, Issel, and Mazzuoli, that instead of supposing them to have been erupted like basalts, they now conceive that serpentines, and the associated rocks of the ophiolitic group, were formed by submarine eruptions, in Tertiary time, of magnesian and feldspathic muds, of unexplained origin but of no very elevated temperature; which subsequently consolidated and crystallized into euphotide, diorite, and serpentine, with their associated feldspars, enstatite, chrysolite, and other minerals.

In the change of chrysolite into serpentine, as I have elsewhere shown, "one hundred parts by volume of the former species, with a specific gravity of 3.33, if converted into serpentine of specific gravity 2.50, without change in its content of silica, must lose one-eighth of its weight of magnesia, and acquire the same amount of water instead, while at the same time its volume will be augmented one-third, or to one hundred and thirty-three parts." That such a change takes place in some instances, probably through the action of carbonated waters removing a portion of magnesia from chrysolite, and leaving behind the more stable hydrated and colloid silicate, serpentine, is evident. Until, however, the precise conditions under which this may take place are better understood, we cannot explain why in some cases chrysolite is exempt from such change. I have long since described in the vicinity of Montreal, in Canada, cutting the limestones and pyroschists of the Ordovician series, great masses of a granitoid chrysolitic dolerite, itself of Palæozoic age, in which the chrysolite, in large crystals, often predominates, and is still unchanged, hard, and anhydrous. The assumption, lightly made by some plutonists, that chrysolite is always of plutonic origin, and serpentine always a product of epigenesis, rests upon a slender foundation, and is in

contradiction with a great number of facts. While the production of chrysolite from mixtures in a state of igneous fusion is well known, and while the chrysolitic rocks just mentioned are, as I have endeavoured to show, the result of crystallization and partial eliquation in a truly plutonic mass, it is not less certain that to other chrysolitic rocks a neptunian origin must be assigned; as was maintained by the writer in 1879, for the so-called lherzolite or chrysolite-rock which, accompanied by enstatite, serpentine, and chromite, is interstratified with the younger gneissic and mica-schist series in North Carolina. The same may be said of the similar chrysolite rocks in Norway, which, like these, are gneissic in structure and interstratified in crystalline schists. In this connection I have also elsewhere noted the variety of chrysolite known as glinkite, found in nodules in talcose or micaceous schists in the Urals, and that purely magnesian chrysolite or forsterite which occurs abundantly in crystalline limestone in eastern Massachusetts. It appears evident that chrysolite, like pyroxene, feldspars, spinel, and many other species, is generated alike by plutonic and by neptunian agencies.

As regards serpentine, while it may occur as a product of the decay of chrysolites either of igneous or of aqueous origin, no one who has intelligently studied the mode of its occurrence in grains, nodules, interstratified layers and beds, sometimes hundreds of feet in thickness, in the crystalline limestones and dolomites of Archæan rocks alike of Laurentian and of Taconian age, and even in Palæozoic strata, can doubt the direct formation of serpentine and its accompanying silicates, in such cases, by aqueous deposition. Its separation from solutions is also made apparent by the frequent occurrence of veins carrying the species marmolite and chrysotile (which are but crystalline forms of the same silicate as serpentine) either with or without calcite, traversing ophiolitic rocks, and even, as noticed by Gastaldi, in serpentinitic breccias of comparatively recent date.¹

Gastaldi had already, in 1871, expressed in general terms his opinion that "all the serpentinitic masses of the Tuscan and Ligurian Apennines," as well as the similar rocks in Calabria, are but prolongations of the great *pietre verdi* zone of the Alps, in which he included what are known as the Apuan and the Maritime Alps. To the same horizon also he referred the so-called ophitic rocks of the Pyrenees. From my own observations in Italy in 1881, I could not doubt the correctness of these earlier generalizations of Gastaldi, who however apparently did not verify his conclusions by personal observations of the so-called Eocene serpentines of Liguria and Tuscany until 1878, a few months before his death, when he examined both of these regions with especial reference to the question. His final conclusions thereon, a fortunate circumstance now permits me to give to the world.

