THE ROCKS OF MOUNT RAINIER.

By George Otis Smith.

INTRODUCTORY.

The earliest geological observations on the structure of Mount Rainier were made in 1870 by S. F. Emmons, of the Geological Exploration of the Fortieth Parallel. The rock specimens collected at this time were studied later by Messrs. Hague and Iddings, of the United States Geological Survey.[1] This petrographical study showed that "Mount Rainier is formed almost wholly of hypersthene-andesite, with different conditions of groundmass and accompanied by hornblende and olivine in places." The only other petrographical study of these volcanics is that of Mr. K. Oebbeke, of Munich,[2] upon a small collection made on Mount Rainier by Professor Zittel in 1883.

On the reconnaissance trips on the northern and eastern slopes of Mount Rainier, during the seasons of 1895 and 1896, the writer had opportunity to make some general observations on the rocks of this mountain, and the petrographical material then collected has since been studied. The observations and collections were of necessity limited, both by the reconnaissance character of the examination and by the mantle of snow and ice which covers so large a part of this volcanic cone.

Two classes of rock are to be discussed as occurring on Mount Rainier: the lavas and pyroclastics which compose the volcanic cone and the granitic rocks forming the platform upon which the volcano was built up.

VOLCANIC ROCKS.

GEOLOGIC RELATIONS.

On Crater Peak a dark line of rock appears above the snow, and here the outer slope of the crater rim is found to be covered with blocks of lava. A black, loose-textured andesite is most abundant, and from its occurrence on the edge of this well-defined crater may be regarded as representing the later eruptions of Rainier. Lower down on the slopes of the mountain opportunities for the study of the structure of the volcanic cone are found in the bold rock masses that mark the apexes

[1] Am. Jour. Sci., 3d series, Vol. XXVI, 1883, pp. 222–235.

[2] Neues Jahrbuch für Min., etc., Vol. I, 1885, pp. 222–226.

of the interglacial areas. Examples of these are Little Tahoma, Gibraltar, Cathedral Rock, the Wedge, and the Guardian Rocks. These remnants of the old surface of the cone, together with the cliffs that bound the lower courses of the glaciers, exhibit the structural relations very well.

Even when viewed from a distance these cliffs and peaks are seen to be composed of bedded material. Projecting ledges interrupt the talus slopes and express differences of hardness in the several beds, while variations in color also indicate separate lava flows and agglomeratic deposits. Gibraltar is thus seen to be composed of interbedded lavas and pyroclastics, and on the Wedge a similar alternation is several times repeated, a pink agglomerate being exceptionally striking in appearance.

These lava flows and beds of volcanic ejectamenta thus exposed dip away from the summit at a low angle. The steepest dip observed was in the amphitheater at the head of Carbon Glacier, where in the dividing spur the dip to the northeast is about 30°. Some exceptions in the inclination of the beds were noted on the southeastern slope, where in a few cases the layers are horizontal, or even dip toward the central axis of the cone. In general, however, the volcanics composing Mount Rainier may be said to dip away from the summit at an angle somewhat lower than that of the slopes of the present cone. In the outlying ridges to the north, the Mother Range, Crescent Mountain, and the Sluiskin Mountains, the structure seems to be that of interbedded volcanics approximately horizontal. The extent of the volcanics from the center of eruption has not been determined. Similar lava extends to the south, beyond the Tattoosh Range, and volcanics of similar composition occur to the north, in the Tacoma quadrangle. The latter lavas and tuffs may have originated from smaller and less important cones, now destroyed by erosion.

A radial dike was observed at only one locality, near the base of Little Tahoma. In several cases the lava masses, as seen in cross section, are lens-shaped, and where associated with fragmental beds have unconformable relations. This shows that some of the lava flows took the form of streams, relatively narrow, rather than of broad sheets. Such a feature is in accord with the distribution of rock types. Thus along Ptarmigan Ridge for considerable vertical and horizontal range the rock shows only slight variation. The distribution of rock types will be more fully discussed in a later paragraph.

Of how large a part of the lava flows the crater still remaining was the point of origin is a question to be answered only after more detailed observation has been made. The best section for the study of the succession of flows and ejectamenta is the amphitheater at the head of the Carbon Glacier. The 4,000 feet of rock in this bold wall would afford an excellent opportunity for this were it not that frequent avalanches preclude the possibility of geologic study except at long range.

MEGASCOPIC CHARACTERS.

