



MAP OF GODHAVN PROVINCE, NORTH GREENLAND, BY R. HAMMER AND K. I. V. STENSTRUP, 1878-80.
(Meddelelser om Grønland, vol. iv, pt. ii, 1893.)

NOTES ON THE ROCKS OF NUGSUAKS PENINSULA AND ITS ENVIRONS, GREENLAND

By W. C. PHALEN

PART I

INTRODUCTION

The rocks which prompted the following study were collected by Messrs. Chas. Schuchert and David White on Nugsuaks peninsula and its environ, Umanak island, during the summer of 1897. It will be recalled¹ that the object of the excursion of the above named gentlemen was primarily paleontological and stratigraphical, and not petrographical, hence the field relations of the rocks were not worked out with the detail demanded by the student of petrography. When it is understood, moreover, that but twenty-three days were at the disposal of these travelers for the pursuit of the legitimate object of their trip, it will be evident that but little time could be devoted to side issues.

"Nugsuaks peninsula . . . lies somewhat obliquely between $69^{\circ} 55'$ and $70^{\circ} 57'$ north. From the nearest point between Karajaks fjord and Torsukatak glacier at its base to the western extremity is about 90 miles, the width for nearly two-thirds of its extent being 30 miles. The Cretaceous and Tertiary deposits constitute the western two-thirds of the peninsula, the Tertiary sediments continuing to near its western extremity. The interior of the peninsula is either covered by local ice caps or is unexplored, so that, with the exception of Ifsorisok, an inland point near the western end of the peninsula, the Cretaceous and Tertiary have been seen only beneath the basalt along the coast or along two short river valleys."² For all practical purposes Umanak island may be considered a portion of this peninsula, and, geologically speaking, continuous with the mainland lying to the south; hence its sedimentaries, if such exist, must be of lower Cretaceous age, belonging to the Kome series. It is a very small body of land, lying directly northeast of Kook, the point where the Greenland expedition landed,

¹ See *Bulletin Geol. Soc. Amer.*, IX, p. 344, 1897-98.

² *Ibid.*, p. 345.

and judging from the character of the material submitted for study, its surface rocks are in a remarkably perfect state of preservation, as compared with those collected from the mainland. Why this should be so is rather difficult to say off-hand, though it seems most plausible to assign it to recent glacial scouring, the island being a typical nunatak. A short distance west of Kook glacier, on the mainland of Nugsuaks peninsula, the Kome plant beds are described¹ as overlying probable older beds, lying between gneissoid hillocks. These gneissoid terrains are assumed by me to be Archean and of undoubted continuation with that gneiss, to be directly described, which constitutes the entire southern portion of Umanak island, stretching back from the coast in low-lying irregular masses for a mile or so.

UMANAK ISLAND

Gneiss (Cat. No. 75,478).—This rock is typically gneissoid in character, consisting of roughly alternating layers of quartz, associated with feldspar and biotite. At times these layers may be traced completely through an ordinary hand specimen. At other times they pinch out, or merge into each other, forming broad bands of dark and light colored constituents. These are bounded by slightly narrower bands of pure quartz and feldspar. This latter constituent is apparently fresh. It is light pink in color and may be readily recognized by its numerous glistening faces from the base and brachypinacoid. The quartz may be readily recognized by its glassy appearance and lack of cleavage. The micaceous constituent is perfectly black; in spots, where alteration has occurred, it is golden brown. Withal the specimen appears as though it might have come from a zone far within the crust of the earth, instead of from its surface, as is the case.

When viewed in thin section, the structure is typically hypauto-morphic granular, consisting of an irregular mosaic of the constituents already noted with feldspar as the most abundant mineral. Excepting an occasional microcline, the feldspar is nearly all orthoclase and albite. It frequently exhibits perthitic intergrowths, the interlamination, at times, being exceedingly fine. Slight alteration has resulted in the usual products, kaolin and sericite. These occupy, at times, the entire grain; again occurring in irregular lines or patches or simply scattered along cleavage lines or the bounding planes of twinning lamellæ. When in the last position, the included particles are frequently oriented normal to the bounding planes.

¹ Op. cit., p. 346.

Even with the highest powers of the instrument, the determination of the exact nature of these inclusions is unsatisfactory. The most that may be said is that they are exceedingly irregular, often continuous and skeleton-like in shape. Of a dull brown color, they must be composed essentially of iron oxide and are undoubtedly the basis of the pink color of the feldspar.

Such inclusions are often observed in the quartz, though when present in this mineral, they are confined generally to the cracks which seam this constituent. They have probably reached their present position through capillary action, having originated in the adjoining feldspathic minerals. Besides orthoclase, albite, and microcline, there is still a fourth feldspar, which reveals a faint suggestion of albite twinning. Owing to the imperfect development of the twinning, and its extreme rarity, absolute measurements of its extinction were well nigh impossible. Such as were made are very small and the feldspar is undoubtedly the acid plagioclase, oligoclase. The feldspars show a few inclusions of apatite, zircon, and sphene, and at times rather large quartz grains. Rarely these latter show a tendency toward micrographic development.

Quartz is present in abundance, but only in its ordinary form. The only colored constituent is biotite. It occurs in irregular scales, never automorphic, rounded against the quartz and feldspar. At times it is deep green in color, but more usually deep brown. The greenish tints are peripheral and may be due to alteration. With the biotite is associated much secondary magnetite, often in skeleton crystals, often occurring in seams, and at times replacing its parent mineral. Inclusions in the biotite could not readily be detected, owing to the opacity of this mineral. Titanite, which is a notable accessory, is frequently associated with the magnetite. Zircon and apatite, which occur in small amounts, have already been mentioned. To summarize, then, there are present albite, orthoclase, microcline, oligoclase, quartz, biotite, kaolin, sericite, apatite, zircon, and sphene.

An analysis of the rock follows:

ANALYSIS OF GNEISS. (W. C. PHALEN, ANALYST.)

