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THE PHYSIOGRAPHY OF VERMONT[1]

AT this time no discussion of many interesting though difficult and perplexing questions to which a study of Vermont physiography gives rise will be attempted, but simply a brief consideration of its most conspicuous features.

Geologically Vermont is one of the oldest parts of the country as it contains very little rock that was formed later than the Ordovician. The geological history of Vermont, like that of most regions, may be properly divided into several distinct periods.

The Adirondacks of New York on the west side of Lake Champlain are mostly Pre-Cambrian and at the same time, or probably somewhat later, but still in Pre-Cambrian time, a fold or folds, rose on the east and formed the first elevation of the Green Mountains. Thus the Champlain Valley with its present outline was established in this early period.

Pre-Cambrian rocks have been found in the Green Mountains in only a few localities, but as yet no extended study of these mountains has been made. When thorough investigation shall reveal their complete structure the backbone or axis of the Green Mountains will almost certainly be found to be of an age earlier than the Paleozoic.

At this time then there was the Adirondack ridge on the west and the Green Mountains ridge on the east and between them a strait or channel which connected New York Bay with the St. Lawrence Gulf. An era of erosion and subsidence followed and the great ocean rolled over the whole country east of the Adirondacks.

[1] Address of the vice-president and retiring chairman of Section E, Geology and Geography, American Association for the Advancement of Science, Baltimore, December, 1918.

In these waters were laid down thousands of feet of Cambrian and Ordovician sediments which later became the sandstones, limestones and shales now found along the shores of Lake Champlain and for a few miles eastward.

Not long after the close of the Ordovician, metamorphism occurred and the sedimentary beds became mainly schist, slate and gneiss, although there were also quartzite, conglomerate and silicious limestones where the alteration was less complete. The marbles of Rutland County are the result of a somewhat varied phase of this metamorphism, acting chiefly on Chazy and Trenton beds.

Upheaval, folding, faulting and dike intrusion came at this time, as did also the elevation of the present Green Mountains. The sedimentary beds had been laid down before the final elevation upon the eroded and sunken Pre-Cambrian.

Now came an immense interval when, so far as there is any evidence, practically no rock formation occurred in Vermont. There are slight exceptions. A bit of Devonian on the shores of Lake Memphremagog, a trifle of Silurian on the extreme southern border of the state and a larger, but comparatively insignificant belt of Tertiary with its most important outcrop, the Brandon Lignite, are all before the Pleistocene.

What happened during the incalculable time between the Ordovician and the Pleistocene no one knows, but there is no doubt that during this age-long interval erosion beyond imagining must have taken place, and in many respects the land forms were changed.

As is well known, Vermont is decidedly a mountainous state. There is, to be sure, abundance of level ground and good tillable land, but dominating all are the mountains. In single townships there are thirty or forty peaks of noteworthy size and in some instances more than half of these have never been named. In northern Vermont the Green Mountains are somewhat irregularly scattered, but about fifty miles south of the Canadian border they come together in the single range which continues southwards. By this range Vermont is sharply divided into the eastern Connecticut Valley and the western Champlain Valley.

Any one who journeys through the state finds it easy to pass by good roads from north to south, but from west to east it is often very difficult and in many places impossible. Even politically Vermont has an east and west side, and the very shape of the state is suggested by the presence of this north and south series of mountains.

Naturally, the name of the state recalls only the Green Mountains and certainly the peaks and foothills of this range are by far the most important physical features. On the western border, however, is the not inconsiderable Taconic Range and the series of Sand Rock Hills, while east in the Connecticut Valley are the Granite Hills.

Probably the Taconics were formed somewhat later than the better known Green Mountains. They begin just south of the middle of Vermont and continue, as the Berkshire Hills, into Massachusetts. Though far less important than their larger and more widespread associates, the Taconics are not insignificant. They extend for many miles and include a number of summits over three thousand feet high. Equinox in Manchester is nearly four thousand feet high. In passing through the beautiful valley from Bennington to Rutland the Taconics are conspicuous on the north and the Green Mountains on the south, and the two ranges differ noticeably in outline. The Taconics are largely synclinal in structure, while the Green Mountains are anticlinal or monoclinal. Says Dale in "Taconic Physiography":[2]

> The synclinal mountains must correspond to the original valleys and the anticlinal valleys to the original mountains.

This statement also gives a hint of the great extent to which erosion has taken place in these mountains. This is also shown by the following from the same article:

> As the limestone of the valley underlies the schist these valleys must originally have been covered by schist and therefore about half a mile of

[2] Bulletin 279, U. S. G. S.

schist besides the eroded limestone ought to be restored to the valley (and) where the Cambrian limestone comes to the surface in anticlines, the entire limestone formation as well as the schist ought to be added, *i. e.*, at least 3,500 and possibly 5,000 feet, leaving out the Silurian Grit.