There lies before me a letter of eleven pages, to my address, from

¹ For a detailed discussion of the questions here raised as to serpentine and related silicates, see *The Genesis of Serpentine*, in the author's *Mineral Physiology and Physiography*, pp. 497-509; also further for analyses and description of the chrysolitic dolerite, *ibid.* pp. 211-213.

Gastaldi, written in French, and dated Turin, July 20, 1878, which reached me in London in due time. After reading the first and last pages of this epistle, concerning matters which demanded and received an immediate answer, it was put aside for careful perusal, and by a curious chance was mislaid, and believed to be lost until recovered during the present year (1887). As it is the last recorded word of Gastaldi with regard to various geological problems which had occupied many years of his life, and moreover sustains fully my own opinion formed three years later regarding the rocks in question, as set forth above, I have thought it well to translate into English this precious letter, omitting only those portions which have no reference to the subject before us,—premising that with the exception of the references to the regions then lately examined by him, the conclusions, for the greater part, are already embodied in his previously published papers and in the present writer's summary of them:—

“TURIN, July 20, 1878.

“DEAR FRIEND AND COLLEAGUE,—On returning from a long campaign in the Apennines of Prato (Tuscany) and the Apennines of Liguria, I was agreeably surprised to receive your letter from Montreal of June 25, announcing your speedy departure for England. . . . I am very glad that you are about to give us a historical and critical work on the Azoic rocks of North America, respecting which it has not been easy to get clear ideas, on account of the extent of the literature and the difficulty of procuring it. I agree with you that we are now enabled to place on a solid foundation the classification of the Azoic rocks, and you may rely on my support of your views which you will lay before the International Geological Congress, where your skill in exposition will be more effectual, because the facts are evident. I cannot myself attend the Congress, for at that time it is necessary that I should be in the high valleys of the Maritime Alps; besides which please consider that I am sixty-one years of age, and cannot put off labours which involve great fatigue, and of which I may not be capable another year. . . .

“You propose to give in your volume my conclusions as to the crystalline terranes of the North of Italy. For this I thank you with all my heart, and demand permission to set forth a summary of my observations.¹ As to crystalline rocks, I am even more radical than you; for me all crystalline rocks are stratified; for me there is no plutonism; for me volcanic activity commenced only with the lavas of the Lower Tertiary; at least I know no intrusive rocks in the Alps; the porphyries there are, to my eyes, sedimentary.² I

¹ The volume here referred to was that on Azoic Rocks, being Report E. of the Second Geological Survey of Pennsylvania, 1878 (8vo. pp. xxi. and 253), and was already printed at that date, a point which I had apparently not made clear to Gastaldi, who sent the notes for the volume in question, as well as for use at the Geological Congress of 1878, where, however, the time had not yet come for their presentation. The volume on Azoic Rocks contains a brief summary of the views of Gastaldi, drawn from his published papers.

² I have elsewhere remarked that Gastaldi, misled by his too exclusive Wernerianism, appears to have included under the name of porphyry both stratified neptunian rocks and intrusive plutonic or pseudoplutonic rocks of more than one kind.

divide the crystalline rocks into two great zones; the lowest consisting of the oldest rocks of the Alps, and probably of the globe, is that of the central, ancient, or primitive gneiss. It is emphatically the zone of the orthoclase feldspar, and is very poor in minerals. The other zone is that of the *pietre verdi*, or green rocks, and is especially the zone of the triclinic feldspars, like those of the diorite, euphotide and apenninite. The granites themselves of this zone—and I cite those of Elba, of Baveno, of Mont Orfano, and of Alzo. etc.—although characterized by the beauty of their crystals of orthoclase, are rich in albite. I have cited apenninite, which will be new to you, so that I give the following explanation. Our geologists have long recognized in the Apennines of Savoy the presence of a great body of protogine or protogine-like gneiss. This rock is composed of quartz and feldspar, in nodules rather than in crystals, and of chlorite. A rock of the same character has been recognized by Giordano in the Grand Cervisa. Now the feldspar of this rock, which in the Ligurian Apennines, as well as in the Pennine Alps, occupies a large surface, is in part soda-bearing, and I have thought best to distinguish it from the true protogine, the feldspar of which is orthoclase, by the name of apenninite.