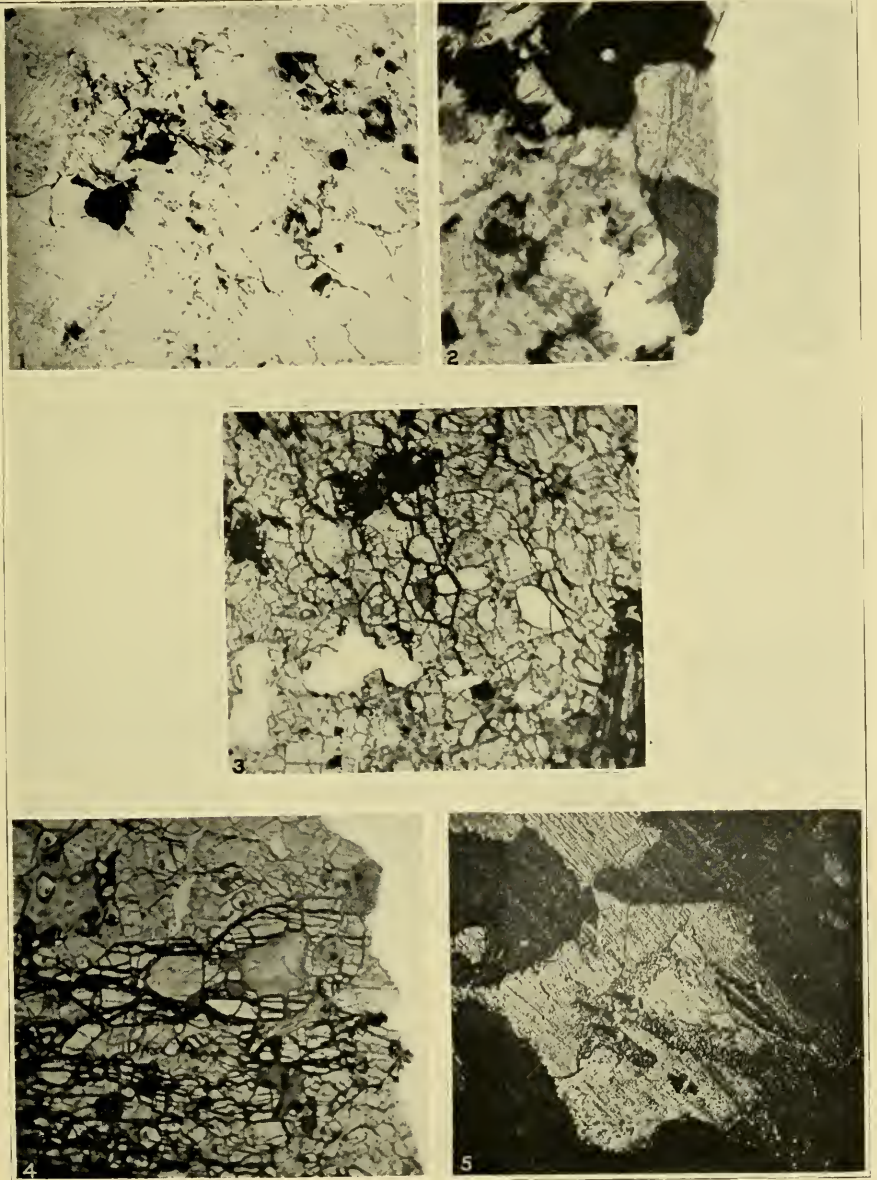
SiO ₂	69.07
Al ₂ O ₃	14.09
Fe ₂ O ₃	1.49
FeO	2.37
MgO .....	.98
CaO	3.14
Na ₂ O	5.18
K ₂ O	2.71
H ₂ O above 100° .....	.26

H ₂ O below 100° .....	.04
TiO ₂ .....	.78
P ₂ O ₅	Trace
MnO	Trace
	<hr/>
	100.11

Granite.—Associated with the gneiss occurs a rock without banding, a normal granite (Cat. No. 75,479). It is probably of similar genetic origin to the gneiss. Its mineralogical constituents are the duplicates of those in the gneiss, even to the merest accessories and alteration products, but the proportions vary, especially that of the micaceous mineral, biotite. Its geological relationships, further than that it constitutes a part of the lower portion of the island, as with the preceding rock, are unknown. It is of medium grain, of pinkish hue, and though a surface sample there are no evidences of alteration visible to the naked eye, with the possible exception of an occasional green speck of chlorite, which may be a product of biotitic alteration. The structure is hypautomorphic granular.

Under the lens the feldspar is seen to constitute fully seventy-five percent of the rock, the four varieties mentioned with the gneiss being present, viz., orthoclase, albite, microcline, and oligoclase. There is also an excellent development of the micrographic structure. The feldspars have slightly changed, producing kaolin and sericite, and contain many liquid inclusions, as is also the case with the quartz. Strongly pleochroic biotite, slightly altered and frequently surrounded by a rim of secondary skeleton magnetite, primary magnetite, zircon with small portions of epidote, chlorite, and apatite, constitute the remaining constituents of the rock. A unique association of original magnetite and zircon was noted as shown indistinctly in plate LIV, 1. The zircon forms a nearly complete ring about the magnetite, its *c* axis occupying a tangential position with respect to the periphery of the enclosed mineral.

Directly back of this low lying expanse, which has been described as stretching a mile back from the coast, there rises to a height of 3,700 feet, a typical nunatak, composed of granite (Cat. No. 75,480), essentially similar to that just described. This forms the main residual mass of the granite intrusion, and it is fairly probable that the more basic gneiss already described is simply a differentiated portion of this central magma. Thus it agrees beautifully, so far as position goes, with our usual conceptions of magmatic segregation which places the acid phases in the center of an eruptive mass and the more basic phases in the periphery. The difference in elevation of the granite masses is perhaps due to a fault. That



PHOTOMICROGRAPHS OF GREENLAND ROCKS.

dislocations have occurred in certain portions of the elevated mass is evident from the foldings exhibited in the dark intercalated layers in the granite. These horizontal dikes of diorite, for such they prove to be, present many phases, as present in the Museum collection, ranging from the finest grain in the lowest to a pegmatitic facies. In every case the structure is decidedly schistose, traceable to the shearing action consequent to earth movements.

An analysis of this granite follows:

ANALYSIS OF GRANITE. (W. C. PHALEN, ANALYST.)

SiO ₂	76.03
Al ₂ O ₃	12.02
Fe ₂ O ₃ .....	.69
FeO .....	.68
MgO .....	.18
CaO	1.61
Na ₂ O	2.97
K ₂ O	5.72
H ₂ O .....	.20
TiO ₂ .....	.28
	100.38

The granite needs no detailed description, agreeing so far as constituents go with the granites previously described. Like these, it contains the four feldspars, orthoclase, microcline, albite, and oligoclase. The albite frequently exhibits perthetic intergrowths with both the potash feldspars. Granophyric groups were also noted.

Diorite.—This rock (Cat. No. 75,481), constituting the lower dark zone in the central elevated mass of the island, might on casual inspection be called amphibole schist, for it has a decidedly laminated structure, produced by a similar orientation of its two essential components, amphibole and feldspar (for such the lighter mineral proves to be). The amphibole occurs in elongated, lath-shaped forms with glistening cleavage plates and is perfectly fresh. Associated with it in a very few places occurs a greenish mineral, probably chlorite, though no such mineral was observed in the thin sections studied.

In spots the crystallization of the amphibole is much coarser than the average. Here it is associated with feldspar, also of coarser grain, producing a pegmatitic facies. An occasional grain of pyrite was observed on the fresh fracture, and an occasional garnet also was noted.

Under the microscope the amphibole proves to be the light green variety, hornblende. It occurs in continuous masses, with splendid

development of the prismatic cleavages. The pleochroism is very strong with *A*, yellow, *B*, yellowish-green, and *C*, bluish-green. The absorption scheme is the usual $C > B > A$. Very few basal sections were observed, but when noted, the rather rarely developed macro-pinacoidal cleavage (100) was distinctly seen. An occasional twin was noted, and with the exception of an occasional apatite, a fragment of feldspar, and perhaps a zircon or two, the hornblende contains no included minerals. The feldspar, the light colored mineral filling the interstices between the hornblende, has undergone considerable change. In polarized light it appears rather clouded, though not at all commensurate with the amount of change which it has undergone. The true extent of this change may be seen by diminishing the illumination; then it appears that alteration is quite general, that as a rule it follows the cleavage cracks or composition planes of the twins, and that, as a result, a secondary mineral has been produced with brilliant interference tints, probably sericite. To a very small extent calcite is present in spots, as proved by faint effervescence when the specimen is touched with acid. Twinning of the plagioclase, according to the albite law, was noted, though it is not general, and the high symmetrical extinctions indicate, together with those on the pinacoids, that the feldspar is a labradorite of a composition approximating Ab_1An_1 to Ab_5An_5 . It is evident that the feldspar has accommodated itself to the space remaining after the crystallization of the ferromagnesian constituent, and in the complete absence of quartz was the last constituent to crystallize.