The volcanic rocks of Rainier are of varying color and texture. Dense black rocks with abundant phenocrysts of glassy feldspars, rough and coarse lavas of different tints of pink, red, and purple, and compact light-gray rocks are some of the types represented upon the slopes of this volcanic cone. In color, the majority of the rocks may be grouped together as light gray to dark gray. The black and red lavas are less common. In texture, the Rainier lavas are, for the most part, compact. Slaggy and scoriaceous phases are common, but probably represent only a small part of the different flows. Near the Guardian Rocks large masses of ropy lava are found which suggest ejected bombs. Agglomeratic and tuffaceous rocks are of quite common occurrence, although less important than the lavas. Vesicular lavas occur at several localities, and fragments of a light-olive pumice, many as large as a foot in diameter, wholly cover some of the long, gentle slopes southeast of Little Tahoma and in Moraine Park.

Contraction parting or jointing is often observed, being especially characteristic of the basaltic types. The platy parting is the more common, but the columnar or prismatic parting is well exhibited at several localities. The black basaltic lava east of Cowlitz Glacier shows the latter structure in a striking manner. The blocks resemble pigs of iron in size and shape, and where exposed in a vertical cliff these seem to be piled in various positions.

The rocks on the higher slopes of Mount Rainier are in general very fresh in appearance. An exception may be noted in the case of the rocks at the base of Little Tahoma, where some alteration is evident. The bright coloring of the surfaces of the lava blocks and the general appearance of the face of the cliff may indicate fumarole action at this point. There is also some decomposition along the inner edge of the crater rim, near the steam vents. On the lower slopes, some distance below the snow line, the freshness of the rock is not a noticeable feature, and it is seen that here weathering is of the nature of chemical decomposition as well as of mechanical disintegration.

MICROSCOPIC CHARACTERS.

Microscopically these lavas show more uniformity than is apparent megascopically. Rocks which in color and texture appear quite diverse are found to be mineralogical equivalents. The majority of these rocks are andesites, the hypersthene-andesites predominating, as was shown by Hague and Iddings; but over large areas the andesites are decidedly basaltic, and, indeed, many of the lavas are basalts. The megascopic differences are mostly referable to groundmass characters, the color of the rock being dependent upon the color and proportion of glassy base present. Therefore the degree of crystallization of groundmass constituents is of more importance in determining the megascopic appearance than is the mineralogical composition, and the basaltic lavas are for the most part light gray in color, while the more acid hypersthene-andesites are often black or red.

In petrographic character the lavas range from hypersthene-andesite to basalt. This variation is dependent upon the ferromagnesian silicates, and four rock types are represented—hypersthene-andesite, pyroxene-andesite, augite-andesite, and basalt—any of which may carry small amounts of hornblende. A rigid separation of these rock types, however, is impossible, since insensible gradations connect the most acid with the most basic. In the same flow hypersthene-andesite may occur in one portion, while in close proximity the lava is an augite-andesite.

These lavas have groundmass textures that vary from almost holocrystalline to glassy. The felted or hyalopilitic texture is the most common, and plagioclase is the principal groundmass constituent. The feldspars are lath-shaped, often with castellated terminations. In the more basic phases anhedrons of augite and of olivine appear, and magnetite grains are usually present. Flowage is often beautifully expressed by the arrangement of the slender laths of feldspar.

Among the phenocrysts feldspar is the most prominent. It has the usual twinning characteristic of plagioclase and belongs to the andesine-labradorite series, extinction angles proving basic andesine and acid labradorite to be the most common. Zonal structure is characteristic, being noticeable even without the use of polarized light. Zonal arrangement of glass inclusions testifies to the vicissitudes of crystallization, and often the core of a feldspar phenocryst is seen to have suffered corrosion by the magma and subsequently to have been repaired with a zone of feldspar more acid in composition.

Of the darker phenocrysts, the pyroxenes are more abundant than the olivine or hornblende. Hypersthene and augite occur alone or together, and are readily distinguished by their different crystallographic habits as well as by their optical properties. The hypersthene is usually more perfectly idiomorphic and occurs in long prisms, with the pinacoidal planes best developed, while the augite is in stout prisms, usually twinned. Both are light colored, and the pleochroism of the hypersthene is sometimes quite faint. According to the relative importance of these two pyroxenes, the lavas belong to different types, hypersthene-andesite, pyroxene-andesite, or augite-andesite.

Olivine occurs in certain of the Rainier lavas, in stout prisms somewhat rounded and often with reddened borders. The usual association with apatite and magnetite crystals is noted. The olivine varies much in relative abundance, so as to be considered now an accessory and now an essential constituent, and in the latter case the rock is a basalt.