"In a great many localities in the Alps we see the *pietre verdi* resting against the central gneiss, but in others the same series is found lying nearly horizontally thereon. In the latter case meteoric agencies destroy this superimposed series, and thus extend more and more the area of the ancient gneiss, already widely exposed. Were the rocks of the *pietre verdi* zone thus made to disappear from the Alps, the height of these in many places would be much reduced (thus, for example, the Grand Cervisa and the Grivola are formed of this zone); and when at last these rocks were destroyed, we should find the region entirely occupied by the ancient gneiss. In a word, the mass of the Alps is formed of the ancient or primitive gneiss, here and there overlain by the rocks of the *pietre verdi* zone."

[For illustration of these different relations two figures are given in the letter, one of which is along the valley of Lanzo, showing the stratified *pietre verdi* series resting at a considerable angle upon the ancient gneiss (the stratification of which is not indicated), and overlaid by more recent sediments. The other section, in the valley of Chisone, represents the ancient gneiss overlaid by a stratum of lherzolite, one of serpentine, and one of diallagic euphotide, the attitude of all three being nearly horizontal.]

"The ancient gneiss is very poor in minerals, but includes a limited number of other rocks, such as quartzite, amphibolite, and crystalline limestone. The zone of the green rocks or *pietre verdi*, on the contrary, is very rich in minerals, as well as in varieties of rocks. Whence have come the minerals of this zone, since they have not [apparently] traversed the gneiss? Whence the porphyries and the granites of this same zone, which we nowhere find intersecting the gneiss? We must conclude—and direct observation of the facts demonstrates it—that the masses, the veins, and the so-called bedded veins in which the zone of the *pietre verdi* is so rich, are

characteristic elements of these rocks, and do not come from great depths. The porphyries and the granites, which are found so frequently in this zone, are not intruded rocks, since they do not traverse the underlying gneiss, but of sedimentary origin, like the limestones, the calcareous and argillaceous schists which accompany them. These are points upon which it seems to me important to insist.

"At Chaberton, a mountain of the Cottian Alps, I found resting directly upon the serpentinic series a semi-crystalline limestone holding organic remains. Not then suspecting a hiatus in the succession, I was led to suppose that these fossils, which were badly preserved, might be very ancient, and my friend Michellotti, who was so good as to study them, thought like myself that they were Lower Palæozoic forms. Upon these fossils I have published two papers.¹ It appears, however, that our notion of the existence of Silurian [Cambrian] forms in the Alps was an illusion.² I subsequently discovered more complete sections in the valley of the Macra, and in that of the Stura de Caneò (Maritime Alps), and in these, in limestones which appear to be a continuation of those of Chaberton, we have found a good number of fossils which have been described by Messrs. Zittel and Gümbel, and show the existence in the Alps, above the zone of the *pietre verdi*, of various Mesozoic and Cænozoic terranes. Resting upon the crystalline rocks we have, first a quartzite alternating with a semi-crystalline limestone, then a compact limestone with layers of anthracite, followed by another compact limestone of Triassic age, with *Encrinurus liliiformis*, and finally by a series of limestones, Liassic, Jurassic, and Cretaceous; the whole overlain by Nummulitic and more recent Tertiary strata. The complete succession is then (1) The ancient central or primitive gneiss, with quartzite, crystalline limestone, graphite, etc. (2) The *pietre verdi* series, principally formed of serpentine, Iherzolite, euphotide, diorite, variolite, porphyry, calc-schists, apenninite, etc.; (3) The anthracitic series; (4) Triassic; (5) Liassic; (6) Jurassic; (7) Cretaceous; (8) Nummulitic, Miocene, Pliocene." [This is illustrated in the letter by an ideal section.]