Additional to the feldspar and hornblende occurs magnetite, most commonly situated on the peripheral portions of, or enclosed by, the hornblende. Usually it is surrounded by a colorless or light-green rim, appearing as though formed at the expense of the amphibole. An occasional red scale of hematite was also observed, associated with the magnetite. Pyrite, already noted among the megascopic constituents, is readily diagnosed in incident light. Tabulated in the order of their abundance, there are present:

As Essentials	{	Hornblende.	{	Sericite.
		Labradorite		Calcite.
As Accessories	{	Magnetite.		
		Pyrite.		
		Hematite.		
		Zircon.		
		Apatite.		
		Garnet.		

The upper intercalated dikes (Cat. Nos. 75,482, 75,483, 75,484) are as a rule more coarsely grained than the lowermost, but in most instances the decided schistose structure is still apparent. In addition to the minerals mentioned in the description of the lowermost dike, biotite is developed macroscopically, and is especially prominent in the most coarsely grained phases of the rock. There is present also a silvery, micaceous mineral, evidently a secondary product after amphibole and biotite. When viewed in thin section, the minerals appear pronouncedly coarse in grain and irregularly segregated. At times whole areas of variously oriented amphiboles occur with no feldspar whatever; while masses of feldspar with no foreign minerals occur in the same way. The pleochroism of this amphibole is similar to that of the hornblende already described, namely, *A*, yellow with greenish tinge; *B*, green with a yellow cast, and *C*, blue or bluish-green. The absorption scheme is $B \cong C > A$. Generally the mineral appears to be quite fresh; it, however, shows bright interference tints at its edges, as compared with those of its mass. This is due to incipient alteration which has produced a light brown micaceous mineral, strongly dichroic, and with bright interference tints, as already noted. In some cases much of the unaltered hornblende still remains.

The development of the feldspars reaches its largest scale, of course, in the pegmatitic facies, and here could be observed albite twinning in the macroscopic way. Here, however, the feldspar could be determined only unsatisfactorily in the ground mass of the rock, alteration having proceeded too far to admit of positive measurement. A fresh cleavage fragment from one of the pegmatite areas gave extinctions of oligoclase. This is too acid, however, to agree with the main mass of the feldspar, which, as in the case of the lower dike, is made up chiefly of andesite-labradorite or a plagioclase of intermediate composition. Sections which might ordinarily have served as diagnostic material are completely transformed into brightly polarizing scales, leaving, but not always, a tiny spot, still showing the albite lamellæ intact.

Additional to the minerals already described, quartz and biotite occur in the pegmatitic facies of this rock. The latter mineral is best developed in the coarser portions, but it occurs also in the main ground mass, in the usual lath-shaped forms with fringed terminations, and also in scales from the base. In ordinary light it is brown in hue; in polarized light, strongly dichroic with rays of a brownish tint, vibrating normal to its cleavage, while those parallel to this direction are so strongly absorbed as effectually to obscure all color.

Magnetite occurs rather plentifully, especially in the region of the altered mica. It has been produced as an alteration product of the ferro-magnesian minerals and simultaneously with the secondary mica. Some original magnetite was also noted.

The lower dike material, with its finer grain and homogeneous structure, represents perhaps more fairly than do any of the upper sheets the typical dioritic magma, whence the sheets have come. Its homogeneity renders it a safer criterion to judge of the constitution of the dioritic magma—hence its analysis is given, as follows:

ANALYSIS OF DIORITE. (W. C. PHALEN, ANALYST.)

SiO ₂	47.80
Al ₂ O ₃	18.24
Fe ₂ O ₃ .....	.35
FeO	9.27
MgO	8.08
CaO	11.44
Na ₂ O	2.24
K ₂ O .....	.45
H ₂ O above 100° .....	.58
H ₂ O below 100°	—
TiO ₂	1.46
P ₂ O ₅ .....	.24
MnO .....	.55
	100.70

In addition to the rocks already described from Umanak island, there occur others of sufficient interest to warrant description. Unfortunately the relationships of these rocks are entirely unknown, hence their value as petrographic factors in this province is largely curtailed. The one is a syenite, the other a diorite of more than passing interest, owing to the occurrence in it of an amphibole with peculiar parting. The description of these rocks with an analysis of the separated amphibole follows.

Syenite.—This rock (Cat. No. 75,485) is salmon pink in color, with holo-crystalline texture, consisting for the greater part of feldspar with an occasional vitreous quartz. The structure tends to the porphyritic, the largest feldspars frequently having diameters of one centimeter or more and sinking from this size to microscopic dimensions. Occupying fissures between the feldspathic particles may be seen a green mineral, closely resembling epidote in color, while lustrous specks of pyrite are not uncommon. Cavities are scattered throughout the mass of the rock.

The texture is typically hypautomorphic granular, with porphyritic structure, and when viewed through the microscope presents a most heterogeneous appearance. This heterogeneity is in complete accord with the macroscopic appearance of the rock, for in places it is essentially syenitic, in other spots granitoid. Areas devoid of quartz are contiguous to those where silica constitutes fully one-fourth the mass.

This silica does not have the appearance of typical original quartz; it does not form distinct crystals, but appears in vein-like masses, elongated and irregularly shaped, surrounding large and distinct microclines, and frequently enclosing smaller particles of the same mineral. In this occurrence it is distinctly pœcilitic. It has evidently, at least in part, in these spots been produced as a result of changes which the feldspar has undergone. To strengthen this hypothesis, similar irregular masses, very much smaller than those above referred to, occur in the midst of the larger feldspars.

In addition to the secondary quartz, there is also present a smaller portion of undoubted original quartz. This occurs with automorphic outlines in sections from the prism zone with pyramidal terminations and in various other irregular forms. Liquid inclusions are abundant.

Feldspar, of the variety microcline, constitutes the largest mass of the rock. It is associated with a small amount of orthoclase. In the former mineral a splendid development of the characteristic grating structure obtains. This constituent, as well as the orthoclase, is universally filled with minute scales or lenticular particles of iron oxide, at times segregated so as comparatively to obscure the mass of the rock. These particles give, even in the thin sections, a faint reddish-brown tinge to the rock and are the basis of the salmon pink color observed in the hand specimen. These inclusions are frequently massed, especially at the boundaries of the crystals and in those portions of the rock where crystallization has taken place on a fine scale, *i. e.*, in the non-porphyritic portions. In the phenocrysts they are scattered in irregular and broken lines and are accompanied by a multitude of liquid inclusions. No perithitic intergrowths were noted.

