CHAPTER XXVI

A GEOLOGICAL SKETCH OF JAFFREY

By Charles Palache, Ph.D.

Charles Palache was born in San Francisco, California, July 18, 1869. He was graduated at the University of California in 1891 with the degree of Bachelor of Science. He became a teaching fellow of mineralogy there in 1892 and received the degree of Doctor of Philosophy in 1894. He began teaching at Harvard University in 1896, first as instructor and then as assistant professor, and since 1910 he has been professor of mineralogy at that institution. He also has in his charge the large collections of the Mineralogical Museum, of which he is curator. He is a member of the National Academy of Science, a Fellow of the American Academy of Arts and Sciences, and a member of the Geological Society of America and of the Mineralogical Society of America, of which latter he was President in 1921.

He married August 15, 1899, Helen Harrington Markham of Cambridge, Massachusetts, and has three children. In 1910 he bought the Amasa Milliken farm on the Mountain Road in Jaffrey, in late years called the Downs farm, where he has since spent his summers in close neighborly relations with the Grand Monadnock, the subject of the following sketch.

The town of Jaffrey lies at the foot of Mt. Monadnock which rises nearly two thousand feet above the general level of its ponds and hills. The mountain is its most marked topographic feature and although the summit lies in an angle of the township and its long ridge is largely shared by the adjacent town of Dublin, Monadnock in a way *is* Jafrey.

The question must often arise in the mind of an observer why this mountain soars as it does so high and so isolated in the midst of the lower region at its foot. Is it perhaps because its rocks are different from and more resistant than those about it? Or has some volcanic force raised up this monument of deep-lying activity by piling up lavas? Why is it there? The answer is not easy to give nor is it perfectly sure. But some aspects of the geological history of the mountain can be stated which in part at least tell us why it stands so boldly forth.

The rocks composing Mt. Monadnock are not markedly different from those of the lower hills. The principal formation is the Monadnock schist, a banded, layered rock with abundant mica which stands with its schistosity at high angles in most of its exposures. On the bare ledges of the mountain one can clearly observe how the layers of this formation vary in mineral composition from place to place. Some bands are almost pure gray quartz; others are much more micaceous and some are filled with stout prismatic crystals of andalusite, a silicate of alumina, white or pinkish, which shows its presence best on the weathered surfaces. With it are sometimes seen red garnets, rarely large but always showing their characteristic round cross section and definite crystal boundaries. Some of the bands of schist contain graphite, others pyrite, the yellow sulphide of iron, which weathers to a rusty iron-stained rock with veins and efflorescences of bitter, white iron sulphate. Such weathered rusty schist is well exposed at the beginning of the Mountain House toll road; and the iron spring near the road at Ballou no doubt owes its abundant content of iron and sulphur to some deep-lying bed of this pyritic schist.

Ascending the mountain by the Mountain House trail one can see at many points high on the steep cliffs how the banded rock has been compressed and moulded into broad curving folds, sometimes abruptly cut off by small breaks or faults.

The story of these rocks is not hard for the geologist to read. They were originally sediments, beds of quartz sand and sandy clay, laid down in regular succession as horizontal layers on the bed of some ancient sea. Their age is not certainly known but in other parts of New England similar formations have been traced into localities where they still contain fossils which show them to belong to some part of the Paleozoic era. They are then at least as old as the Carboniferous or Coal-bearing period. To present their existing features however these sediments must have been deeply buried in the earth's crust where they have been heated under great pressure. Under such conditions new minerals form, organic matter is changed to graphite, clay becomes andalusite or mica; the rocks become more crystalline, coarser-grained, the bands deformed by the pressure. This is termed regional metamorphism and through its action we expect the formation of such schists, with such minerals and textures, as have been described.