"The excursions which I have lately made in the Apennines of Prato in Tuscany, and in the Ligurian Apennines, had for their object to study the serpentines of these regions. Some geologists of my acquaintance have lately given themselves much labour and pains to confute my views of the age and the nature of the serpentines. They wish to establish that these are eruptive rocks, in many cases interstratified with the beds of the Upper Eocene—a proposition which is wholly untenable. The serpentines as well as the other rocks of the *pietre verdi* series are ancient rocks, pre-Silurian in age, and are of types which have not been formed in later times. In regarding these from this point of view, the geology of all those

¹ Sul fossili del calcare dolomitico del Chaberton; Roma, 1876. Su alcuni fossili paleozoici delle Alpi marittimi et dell' Apenmini ligure; Roma, 1877.

² In Sardinia, however, Lower Palæozoic forms, both Cambrian and Ordovician, are met with; Mineral Physiology and Physiography, p. 476.

regions in which the *pietre verdi* series plays an important part becomes easy to understand; but it is, on the contrary, extremely complicated if we consider the rocks of this series as intrusive. In a great many parts of the Alps we see these rocks rising into considerable elevations, as in Monte Viso; elsewhere again they are overlain by the anthracitic series, by the Trias, or by still more recent terranes. Thus in the valleys of the Bormida, and the Erro, and in other valleys of the Ligurian Apennines, they are directly covered by the Miocene; and again, as in the Apennines of Bologna, of Florence, etc., are overlain by the Eocene or the Upper Cretaceous. The separation of the two chains, Apennine and Alpine, is but a geographical fiction; it would be absurd to attempt to separate them geologically. I have visited the valleys and the depressions along which geographers have drawn the lines of separation, and have there found nothing but Alpine rocks, serpentine, apenninite, calc-schists, etc. . . .

"To-morrow I leave for the Maritime Alps, where I shall remain for about a month in order to visit the valleys of the Macra and the Stura, that of Geno and that of the Vermagna, making for the third time this journey, which is a weary and a painful one, especially for the valley of the Macra, where one is forced to undergo many privations. I am delighted to think that our literary correspondence is renewed, and regret very much that circumstances deprive me of the pleasure of being with you at the Congress in Paris. . . .

"Affectionately yours,

"To Mr. T. Sterry Hunt.

B. GASTALDI."

As regards the *pietre verdi* series, of which he has here so well set forth the importance, I have in the volume already quoted (*Mineral Physiology and Physiography*) shown that Gastaldi not unfrequently employed it, as in the foregoing letter, to designate the whole succession of crystalline schists above the ancient or central gneiss—speaking of these collectively as the "newer crystalline series." This however, includes a great body of younger gneiss and mica-schists above the group characterized by serpentine, euphotide, diorite, etc., which he has here so clearly defined as resting upon the ancient gneiss. Neri, in his sections in north-western Italy, distinguishes above the ophiolitic or *pietre verdi* horizon, a group of mica-schists with granites, while Gerlach described the same as recent gneiss and granite, followed by gneissic mica-schists. Gastaldi himself, in more detailed accounts, used the term *pietre verdi* in the same restricted sense as Neri. Thus in 1874 (*Studi geologici sulli Alpi occidentali*, part 2) he speaks of "the *pietre verdi* properly so-called," and declares it to be comprised between "the ancient porphyroid and fundamental gneiss," and "the recent gneiss, which latter is finer-grained and more quartzose than the other." He elsewhere in this same memoir speaks of this higher portion of the "newer crystalline series" (oftentimes, as in the above letter, comprehended in his "*pietre verdi* zone") as a mica-schist,—a gneissic mica-schist,—as recent gneiss and mica-schist,—and also as a very micaceous gneiss, often passing into mica-schist and sometimes hornblendic. He says

farther, "I will not assert that when specimens of this newer gneiss are confusedly mixed with those of the more ancient, it would always be practicable to distinguish them petrographically; but I do not hesitate to affirm that their distinction in the field is not difficult; on account of the frequent alternation of the younger gneiss with the other characteristic rocks of the upper series [micaceous and hornblendic schists, etc.], while the older gneiss, however wide its extent, is generally unmixed with other rocks."