Of accessories there are very few; epidote and zircon were noted. The former, of undoubted secondary origin, occurs in very irregular patches, frequently elongated. It is faintly pleochroic and is much obscured by segregated iron oxide. Basal cleavage is roughly developed. A scattering zircon was noted, but of apatite there is apparently none. Allusion has already been made to the abundance

of iron oxide, hydrous and anhydrous, which constitute the pigment in the rock.

Diorite (Cat. No. 75,486).—As with the diorites already described (see p. 187), so here also is the orientation of the essential constituents, hornblende and feldspar, such as to produce a decided sheared or schistose structure. Besides these two constituents, an occasional speck of light brownish-gray silvery mica may be seen, usually included in the hornblende.

Hornblende.—This mineral is present in irregular and connected grains, strongly pleochroic, with vibrations of the following color scheme: *C*, generally, bluish-green; *B*, green, and *A*, yellow with absorption $B > C > A$, with *B* and *C* lying very close together. Of inclusions, few were noted, an occasional irregularly shaped magnetite, a fragment of feldspar, and an occasional speck of brown mica, constituting the list.

Upon closer examination the hornblende presents many points of rather unusual interest. Its color has been described as green; this statement, however, needs qualification, for in spots the mineral is perfectly colorless, other amphibolic characteristics remaining in full perfection. This bleaching of the mass of the crystal is apparently not connected with decomposition or alteration in any way. The cleavage lines of the mineral stand out full and clear. The extinction angles remain as in the contiguous green portions and the mineral extinguishes as a unit. The interference tints of the bleached portion are higher than those of the green parts. A bleaching, similar to this, has been remarked by G. H. Williams¹ in the hornblende of cortlandite. This author says: "The mineral (hornblende) becomes colorless and consequently non-pleochroic, while retaining the compact structure and optical behavior of the unaltered portion; later there is developed, particularly around the edges of the hornblende, a bright, emerald green substance which, on account of its lack of dichroism and feeble action on polarized light, may be regarded as chlorite." The hornblende of this specimen also exhibits a uniform bleaching in its peripheral portions, and the hornblende has doubtless become chlorite in these places. Very often the spaces, or boundaries between adjacent hornblendes, are filled with sericitic material which has come from the feldspars. It is possible that the waters which have produced this sericitic change may have bleached the hornblende along its path, thereby changing its composition to the less ferruginous chlorite.

¹ *Am. Jour. Sci.*, xxxi, 1886, p. 34.

Another feature of the hornblende is a perfect parting parallel to the plane (101). This is rather indistinctly shown in plate LIV, 2, in the right portion of the figure, and in the same crystal of hornblende there is shown the dark hornblende associated with the bleached material. This parting is far more perfect than any cleavage possessed by amphibole, not excepting the prismatic. It is present as a series of rather fine, sharp black lines, parallel to each other, and making an angle of 75.8° with the prismatic cleavage on the brachypinacoid. Though rather rare, the phenomenon is not unique; it is first mentioned by Jermejew,¹ and incidentally referred to by Williams² and Vom Rath.³ Cross⁴ and Mügge⁵ have also remarked it.

In more recent articles, Williams⁶ and Weidmann⁷ have described the phenomenon at some length, and have noted in connection with it twinning lamellæ. At times in the sections under discussion a faint white band could be seen between the parting planes. The highest powers, however, failed to resolve any twinning lamellæ, and it is probable that none exists in these particular sections. Though it cannot be positively stated that the parting planes are concentrated near fractures and are hence of dynamic origin,⁸ the evidence which points to this view is very strong. As a rule they are concentrated at the boundaries of the hornblende crystals and tend to pinch out toward their centers. If now it is borne in mind that the rock under discussion has been sheared, and that its present crystalline nature is most evidently the result of dynamic metamorphism, it will not be difficult to assign a similar explanation for the observed parting planes. An analysis of the separated amphibole is as follows:

SiO ₂	42.79
Al ₂ O ₃	15.04
Fe ₂ O ₃	5.44
FeO	11.61

¹ *Neues Jahrbuch f. Min.*, etc., 1872, p. 405.

² *Am. Jour. Sci.* (3), XXIX, 1885, p. 486.

³ *Sitzungsber. d. Niederrh. Ges. f. Natur. u. Heilkunde*, July 7, 1886

⁴ *Tschermaks Min. u. Pet. Mitth.*, IV, p. 386, 1881.

⁵ *Neues Jahrbuch f. Min.*, etc., 1889, I, 243.

⁶ *Am. Jour. Sci.*, XXXIX, 1890, p. 352.

⁷ *Am. Jour. Sci.* (4), XV, March, 1903, p. 229.

⁸ Williams (*Am. Jour. Sci.*, XXXIX, May, 1890, p. 335) and Weidmann (*ibid.* (4), XV, March, 1903, p. 230) both assign a secondary, dynamic action as the cause of these gliding planes.

MgO	11.00
CaO	10.24
Na ₂ O	2.89
K ₂ O .....	.47
MnO .....	.54
	100.02

The feldspar of the rock is much kaolinized and clouded in spots. As a result of this, many tiny flakes of a highly doubly refracting mineral are present. This mineral, sericite, often penetrates the bounding planes between the hornblendes and frequently the larger cracks in the latter mineral. This process of sericitization is peculiar in that its effects are local, *i. e.*, one section of a feldspar may be completely changed, while the contiguous crystal may not have suffered any alteration whatever. Albite twinning, sometimes accompanied by pericline twinning, is frequent, though not the rule. The small extinctions, symmetrical with respect to the traces of the albite lamellæ, indicate a feldspar of the andesine series.

Occasionally there occurs as inclusions in the hornblende and in the feldspar a fibrous mineral, evidently a member of the mica group. Its exact nature, further than this, cannot be ascertained, owing to the paucity of strong diagnostic features. It is yellow in color, strongly dichroic, with rays vibrating parallel to the cleavage planes of a yellow tint and colorless normal to this direction. The hornblende, near at hand, has been bleached, and the yellowish-brown color of the mineral in question naturally leads to the supposition that part of the iron content of the hornblende has been appropriated. It forms an intermediate link between the muscovite, which is present in slight amount, and the bleached peripheral parts of the hornblende.

One other constituent deserves mention, *i. e.*, magnetite present as inclusions in both hornblende and feldspar. It is irregular in shape and is frequently surrounded by a pale halo.

NUGSUAKS PENINSULA

Kaersut.—Returning now to the mainland of Nugsuaks peninsula at Kook and traveling west to Kaersut, the gneissoid crystallines still continue overlain by cretaceous shales and sandstones, intercalated with coal streaks and basalt flows. At an altitude of 880 feet above the plant beds the shales have been baked and the lignite converted to carbonite by the intrusion of a mass of horizontally bedded peridotite which forms a cliff 200 feet high.

Peridotite var. picrite

At first glance this peridotite (Cat. No. 75,487) might be mistaken for a basalt, with an interlacing network of segregated olivine. It is black in spots, or rather has a blackish-brown augitic base, through which the olivine runs in zigzag courses, producing a mottled or inlaid appearance, remarkably clear and striking. A vein-like penetration of olivine into the black ground mass was also observed. On closer examination the grain of the rock proves to be rather fine, the olivine granules, however, being macroscopically distinct, while those of the ground mass are practically irresolvable.