Hornblende is not abundant in any of the rocks studied, although typical hornblende-andesite has been described among the specimens collected by Professor Zittel. Where it occurs it is in brown crystals, which have usually suffered magmatic alteration. In one case, where this alteration is less marked, the idiomorphic hornblende is found to inclose a crystal of labradorite, and thus must have been one of the latest phenocrysts to crystallize. It also surrounds olivine in this same rock,[1] which is a hypersthene-andesite, the hornblende and olivine being only accessory.

The different textures of these lavas are doubtless expressive primarily of diversity in the physical conditions of consolidation, but also in part of variations in chemical composition. The variations in mineralogical composition are likewise referable to these two factors, but here the latter is the more important. The hypersthene-augite-olivine variation, already referred to, doubtless well expresses the chemical composition of the magma, and deserves to be taken as the chief criterion in the classification of the lavas. As was noted by Hague and Iddings, the hypersthene and olivine play a like rôle, the former occurring when the silica percentage is somewhat higher than in basalt. It is exceptional to find the two in the same specimen, the one being absent whenever the other is present. The following analysis[2] of the typical hypersthene-andesite from Crater Peak shows the lava to be a comparatively acid andesite:

Analysis of hypersthene-andesite from Crater Peak, Mount Rainier.

	Per cent.
SiO_2	61.62
Al_2O_3	16.86
FeO	6.61
CaO	6.57
MgO	2.17
Na_2O	3.93
K_2O	1.66
	99.42

An analysis[3] of one of the light-gray, olivine-bearing rocks on the northern slope of the mountain gives a silica percentage of 54.86, and is doubtless representative of the more basic of the Rainier lavas.

The sporadic occurrence of hornblende in these andesites is principally the result of physical conditions rather than of chemical composition. The magmatic alteration of the phenocrysts of hornblende affords evidence of this variation in consolidation conditions, a diminution of pressure with continuance of slow cooling giving rise to the magmatic

[1] Observed by Iddings: Twelfth Ann. Rept. U. S. Geol. Survey, p. 612.
[2] Hague and Iddings, op. cit,, p. 225.
[3] Oebbeke, op. cit., p. 226.

alteration of the hornblende. That this change took place during the later stages of consolidation is shown by the relative age of the hornblende, noted above, and also by the fact that in one case a phenocryst of augite, where it abuts against the hornblende, has protected the latter from this alteration. The alteration is in part pseudomorphic, the hornblende retaining its characteristic outlines, but often there has been resorption. In one andesite the abundance of these remnants of hornblende and also of augite anhedrons in the groundmass may justify the conclusion that this augite andesite is of derivative origin, of the class described by Washington.[1] It may be noted also that hypersthene shows a tendency to magmatic alteration, although only rarely.

In a basal flow in Moraine Park, the slaggy and compact phases show differences in phenocrysts as well as in groundmass. The glassy rock has hypersthene as the predominant phenocryst, while feldspar is the more important in the compact and more crystalline andesite.

The distribution of the rock types described above is of interest. On the northern slope of the mountain, between Willis and Carbon glaciers, the characteristic lava is a gray andesite, smooth to rough in texture, and showing platy and columnar parting. Hypersthene is not the prevailing pyroxene, and olivine is usually present, often in such abundance as to make the rock a basalt.

In Moraine Park gray andesites also predominate, with both pyroxenes as phenocrysts, but here hypersthene is the more important. On the eastern slope on the Wedge, between Winthrop and Emmons glaciers, the lavas are pyroxene-andesites and vary much in megascopic appearance, although little in microscropic characters. These rocks are quite distinct from any seen to the north. The nunatak in Emmons Glacier is composed of hypersthene-andesite, but on Little Tahoma the lava shows more variety. Both augite-andesite and hypersthene-andesite occur, while at the southern end of this interglacial rock mass, just east of Cowlitz Glacier, the cliffs are composed of the prismatic black basalt. On Crater Peak, and below on Gibraltar, hypersthene-andesite occurs with considerable variation of color and texture. On the spurs west of Nisqually Glacier the andesites contain both pyroxenes, the augite being somewhat the more important.

The distribution of the volcanic rocks, as determined in the study of reconnaissance collections, indicates that the cone has been built up by eruptions of lava and of fragmental material. The successive lava streams were doubtless of considerable thickness, but were limited in lateral extent. The beds of fragmental material are of the nature of flow breccias and of coarse agglomerates on the higher slopes, while tuffs occur at a greater distance from the center of eruption. This composite cone appears to be remarkably free from radial dikes, which may indicate that the volcanic energy was expended chiefly at the crater. The variation in rock types on different sides of the volcanic

[1] Jour. Geol., Vol. IV, 1896, p. 276.

cone may be evidence of changes in position of the center of eruption. The destruction of an earlier crater and the eccentric position of a later would give rise to such a radial distribution of lavas as has been described above.