Above this recent gneissic and mica-schist division, but below the anthracitic group, and included in the "newer crystalline series" of Gastaldi, there is a considerable thickness of crystalline schists, often soft and unctuous, and variously described as argillaceous, talcose, and micaceous, or as grey lustrous schists, which are sometimes sericitic. These, moreover, include quartzite, karstenite, dolomite, and banded and statuary marbles, with occasional serpentines and amphibolic rocks. Serpentines are also met with in intimate association with the younger gneisses, and hence Gastaldi often spoke of the whole triple group of the newer crystalline series above the ancient gneiss as the "pietre verdi zone." To each of these three divisions he, in common with other Alpine geologists, assigns a thickness of several thousand metres.

While these great divisions of the crystalline rocks were thus being defined in the Western Alps, Von Hauer had already, in 1868, shown the same succession further to the eastward, in the Lombardo-Venetian Alps, where he distinguished, first, the ancient gneissic and granitic rocks, called by him the central gneiss; second, a great thickness of green rocks or *pietre verdi*, including serpentine, euphotide, and diorite, with various amphibolic and chloritic rocks, together with saccharoidal limestones; and, third, a recent gneiss and mica-schist series. Gastaldi, at an early date in his studies, recognized in the older or central gneiss the Laurentian series of North America, and in the succeeding green rocks, or *pietre verdi* proper, the group which I had in 1855 called Huronian. It was not until 1870 that I attempted to define as a distinct and newer series the group of younger gneisses and mica-schists in North America, called by me subsequently, in 1871, the White Mountain or Montalban series, and corresponding both lithologically and stratigraphically to the recent gneiss and mica-schist series already recognized in 1868 by Von Hauer in the Eastern Alps, indicated by Gerlach in the Western Alps in 1869, and described more at length by Gastaldi in 1871. The work of none of these was known to me when, in 1870, I first set forth the distinctness of this great group of younger gneisses and mica-schists in North America, and also indicated their existence in the Scottish Highlands.

I had, in 1881, an opportunity of examining this upper gneissic series in the Western Alps, near Biella in the province of Novara, and in company with Quintino Sella (who with Berutti had carefully mapped the region), of going over a section which had been studied and described alike by Gerlach and by Gastaldi. Here, besides the ancient gneiss, with included graphitic and pyroxenic limestone, the

whole indistinguishable from the Laurentian of North America, and also the characteristic serpentinitic or proper *pietre verdi* group overlying it, I found the recent gneiss and mica-schist series apparently overlying transversely both of these, and seemingly identical with the Montalban or younger gneissic series of the White Mountains and of Philadelphia in North America. An absence of the ophiolitic or true *pietre verdi* group between the older and the younger gneissic series, which is apparent elsewhere in the Alps, and in many places in North America, may be due either to non-deposition or to erosion. The existence of conglomerates holding rolled pebbles in the younger gneissic series, both in Europe and America, shows erosion to have played an important part in Archæan as in later times, and is in harmony with the observed stratigraphical discordances in the crystalline rocks, each one of the upper divisions in turn being found to rest upon the ancient gneiss.