Under the microscope the following minerals were observed—olivine, augite, chlorite, feldspar, biotite, magnetite, limonite, hematite, and apatite. Of these constituents olivine is by far the most abundant. It occurs in perfectly automorphic forms, excepting when corroded by the surrounding magma. The crystals are in large part isolated and distinct from each other. Often very irregular masses are present. When isolated, there is, as a general rule, a development of the micropœcilitic structure, though in no case are the isolated particles broken from a parent crystal, but are *per se* crystalline units. In many instances the olivines present a completely shattered aspect. Fissures penetrate them in all directions, often arranged radially with respect to the center and generally filled with a light-brown ferritic pigment. This phenomenon is not attributable to any pressure which the rock has sustained, for no evidences of strain are visible in any of the sections studied. Only in a single instance was undulatory extinction noted. Not only are the individual phenocrysts shattered, but the entire sections themselves seem to be rifted in a more or less regular manner. Along these zones of fracture the rock is broken up into a series of parallel cracks, filled as with the olivines with brown and black iron oxides. We have here a phenomenon closely related to rifting, a microscopic phase of jointing, as it were.

In many instances the olivines are in an advanced state of alteration and often the entire nucleal portions of crystals have been converted into light green, slightly dichroic prochlorite. This chloritization furnishes the key to the explanation of the radiating cracks observed in the olivine, for the process is essentially one of hydration and expansion, which produces the radial cracks observed.¹ The process is not always nucleal, however, for simultaneous with and independent of these changes in the interior of the crystal,

¹ See plate LIV, 3, in the automorphic olivine, represented in the middle of the illustration.

similar changes have occurred in the peripheral portions. Accompanying the separation of prochlorite there is much light-brown iron oxide, limonitic matter, resulting from the ferruginous portions of the olivine. Often these ferritic portions are oriented in fairly parallel layers about the prochlorite nuclei. Immediately adjacent occurs a layer of limonite, bounded in turn by a rim of serpentine, while this in turn is surrounded by a border or zone of magnetite, compact and black with jagged border, the points projecting normal to the surfaces of alteration. At times the limonite is absent; in other cases limonite alone is present with no magnetite.

Alteration is not at all confined to the olivine, for whole areas of pyroxene have made way for it and, curiously enough, in those spots where the changes in the pyroxene has been most profound, the olivine retains its original perfection of form and composition.

Liquid inclusions are abundant and are arranged in zones or clouds, nearly always concentrically and in juxtaposition to a layer of iron ochre. Often these inclusions are so numerous as to cause these particular areas to become nearly opaque.

The ground mass of the rock is formed by a violet-tinted augite, faintly green, however, in spots. It is not pleochroic. Sections from the two pinacoids are well represented. The augite, like the olivine, exhibits the micropœcilitic structure, with a particularly interesting development represented in the accompanying plate LIV, 4, to the right. It will be noted that there are two automorphic olivines adjacent; that to the left has its interior filled with augite, optically continuous with that which partially surrounds it. That the olivine formed first is assured; that the augite filtered in after the formation of the olivine was complete forces the assumption of a primary cavity in the olivine. It seems to the writer that the phenomenon is an excellent illustration of the power of crystallization even under the most adverse circumstances, the olivine assuming its perfect form, even in spite of the intimate admixture of foreign augite molecules; that with the formation of the olivine phenocrysts the augite molecules were thrust apart to the interior and here segregated, optically continuous, however, with the main augitic mass without. The phenomenon is unique, only this instance having been observed in the sections studied in this series. In spite of this, I have dwelt at some length upon it with the hope that my explanation might be the means of bringing to light a more plausible solution of the phenomenon.

The iron oxides occur in the usual forms of magnetite, hematite, and limonite, included in the olivine, augite, chlorite, etc. Most

abundantly in the prochlorite occur magnetite and hematite, without definite form, appearing in irregular scales, sometimes occupying entire centers of chlorite masses, at other times arranged peripherally in tiny elongated and jagged masses, normal to and in contact with altering olivine surfaces, as already noted under that mineral. Iron ore is also included in the chlorite, resulting from pyroxenic alteration. What appears to be iron ore is also relatively abundant in both the radial and parallel systems of cracks. That it is not mica is proved by its non-pleochroic character and from the fact that it is almost universally confined to the ferromagnesian constituents, ending abruptly at their junctions with the plagioclase. In color it is light reddish-brown, and this ends its resemblance to the small amount of biotite occurring in the rock. It is filled with flakes of black iron oxide, which seem to have resulted from it, and is without doubt limonite, partially changed in spots to magnetite and hematite.

The remaining constituents of the rock are biotite, feldspar, apatite, with small amounts of chromite and pleonaste. The biotite is dichroic in dark and light shades of brown, the latter tint becoming very nearly colorless. Owing to the trifling amount of feldspar present, enough satisfactory measurements could not be made to judge of its exact composition with any degree of assurance. It exhibits albite twinning wherever it occurs, but symmetrical extinctions were more difficult to obtain. The highest equal extinctions were 25.5° , indicating a feldspar of composition approximating Ab_1An_1 .

Apatite occurs in relatively large amounts in the usual form of long, slender prisms in radiating aggregates. A small amount of chromite with a trifling amount of pleonaste were also detected by chemical means.

An analysis of the pyroxene follows:

SiO ₂	49.49
Al ₂ O ₃	5.45
Fe ₂ O ₃	1.04
FeO	3.39
MgO.....	15.88
CaO	24.07
Na ₂ O .....	.82
MnO .....	.18
	<hr/>
	100.32
Sp. Gr.	2.890 ✓