At intervals on the bare crags of the mountain top other kinds of rocks may be seen although not in abundance. Veins of grey or white quartz, cutting across the bedding of the schists sometimes contain along their walls fine needles of black tourmaline. Larger crystals of the same mineral are seen rarely in dikes or veins of coarse granite pegmatite composed of feldspar and quartz with some mica. These are granitic in origin and show that somewhere not very deep beneath the present surface lie intrusions of the granite which is exposed and quarried in neighboring, lower-lying localities as in Fitzwilliam, Troy, and Marlboro. This granite when intensely hot and therefore molten was undoubtedly forced into the still deeply buried sediments and aided by its heat and gaseous exhalations in their mineral transformation.

Such are the chief rocks of Mt. Monadnock; and wherever the bedrock appears in neighboring lower grounds it is of similar nature. We cannot explain the mountain as due to peculiar or more resistant rocks. On the other hand we find no lavas nor any of the evidences of volcanic action such as elsewhere has piled up volcanic mountains. Our question is not yet answered. To find an answer we must trace the later history of these rocks.

The Paleozoic sediments and the granite intruded into them were transformed to their present condition when buried mile-deep beneath what was then the surface of the earth. For an unknown but doubtless very long time they lay thus buried. But finally they were slowly upheaved by gigantic earth forces over at least the larger part of New England; and through geologic ages the rising crust became at the surface subject to the attack of the agents of erosion. The higher the great mass rose, the more active, in a general way, became the disintegrating forces of frost and running water transforming the vast uprising block into mountains and valleys and gradually lowering the whole surface. This period of its history is perhaps at least as long as the unnumbered millions of years required for the formation and metamorphism of the rocks. Its immensity may perhaps be better understood when we know that long after its beginning the rocks composing the Alps and the Himalayas rose from the sea to become mountains and the volcanic cones of the Andes began to be formed. Our human time scales give us but feeble standards of comparison for these almost infinitely slow and long-enduring processes.

How high the old New England mountain mass may have been in its youth we do not know. But it is certain that however lofty it may have been, time has elapsed sufficient for its almost complete obliteration. In old age the larger part of the area of New England was reduced to a surface of low relief—almost in fact a plain in comparison to its earlier mountainous form. This *peneplain,* as it was first termed by William M. Davis of Harvard many years since, rises from near sea-level along the southern coast of New England with a gradual increase of elevation northerly so that about Jaffrey it lies somewhere between a thousand and thirteen hundred feet above the sea.

The main drainage lines of the region such as the Connecticut River were established early in the development of the *peneplain.* Those portions of the mountains furthest from the rivers were, at least in the later stages, lowered more slowly than the parts nearer to the streams and thus they stood out as residual masses, mountains standing as it were upon the general plain of erosion. Look at Monadnock from a distance as from some hill near Rindge or from Garfield Hill in Jaffrey, see photograph Chapter XXIX, and see how the mountain seems to float like a great battle-ship on the ocean of the forest-covered lower lands whose inequalities are lost in the general view. So also do Wachusett and the Temple Hills stand up from the lower regions about them—the *peneplain.*

So striking was this relation in the case of Mt. Monadnock that Davis took it as a type of such residual mountains and used its name to designate them with all their implied physiographic history. It has been widely adopted by geographic writers and one may come across the name *Monadnock* as a generic term in descriptions of lands of every continent.

This then is our only answer to the question first propounded. Mt. Monadnock is high, not so much because it was pushed up, since all the surrounding country was pushed up an equal amount; but because it withstood the destructive attack of the agencies of erosion better than the neighboring regions. It is a residual mountain.

The last agency to affect the physical form of the Jaffrey country was the ice of the glacial period. Compared with the vast expanse of time through which the processes already pictured were working, the glacial epoch is a modern event. It may perhaps have had its inception about one hundred thousand years ago; and we are fairly certain that the last ice disappeared from New England about thirty thousand years since. Its influence on the form of the landscape may be compared to that of a sculptor upon the block of stone from which he hews his statue. It modified the surface form of the mountains, scoured off disintegrated surface material, and spread the parings of the higher lands far and wide over the low lands, filling the hollows and damming the rivers to form ponds and lakes. But the effects were on the whole superficial.