The differences in form are clear when the two ranges of mountains are before one, but they are not easily described. The Green Mountains are characterized by rounded, though not dome-shaped, summits, frequent long ridges radiating from them and occasionally sharp cliffs, but nowhere is there the very rugged, angular, pyramidal outline of the Matterhorn type.

The greater part of the mountain mass consists of gneiss and, of course, the general forms of the various summits are due to the effect of long weathering and glaciation upon this material.

The outlines in the Taconics are even more rounded than are the Green Mountains, the mass is often more elaborately dissected, the ridges more numerous and longer. Beginning in Snake Mountain in Addison, somewhat north of the middle of the state is a series of low mountains and hills, nowhere united in a range, but standing as isolated elevations not far from the shore of Lake Champlain.

Nearly all of these are less than a thousand feet high, though one or two are more, and they are mostly composed of Lower Cambrian red sandstone, but there are occasionally shale and quartzite. Silicious limestone of the same age also occurs in small amount. This series has been known as The Red Sandrock Formation, but as this name is preoccupied and as the terrane as found in western Vermont appears to be sufficiently distinct to deserve a local name, it is suggested that these beds of sandstone with some shale, quartzite and limestone be called the "Winooski Beds."

Among the characteristic fossils are *Olenellus thompsoni, Ptychoparia adamsi, Kutorgina cingulate, Billingsella orientalis, Huenella vermontana.* These place the terrane in the Waucobian of Walcott.

It seems evident that the outcrops in the lowlands and in the elevations—the series of hills—are Cambrian remnants and that before the Ordovician, Cambrian strata some thousands of feet thick covered the western part of Vermont.

What has been called "The Champlain-St. Lawrence Fault" came after the close of the Ordovician running from Canada through western Vermont and on along eastern New York. This broke through the Cambrian and Ordovician, lifted the eastern side hundreds of feet above the western and shoved it over so that now in many places on the shore of Lake Champlain beds of Lower Cambrian rest directly on those of the Utica Shale, which is at the water's edge. These exposures are very impressive as they form cliffs on the shore of the lake.

The fourth series of elevations in Vermont are not very numerous nor massive, but commercially they are of great importance because it is in these Granite Hills that all the granite quarries are situated and Vermont at present leads the world in production of this stone, as it does in marble.

As the Taconics and Cambrian Hills are west of the Green Mountains, so these are on the eastern side—a series of low mountains wholly of granite, usually more or less dome-shaped and not more than a few hundreds of feet high. Millstone Hill in Barre and Robeson Mountain in Woodbury are types of these granite masses. Probably all are laccoliths and as the granite has a structure that indicates slow cooling of intrusive masses held down by heavy pressure, there was originally a considerable thickness of other rock resting upon the upthrust granite.

As Ordovician fossils have been found in the unchanged limestone near the granite, it seems probable that the covering beds were of this age, though there may be some of the Cambrian as well.

The rocks now associated with the granite are metamorphic so that the igneous activity which resulted in the granite thrust did not take place until after the great metamorphism following the Ordovician. It has been thought that it did not occur till the Devonian or even somewhat later.

One other elevation should be mentioned. Mount Ascutney in Windsor is a conspicuous object in the Connecticut Valley as it stands alone twenty miles from any other hill. Of this it must be sufficient to note that its structure is unique among Vermont mountains and unusually complex, as any one who will refer to Dr. R. A. Daly's account in Bulletin 209, U. S. G. S., will find. Dr. Daly says:

> Ascutney owes its existence to a great stock of quartz syenite.

Also

> Mount Ascutney is, like most New England mountains, a residual or erosion, a monadnock overlooking a dissected rolling plateau.

In so mountainous a region as that of Vermont the elevations of all sorts must form the most obvious part of its physiography, but in any other than an arid region where there are mountains there must also be streams and lakes. Everywhere in Vermont the stern, rugged, impressive mountain scenery is softened by the charm of stream and lake. Aside from Champlain and Memphremagog, there are not far from four hundred lakes and ponds in the state. Some are but a fraction of a mile long, others several miles. Most of them are of glacial origin. The streams are innumerable. There are four rivers that empty into Lake Champlain, although they rise in the eastern part of the state and thus do not conform to the general trend of surface features. These, the Missisquoi, Lamoille, Winooski and Otter have found their way across the mountains. They are antecedent streams and therefore old. Other rivers flow into the Connecticut and a few others elsewhere. Nearly all have formed deltas.

Necessarily the general character of Vermont physiography is much modified by the character of the rocks. As one crosses the state from east to west he will find at least a dozen belts or strips of differing rock material. Along the Connecticut River are schist and slate for the most part, while between these and the mountains are schist, limestone, conglomerate quartzite, etc. The common schists are sericite and phyllite.