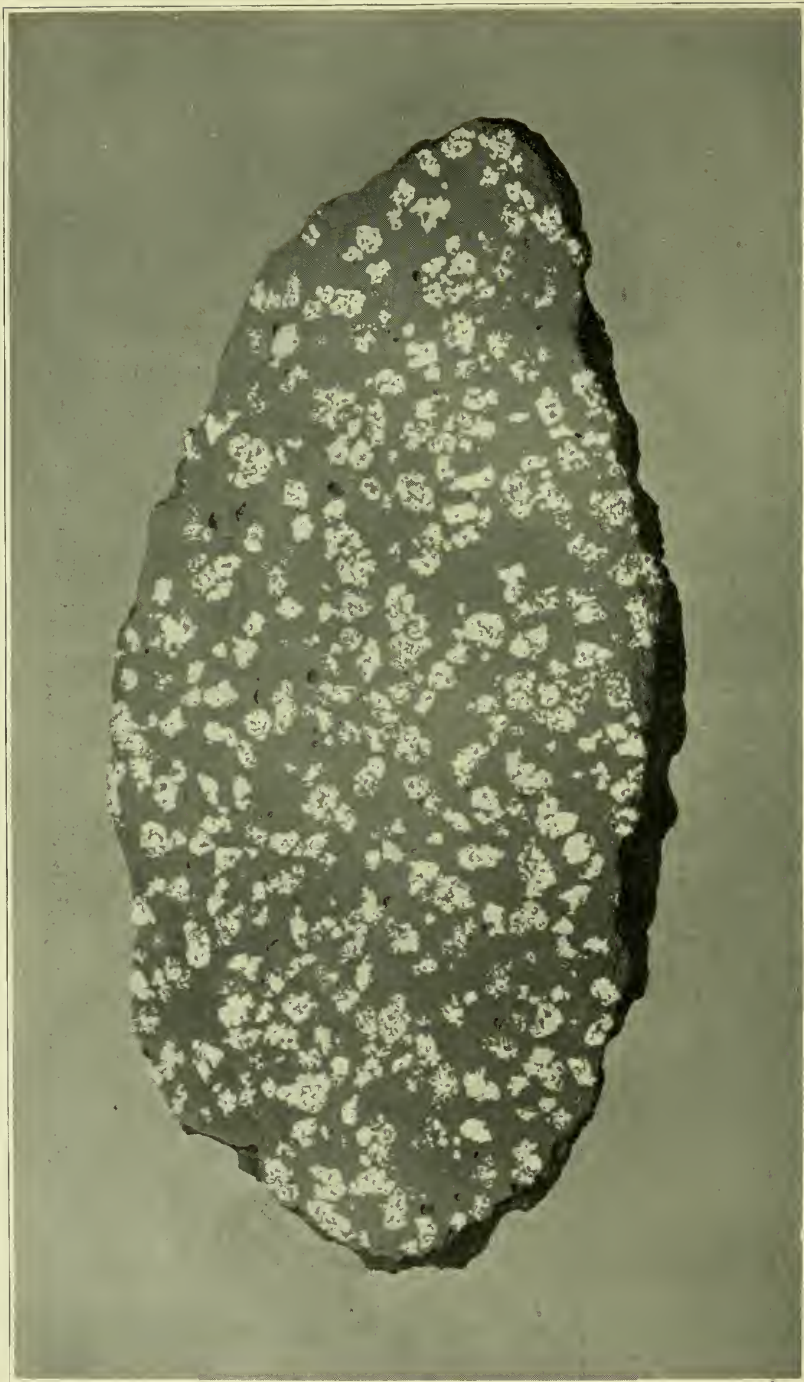
Basalt (Bearing Native Iron)

In addition to the occurrence of basalt in sheets, conformable with the bedding, the basalt of the region about Kaersut cuts the sedimentaries in dikes. Much of this basalt is decomposed, that with original vesicular structure (Cat. No. 75,495) having its cavities filled with zeolitic material and secondary quartz. Of peculiar interest among the basalts is the occurrence at Kaersut of the far-famed iron-bearing rock. Its occurrence at this particular point, so far as the writer is aware, has not been reported before, though its occurrence in the immediate vicinity has been described, as at Blaafield (Ovifak), Mellemfjord, Asuk, Arveprindsen's Eiland, Niakornak, Fortune's Bay, Fiskernaes, Ekaluit, etc., where the rock has been collected and of which analyses have been made.¹

From a petrographic point of view this is by far the most interesting of all the specimens brought from Greenland, and so far as the writer is aware is the only rock of undoubted terrestrial origin known which carries native iron in any considerable amount. It resembles closely an aërosiderolite, stony iron, and for many years was supposed to be of extraterrestrial origin.² Its very close resemblance to certain members of the meteorite family will be noted from the accompanying illustration, plate LV. The specimen (Cat. No. 53,479) now in the petrographic collection of the U. S. National Museum was, before cutting and polishing, roughly ellipsoidal in shape, with a major axis of 17 cm. and a minor axis of 9 cm. When cut, polished, and etched with nitric acid (sp. gr. 1.42, dil. 1:10) the variation in size and structure of the metallic blebs was beautifully developed. It will be observed that the inclusions are of most irregular shapes and sizes, ranging from 1.5 cm. in greatest dimension down to mere points. They often surround patches of the basaltic ground mass, and frequently several blebs of minute size colonize and closely simulate typical graphic structure, with, however, the regular outlines of the inclusions lacking. It is quite probable that such patches represent cross-sections of the ramifications of a single enclosed mass. While studying the thin sections of the basalt, it was observed that these metallic segregations were not at all as homogeneous as they appeared after remaining on exhibition for some years. It was plainly evident that at least two different kinds of iron are present, a black variety and a lighter variety with a silvery sheen. The irons are very irregular in outline. On etching

¹ Chemical Researches on the Metallic Iron from Greenland, by J. Lorenzen, 1882, *Meddelelser om Gronland*, IV, pt. II, 1893, p. 135.

² Nordenskjöld in *Geol. Mag.*, IX, 1872, pp. 88, 461.



BASALT WITH NATIVE IRON, KAERSUT, NUGSAKS PENINSULA, GREENLAND. (No. 53479, U. S. N. M.)

this composite nature is plainly exhibited and may be seen in detail in the accompanying illustration (plate LIV, 5). Macroscopically the two irons appear to be mixed promiscuously, and it is impossible to say with any degree of assurance which is the older, assuming that there is a difference in age. On etching, as has been remarked, the structure of these metallic inclusions is beautifully developed. The duality in composition is accentuated and a damascene luster becomes apparent. It must not be inferred, however, that the individual light and dark patches of a given bleb are quadrilateral, for they may be and are of almost any shape whatever. They may best be described as rudely polygonal, with stippled surfaces and sharply contrasted by virtue of their light and dark shades as noted above. Though former writers, Nordensjöld,¹ Rink,² and Steenstrup,³ claim to have observed Widmanstätten figures in some irons, others have been found which do not show such markings. In the specimen at hand, there is no regular orientation of surface markings, the parallel elongated grooves having been produced during the polishing.

It has been remarked that two different irons are present. In the absence of a separation and chemical examination, such a statement needs qualification. From the physical point of view, this is true. A chemical examination may, however, reveal similarity in composition—in this case, the marked difference in structure then might be explained as a peculiar phase of isomerism, viewed from the standpoint of the ultimate chemical molecules, and from the physical side the differences presented may be assigned to peculiarities in the orientation of the physical as contrasted with the chemical molecules. The solution of this problem, however, lies beyond the scope of a petrographical discussion and belongs to the sphere of the metallographer.

In thin section the basaltic portion of this rock is seen to be composed almost entirely of pyroxene and plagioclase feldspar with abundant albite twinning. Of these two components pyroxene is by far the more abundant. It is perfectly colorless and stands out, in virtue of its strong relief, from the accompanying weakly refracting feldspar. It occurs in small irregular patches among the lath-shaped feldspar microlites. Then it occurs in larger, irregular masses, usually elongated and in forms approaching rectangles. When in

¹ *Geol. Magazine*, IX, 1872, pp. 88, 461.

² *Oversigt over Kgl. Danske Videnskabernes Selskabs Forhandl.*, 1854, p. 1.

³ On the Presence of Nickel-iron with Widmanstätten Figures in the Basalt of North Greenland, K. J. V. Steenstrup, 1882, *Meddelelser om Gronland*, IV, pt. II, 1893, p. 115.

basal sections, it is observed that prism faces are poorly developed as compared with the pinacoids. There are traces of a rude and irregular parting parallel to these latter surfaces.