The younger gneissic or Montalban series I have found well displayed in Mont St. Gothard and in the Ticino basin in Switzerland. To it also apparently belong the granulite rocks and the mica-schists of the Mittelgebirge in Saxony, with their *dichroite*-gneiss, *lherzolite*, and garnetiferous serpentine, and also the micaceous gneisses of the Erzgebirge, with their included limestones and amphibolic rocks, and their overlying mica-schists. In these latter are found the remarkable conglomerate beds described by Hauer in 1879, the pebbles of which are apparently derived from the ancient or central gneiss, of which they have the characters.¹

While thus referring the younger gneisses and mica-schists alike of Saxony and of the Alps to the Montalban, I have maintained that the uppermost division of the newer crystalline series of Gastaldi is to be regarded as the equivalent of the Taconian or Lower Taconic of North America, designated by Lieber the *Itacolumitic* series; a great group of strata which is traced from the Gulf of St. Lawrence, with some interruptions, nearly to the Gulf of Mexico, and westward to the basin of Lake Superior and beyond. This series should be carefully distinguished from the Upper Taconic, a younger uncrystalline series, different in geographical distribution, and containing a well-defined Cambrian fauna. The Taconian or Lower Taconic, whose real stratigraphical relations were already clearly defined more than fifty years ago by Amos Eaton, has since, by various theorists of the metamorphic school, been alternately regarded as altered Cambrian, altered Ordovician, altered Silurian, altered Carboniferous, and in part even as altered Triassic;² a history which recalls that of the similar strata of the Apuan Alps, including the marbles of Carrara and Massa, which have by different writers been

¹ See for a detailed discussion of the questions here involved, the author's "Mineral Physiology and Physiography," on The Geology of the Alps and the Apennines, pp. 457-482; The Serpentes of Italy, pp. 482-496; and further, The Metamorphic Hypothesis, pp. 654-673.

² For a detailed account of the Taconic controversy see the author's "Mineral Physiology and Physiography," 517-686; also, more concisely and with new facts, "The Taconic Question Restated," Amer. Naturalist, Feb. Mar. and Apl. 1887.

referred to various horizons from Cretaceous down to pre-Palæozoic, at which latter they are placed by Gastaldi, in the upper part of his "newer crystalline series," as also by Jervis in the second volume of his valuable treatise, *I Tesori Sotterranei dell' Italia*.

This Taconian or newest crystalline group embraces in North America besides quartzites (sometimes in flexible elastic layers) and crystalline limestones affording both banded and statuary marbles, large deposits of iron-ores, alike magnetite, hæmatite, and limonite, the latter being formed by epigenesis, in some cases from pyrites and in others from siderite. It also includes a great mass of argillites, and of soft unctuous schists, often described as talcose, and though more generally sericitic, sometimes containing chlorite and talc, together with occasional amphibolic and feldspathic rocks, massive serpentines and opicalcites, and bearing throughout a marked resemblance to the upper division of the newer crystalline series of the Alps.

As the writer has elsewhere pointed out, the chemical and mineralogical conditions of the underlying *pietre verdi* horizon were repeated, though with diminished intensity, at this later time in the history of the newer crystalline series, producing in the younger rocks thereof such resemblances to the older that the Taconian strata were not unnaturally confounded with the Huronian. Thus, to the south of Lake Superior, Emmons having in 1846 recognized the Taconian, he was led, when the Huronian was announced in 1855, to maintain (in an unpublished paper) that it was in no way distinct from his Lower Taconic. On the other hand, the present writer, in common with Murray, Credner, and others, included these same Taconic rocks in that region with the Huronian, and it was not until after a prolonged study of the Taconian in the more eastern regions of North America, that he was enabled to show that the two series had really been included in the Huronian as defined in the vicinity of Lakes Superior and Huron; where also the recent gneisses and mica-schists are met with, as well as the ancient or primitive granitoid gneiss. In like manner, as we have seen, Gastaldi was led, from such lithological likenesses, to include the upper and lower division of his newer crystalline series, with their intervening recent gneisses and mica-schists, under the comprehensive name of the *pietre verdi* zone. These partial resemblances between the crystalline rocks of succeeding divisions serve to illustrate the different stages in the process of evolution of the crystalline rocks in successive ages by chemical agencies from an originally undifferentiated mineral matter, as I have endeavoured to set forth in a recent paper on "The Elements of Primary Geology."¹

¹ GEOLOGICAL MAGAZINE, November, 1887.