The age of these beds, some of which extend through the length of the state, some only for a few miles, has been long in doubt, but within the last few years Dr. C. H. Richardson, working on the Vermont Survey, has studied the rocks of eastern Vermont and has been fortunate in discovering in limestone beds at many localities crushed graptolites, some of which have been identified by Dr. Ruedeman as undoubtedly Ordovician.

So numerous and widely distributed are these outcrops that it appears quite certain that eastern Vermont is largely Ordovician, though there may be a small amount of Cambrian. As has been indicated, much of the rock east of the Green Mountains is highly metamorphosed and when the mountains themselves are reached exceedingly complex structure is found. It will probably be a long time before all the intricacies of Green Mountain geology are disentangled.

For a few miles west of the mountains the rocks are similar to those found in the Connecticut Valley east of them. Farther west there are sedimentary rocks which have been somewhat changed, and near the lake others which are unchanged. The shores of Lake Champlain afford many excellent opportunities for studying the Lower Cambrian, and the divisions of the Ordovician from Beekmantown limestone to Utica shale. All headlands on the eastern shore of the lake are of these beds, as are nearly all the islands in Lake Champlain.

The last period in the making of Vermont physiography is, naturally, the Pleistocene. The usual events of this age are too well known to need repetition here and what the Pleistocene was elsewhere it was in Vermont. There is here no evidence that more than one advance of the ice came over the region we are considering. Evidences of the action of the glacier that moved over Vermont are everywhere and if other glaciers preceded it, all traces of their coming have been removed by the last. This seems to be of the time of the late Wisconsin and it covered the highest mountains, as scratches on bits of quartz enclosed in the gneiss show. The gneiss itself is

too much weathered to show glacier scratches.

The oscillations of the land surface in the Vermont region are well known to geologists, as are the effects produced upon the surface by which in various ways both highlands and lowlands were modified. One class of these phenomena is found in the ancient water levels which are plainly discernible in many localities.

Geologists are indebted to Professor H. L. Fairchild for his careful study of these levels through New England. So far as Vermont has been studied, Dr. Fairchild's results are given in the Tenth Report of the Vermont Survey.

Of the level plains, terraces and similar features he writes:

> The broad stretches of sand plains on both sides of the Champlain Valley and conspicuous in Vermont are clear evidence of standing water at levels far above Lake Champlain.

Again:

> The terraces, beaches and shore phenomena in the open Champlain Valley were produced by waters confluent with the sea. The summit marine plane lies uplifted to-day about four hundred feet above tide at the south edge of Vermont and about eight hundred feet at the north border of the state.

Most if not all the terraces in the Connecticut Valley which have been explained as due to river flood action are to be accounted for in the same manner as Professor Fairchild has shown in Bulletin, Geol. Society, Vol. 25, pp. 219–242.

The condition of Lake Champlain and the many changes through which this lake has passed from Pre-Cambrian time to the end of the Pleistocene forms an interesting chapter in the physiographic history of Vermont, but the story is far too long to be told at this time.

From what has been shown it will be seen that the present physiography of Vermont has become what it is through the action of a great variety of geological agencies during several periods of past time.

At least eight epochs may be defined. First, in Pre-Cambrian times were formed the hard crystalline rocks found in the interior of the Green Mountains. Second, an unknown interval of erosion and subsidence, during which a large part of the Pre-Cambrian beds were removed. Third, Cambrian deposition when the sandstone, shale and limestone of this time was laid down. Fourth, a relatively short period of erosion when these beds were all carried off except the few remnants now standing. Fifth, deposition of thick beds of limestone and shale in the Ordovician ocean. Sixth, a period of igneous activity and metamorphism during which the schist, quartzite, gneiss and slate and marble were formed. This was the time of the greater uplift of the Green Mountains as now they appear. Seventh, a vast interval from the close of the Ordovician to the beginning of the Pleistocene. Eighth, the Pleistocene glaciation and erosion.

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WHAT KINDS OF BOTANY DOES THE WORLD NEED NOW?[1]

FOR months, even years, after the great war began I felt that the world had suddenly been plunged into darkness, intense and impenetrable, in which one could only grope one's way, unable to determine or to keep one's direction, shocked and grieved that those lights, which were thought to serve as guides before, had so completely gone out. I believe now that this series of figures is wrong; that, instead, the world has had such a light turned upon it that we are dazzled, if not blinded, that its shams have been exposed as the pleasing envelopes of selfishness—mercenary, political and social—that the lights which had guided us before are still burning but that they have become so shaded and dimmed by human goggles that they disappeared in the flood of light which makes war a great revelation of human weakness, human wickedness, human stupidity, and human ideals.

[1] An address delivered at the meeting of the San Francisco Bay Section, Western Society of Naturalists, at Stanford University, on November 30, 1918.