In spots it is partially altered with the separation of yellow and black iron oxides, the former hydrous. Along the cracks chlorite is slightly developed. Twinning with the twinning plane (100) was observed in several instances. The pyroxene is closely related to the augite group. With the feldspar it is often enclosed in the metallic portions.

The feldspar of the basalt is in two generations. The crystals of the first separation often attain a length of 3 mm., the microlites often sinking to ultra-microscopic dimensions. At times the larger feldspars exhibit undulatory extinction; they were undoubtedly subjected to strain during the closing stages of magmatic consolidation. The feldspar is in a perfect state of preservation, colored occasionally by the presence of hydrous iron oxide, especially in the immediate region of the iron inclusions. Its high symmetrical extinction lying between 35° and 40° indicates a feldspar of the composition Ab_3An_4 . It is, therefore, a feldspar of the labradorite-bytownite group.

Magnetite (and this is the only remaining constituent noted in any considerable amount) is relatively abundant. It occurs in irregular elongated forms, often approaching a dendritic development, but the typical skeleton-like development was not seen. It is especially abundant in the region of the native iron, and here a rude fluxion structure of the entire basaltic portion of the rock was noted.¹

The remaining basalts, collected from the vicinity of Kaersut, are of the usual olivine and non-olivine varieties, much decomposed and presenting nothing of unusual interest. Their detailed description will, therefore, be omitted.

Lying loose, just back of Kaersut, occurs a peculiar rock (Cat. No. 75,488) which deserves more than passing notice. It is brownish-red in color on the fresh fracture and is traversed by tiny veinlets of calcite; this latter mineral, however, is not confined to particular strips, the rock effervescing in all parts on the application of acid. Although of a coarsely crystalline character, with the exception of an occasional rather large irregular patch of tarnished olivine, the character of the ground mass cannot be made out with ease. The olivines, for the greater part, glisten in reflected light, and present a

¹ For a very complete bibliography on the iron-bearing basalt of Greenland, see Dr. Th. Nicolau, *Meddelelser om Gronland*, xxiv, 1901, p. 217, and for a brief résumé on the work done on the nickeliferous iron in the basalt of Greenland, see *Gisement et Nature du fer nickelifère du Gronland*, by F. Johnstrup, published in *Meddelelser om Gronland*, iv, pt. II, 1893, p. 270.

brown surface, not characteristic at all. Evidently the olivine has decomposed along its cleavage planes. In spots, the clear green and rough surface of the mineral appear.

The minerals, in their order of abundance, are olivine, feldspar, pyroxene, iron ore, serpentine, calcite, and apatite. These are combined in a hypautomorphic, holocrystalline mass with olivine, the first mineral of the consolidation. This constituent is by far the most abundant, occurring in irregular masses, with the usual hexagonal forms. It is usually much shattered and fractured, due to disintegration, which is far advanced in some of the crystals, and which is accompanied by a copious deposit of iron ore in various stages of hydration which has segregated along the cracks.

In some of the olivines there is present what might be called at first sight a pseudo-cleavage—very fine straight lines or spaces, for the greater part normal to the pinacoidal cleavage, but often parallel to this cleavage. With the highest powers of the instrument this is seen to be due to lenticular masses of iron oxide, rather scattered in the body of the crystals, but becoming more abundant near the main cleavage cracks and finally disappearing in a pleochroic pigment present in such cracks. Liquid inclusions are very abundant.

After olivine had crystallized out, the next mineral to appear was pyroxene. It occurs in irregular masses of light green color, with prismatic cleavages well developed. Extinctions range as high as 44° , indicating an augite of intermediate alumina and iron content. It is extremely abundant and shows no decomposition whatever.

Magnetite, with other iron oxides, occurs in several forms in the rock, inclosed in the ferro-magnesian constituents, rarely or never in the feldspars. It is part original and part secondary, resulting from the olivine. The original crystals are in the form of cubes and octahedrons, sometimes twinned. Then there occur skeleton crystals of the most wonderful patterns, as described by many petrographers and figured by Pirsson¹ and Hobbs.²

Magnetite occurs as an alteration product after olivine, often clouding and rendering opaque whole phenocrysts of this mineral. Patches of olivine are also rendered partially opaque by separated red hydrous iron oxide.

After these constituents, olivine, augite, and original magnetite, had separated, the feldspar accommodated itself to the residual space. It is remarkably fresh and, for the greater part, free from inclusions. It occurs in lath-shaped forms twinned according to the Carlsbad

¹ *Twentieth Ann. Rep. U. S. G. S.*, pt. III, 1898-99, plate LXXI.

² *Twenty-first Ann. Rep. U. S. G. S.*, 1900, pt. III, p. 65.

and albite laws. The extinctions, according to the statistical method, range as high as 31.5° , which would place the feldspar in the class intermediate between those of the formulæ Ab_1An_1 and Ab_3An_4 . The composition may then be represented by the formula Ab_7An_8 and it would be classed among the labradorites.

The remaining constituents are serpentine, calcite, and apatite. Serpentine occurs as an alteration product of the olivine, appearing in cracks with a fibrous structure, with fibers normal to the altering surface. It shows aggregate polarization tints of dull gray, often becoming bright yellow. Apatite occurs in automorphic elongated prisms, enclosed in the olivine and feldspar. Calcite is also present.

A partial analysis of this rock, together with a discussion of its name and place in the new quantitative classification of igneous rocks¹ will be found in Pt. II, p. 211, of this article.

UJARARTORSUAK

Westward from Kaersut, the Cretaceous rocks are seen resting unconformably upon a bluish-green, highly altered basalt. A little to the west, the beds exposed in the sea-cliffs are dislocated for several hundred feet by a fault, directly beyond which the strata are cut by three dikes, the two westerly of which are parallel with the bedding in places. These intrusive basalts are believed to be of Tertiary age. The dikes are apparently of the same rock as the intrusive sheets themselves and probably represent the vents through which the sheeted material has reached the surface. Both olivine and non-olivine varieties are represented in the Museum collection, and from the similarity in composition and general features, the detailed description of but one will be attempted, that from an interbedded conformable sheet at Slibstenfjeld, directly back of Ujarartorsuak.

Basalt.—This basalt (Cat. No. 75,489) is greenish-gray in color and breaks with a roughly conchoidal fracture. In the greenish-gray fine-grained ground mass occasional specks of yellowish-red iron oxide are evident to the naked eye, as also are much larger automorphic crystals of a light-colored and well-cleaved mineral, presumably feldspar. Examined with the hand lens, though not salient, it is very abundant in lath-shaped forms. The rock presents a decomposed appearance, and the acid test reveals the presence of much calcium carbonate.

In thin section the rock appears holocrystalline, xenomorphic with lath-shaped feldspars, pyroxene, magnetite, hydrous iron ore, calcite,

¹ *Quantitative Classification of Igneous Rocks*, by Cross, Iddings, Pirsson, and Washington. Chicago, 1903.

etc. In places it shows undulatory extinction. It appears to be decomposed in spots throughout; the ferromagnesian constituents have completely changed and the feldspar has suffered locally in the same way, while in places the latter mineral is remarkably fresh and determinations of its character may be made with ease. The positions of the pyroxene and olivine, if the latter mineral were ever present, are now occupied by green and brown pigments. Magnetite, of course, is always present.