The ice came from the northeast, advancing in its slow course over all the mountains of northern New England and reaching as far south as Long Island which is its greatest and most advanced terminal moraine. The thickness of the ice must have been at least several thousands of feet and the weight of this vast continental ice sheet was sufficient to warp down the underlying crust to the extent of many hundred feet. As the ice retreated, the land slowly rose again by elastic rebound but the sea followed its front inland many miles before the delayed uplift of the land at length drove it back nearly to its former bounds.

On the northern side of the summit of Monadnock one can see well how the ice ground off the rocks, leaving a rounded, hummocky surface, grooved and channelled in the direction of movement. The tools which did the grooving were rocks embedded in the ice. One can see a particularly vivid picture of this action on the ridge of the mountain about three-quarters of a mile from the summit along the Dublin trail. There on the narrow crest of the ridge, in a low saddle, a great boulder lies stranded on a polished rock ledge. Think of this boulder cased in ice with the weight of perhaps thousands of feet of ice pressing down upon it, and pushed slowly forward by the resistless movement of the glacier. The boulder barely reached the brink of the mountain ridge; had it gone but a few yards further it would have rolled down the southern slope when the ice at last released it. But as it is, the ice left it perched there so that we can see how deeply it must have bitten into the surface of the underlying rock as it was pushed along.

On the southern faces of the mountain the ice worked by plucking away the loosened crags rather than by grinding the surface; and the more precipitous cliffs at the summit still witness this tearing action.

Everywhere that rock is freshly exposed by removal of soil or forest growth, whether lying high or low, its surface is found to be smoothed and scored by the movement of the ice with its stone graving tools. How much actual lowering of the general rock surface was effected we have no means of determining accurately and opinions on this point vary widely. Certainly all decayed rock must have been removed from every projecting ledge.

On its surface the ice easily bore great blocks of rock, fallen upon it from cliffs or torn from the bed-rock and born upwards by inner ice currents. When the glacier melted such blocks were dropped, sometimes in swamps or on hillsides, sometimes on hilltops to perch precariously as "rocking stones," resting generally on rock of a kind different from their own. Those who ever saw above the quarry at Fitchburg the great boulder of gneissic granite brought by the ice from the vicinity of Lake Winnepesaukee and dropped upon the very different granite there, giving rise to the local name of Rollstone Hill, will understand best the strange bedfellows which resulted from this dropping of its load by the melting glacier.

As the advance ceased and before the retreat of the ice began there was probably a long period of stagnation; then followed the slow withdrawal, wholly of course by melting. The streams flowing beneath and upon the vast surface of melting ice must have been tumultuous torrents laden with sand, gravel and boulders and milky with the suspended rock flour, ground from its bed by the formerly moving ice. This flour, deposited in the sea or in lakes on the margin of the ice, formed finely layered clays, the annual layers of which, the "varves" of the Swedish geologists, can be counted to give an exact measure of the years during which the retreat lasted. The coarser material, washed out in vast quantities where the ice fronted on land, and well sorted by moving water, made the level sandplains, favorite growing ground of the white pine and beloved of the road builder, whose sand pits like that near East Jaffrey may be seen all over southern New England. Temporary still-stands of the ice marked accumulations of morainal materials which later were dams for ponds; or ice blocks, covered by detritus and so preserved from melting for long periods, ultimately melted to leave "kettle-hole" ponds. Often, by a process little understood, the ice overrode the debris at its base and thus was formed the "boulder-clay," that curious mixture of clay, sand and scored boulders, never sorted by water, which forms the hard-pan of many a farm.

It is difficult to correlate the scene of desolation which the retreat of the glacial ice must have left in its wake with the present landscape of tree-covered valley and hill. But it is certain that all the present vegetation must have migrated from the south after the ice had gone, the waters had receded and the climate become milder, to reoccupy the lands from which the glacier had stripped all the soil cover and whatever grew upon it. This slow migration of the plants and trees we can perhaps visualize and so obtain a better idea of the vastness of the rhythm of geological events.

Only with minds prepared to accept processes enduring through milleniums of centuries can we unravel the past history of the landscape which surrounds us or understand in any measure what is meant by the mountain which dominates it and is its most vital part —The Grand Monadnock.