GRANITE.

OCCURRENCE.

The presence of an acid holocrystalline rock on the slopes of Mount Rainier was first reported by Lieutenant Krautz in 1857, from whose accounts Dr. George Gibbs was led to announce the occurrence of granite as a dike in recent lavas.[1] Emmons in 1870 observed a cliff of "beautiful white syenitic granite" rising above the foot of Nisqually Glacier and correctly interpreted the geologic relations. In 1895, on a reconnaissance trip, the writer identified granite among the bowlders composing the lateral moraines of Carbon Glacier, as well as on the surface of the glacier itself, and in the following season bowlders of granite were found to be plentiful in the river bed at the foot of this glacier. This anomaly of granite bowlders coming from a volcanic peak was also noted in the canyon of the Nisqually by Emmons.

In the somewhat more careful study of the Mount Rainier rocks, search was made and the granite was found in place at several points on the northeastern slope. A biotite-hornblende-granite was observed on Carbon River at the mouth of Canada Creek, about 12 miles from the summit of Mount Rainier, and at Chenuis Falls, 2 miles up the river, a finer grained holocrystalline rock occurs, apparently an aplitic phase of the granite. In the lower portion of Carbon Glacier, near its eastern edge, a nunatak of granite can be seen, while the same rock occurs farther to the east, beyond the older of the lateral moraines. Higher on the slopes of Rainier a more marked ridge of granite was traced. A knob rises above the eastern moraine of Carbon Glacier at an altitude of between 7,000 and 8,000 feet, and the more prominent features to the east in Moraine Park also owe their survival to the greater erosion-resisting power of the granite.

PETROGRAPHIC DESCRIPTION.

These granites have few features worthy of special mention. Hornblende and biotite are the ferromagnesian constituents and vary much in relative importance. The variations from hornblende-granite to biotite-granite occur in the same knob or ridge, and considering all occurrences the two varieties seem to be of equal development. There is also some variation in the amount of quartz present, and in the relative importance of the orthoclase and plagioclase. All of these characters are also found in the granites of the Northern Cascades.

[1] Emmons, Bull. Am. Geog. Soc., 1877, No. 4, p. 45.

RELATION TO THE VOLCANIC ROCKS.

Along the side of the knob overlooking Carbon Glacier the granite as seen from a distance appears to be intrusive. Blocks of andesite cover the slope, deposited there by the glacier at a time when it possessed greater lateral extent, and the granite talus from above crosses this same slope in a narrow band. The relations prove less deceptive on close examination, and the granite is seen to constitute an older ridge. Farther along this ridge, at the cliffs on the northeastern edge of Moraine Park, the granitic rock is found overlain by the lava. The actual contact of the two rocks is concealed by soil filling the crevice left by disintegration along the contact plane. The granite, however, exhibits no intrusive characters, while the overlying andesite becomes scoriaceous in its lower portion, although compact immediately above. This contact is on the southern side of the granite ridge, the crest of which is approximately east-west. This position of the lava contact considerably below the highest occurrence of the granite indicates that the topographic features of this old granite ridge were even more marked at the time of the eruption of the lavas and the building of the volcanic cone. Above this ridge of granite on the one side tower the cliffs of bedded volcanics which compose the Sluiskin Mountains, and on the other is the andesite ridge bounding the canyon of Winthrop Glacier. Thus Mount Rainier, although a volcanic peak, rests upon an elevated platform of granite which is exposed by erosion at a few points on the slopes of the mountain.

SUMMARY.

The volcanic rocks of Mount Rainier include both lavas and pyroclastics. The breccias, agglomerates, and tuffs, although of striking appearance, are, perhaps, less important elements in the construction of the composite cone.

The lavas vary much in color and texture, but these megascopic differences are referable rather to the degree of crystallization of the magma than to its chemical character. The variation in the chemical composition of the lavas expresses itself in mineralogical differences, and thus four rock types are distinguished—hypersthene-andesite, pyroxene-andesite, augite-andesite, and basalt. The distribution of these types indicates a radial arrangement of lava streams, and hypersthene-andesite is the more abundant variety of lava.

Granite is exposed on the slopes of Rainier where erosion has cut away the overlying lava, and it is plain that the volcanic cone rests upon an elevated platform of older rock, approximately 8,000 feet above sea level.