The constituents may be described as follows: Feldspar, the most abundant of the components still preserved in fresh condition, shows abundant albite and Carlsbad twinning. Symmetrical extinctions on the trace of the clino-pinacoid (010) range as high as 35.6° . The Michel-Levy method of Carlsbad and albite twins corresponds to a plagioclase of the composition Ab_3An_4 , which is borne out by the high symmetrical extinction given above. Thus the plagioclase may be termed a labradorite bytownite and is very basic in composition.

In spots this feldspar is much kaolinized; it is cracked and secondary calcite has filtered into or formed in the fissures, filling them completely. Flakes of the greenish pigment to be subsequently described are also present, as well as elongated, lenticular, and lath-shaped forms of the same coloring substance. In general these inclusions are without regular orientation, but in the vicinity of and along the composition planes, there is a parallelism evident. At times cloud-like masses, elongated normal to the *C* axis, were detected with the number 7 objective. Magnetite, though an inclusion, is not abundant in the plagioclase. Its form is not automorphic, and part, even here, may be secondary.

The residual mass of the rock is largely a conglomerate of decomposition products, of which the most abundant are iron ore, calcite, chlorite, and serpentine, and much material, isotropic and secondary, whose properties are not at all diagnostic. These minerals are scattered promiscuously throughout the rock, in contact with and overlying each other. If we assume that the calcite areas represent original pyroxene and the serpentine is taken as a rough index of former olivine, then the original rock consisted of pyroxene, feldspar, olivine, magnetite, and apatite, in the order given.

From the intervening localities, at which explorations were conducted, namely Saviarkat, Kookanguertunek, and Niakornat on the north side of the peninsula, and Ata and Patoot on the south side, nothing of petrographic interest was obtained, owing to the very advanced state of decomposition of the rocks at these places. At

Alianaitunguak, however, lying to the west of Ata, olivine basalt was collected in a fairly good state of preservation. At Atanekerd-luk, on the southeastern coast, some specimens were collected, among them olivine gabbros and monzonite, the former constituting the main mass of the small peninsula. The only representation of this large areal extent is a single hand specimen (Cat. No. 75,490), somewhat decomposed, but still well enough preserved to admit of satisfactory examination. In color it is old rose, spotted here and there with what appears to be a secondary mineral, but which on examination in thin section proves to be a surprisingly fresh pyroxene. Sometimes this green mineral forms a continuous network in the red feldspar. It is this latter constituent which forms the bulk of the rock and from which nearly all the secondary constituents have been derived. Among these latter, calcite is readily distinguished, occurring in tiny anhedrons throughout the red plagioclase ground mass.

Viewed in thin section the rock presents a hypautomorphic granular appearance. Among the most abundant minerals is pyroxene. It is light brownish in hue, approaching at times a violet. Prismatic sections, both 100 and 010, were observed, the latter giving extinctions as high as 52.9° . These sections are naturally most numerous, but octagonal basal sections showing both prismatic cleavages were surprisingly well developed. Twins of the usual variety, the twinning plane being the orthopinacoid (100) were noted. With the lowest powers of the instrument the augite appears perfectly fresh. Even the highest powers prove that decomposition has not advanced very far. Even those parts of this mineral which project into thoroughly decomposed parts of the rock, consisting mainly of viridite, are plainly discernible, their crystalline outlines showing with much distinctness. Naturally in such areas the augite is much decomposed, but the evidence is plain that the greenish residual product is not *chiefly* derived from the augite. Along its cleavage planes foreign matter has filtered in, while a portion of such material has been produced *in situ*. Inclusions of hydrous iron ore and magnetite are present. Thus, to summarize, we may say that, although the augite has slightly altered, alteration has taken place only at vulnerable points and it is yet the most perfectly preserved of the constituents. In age it is older than the feldspar.

Though augite presents the same appearance throughout its entire extent, so far as progress in alteration is concerned, the same is not true of the plagioclase. Though perfectly fresh in spots, it presents all phases of alteration to the fully kaolinized material. It exhibits a

splendid basal parting in many of its lath-shaped forms, and the process of alteration has begun along these planes of weakness, but not always, for peripheral alteration has advanced to such a degree that it must have been at least simultaneous with, if not antecedent to, the changes along the basal partings. This alteration has filled the space originally occupied by the feldspar with a greenish substance, which, for want of a better term, I have referred to as viridite. In part this viridite is very dark bottle green, changing through various greenish and yellow shades to a bright saffron yellow. Undoubtedly much of the pigment of the viridite is iron oxide in various stages of hydration. In plain polarized light and with the very highest powers these pigments seem to be made up of shapeless patches of brownish-yellow material with occasional specks of magnetite and lath-shaped particles, all identical with that observed in the basal partings of the plagioclase.

Needles of apatite are abundantly scattered throughout, while underlying the heterogeneous mass may be observed the faint grayish-blue interference tints of the feldspar. Hence it is plain that these decomposition products owe their origin to the feldspar chiefly and not to the augite. We also have in these abundant products a ready explanation of the brilliant reddish hue of the plagioclase observed in the hand specimen.

In spite of its almost completely altered condition in places, the feldspar at times is even fresher than the augitic constituent. This is the exception, however, and not the rule. It is fortunate, however, in that it enables the feldspathic minerals to be diagnosed with no difficulty whatever. Its extinctions range in the neighborhood of 25° , the maximum symmetrical extinctions obtained being 26.3° . The feldspar, then, is a typical labradorite of composition Ab_1An_1 .

Of the accessory constituents, olivine was noted in a few sections in an advanced state of change. It appeared with its usual complement of cracks, filled with dark-brown ferruginous matter. Cavities are rather numerous; in many instances their outlines are suggestive of the former presence of olivine. Even were olivine present to this extent, it would still be classed as a minor accessory.

Iron ore is present in considerable quantity. It is confined to the decomposed portions of the rock almost exclusively and is very irregular in outline. Although present in large masses, it appears to be at least in part secondary. Much of this dark opaque mineral is pleonaste. Chlorite is present in small quantity, bordering the augite. Calcite, in tiny anhedrons, also occurs as a decomposition product. Apatite has already been referred to.

In summary we have then as original constituents, labradorite, augite, magnetite, pleonaste, apatite, biotite, and olivine; as secondary constituents, hydrous iron oxide, chlorite and perhaps a small amount of serpentine. Of these original constituents the labradorite and augite only rank as essentials, the remaining constituents are accessory. The rock, therefore, may be classed as an olivine gabbro.

Quartz Monzonite.—This rock (Cat. No. 75,491), of which a single specimen was secured, is light gray in color with a ground mass composed of feldspar with semi-lustrous cleavage plates. Scattered through this white ground mass lie elongated crystals of a black mineral, hornblende. In some places, locally segregated, occur bunches of mica flakes. Drusy cavities are quite frequent. An occasional pellucid quartz was also noted, but though macroscopically evident, it is a very minor constituent.

Though apparently fresh, the rock, a surface sample, has undergone considerable alteration and weathering, and the feldspars are considerably kaolinized, presenting under the microscope grayish-brown cloud-like masses, which, however, give the dull-gray interference tints.

In texture the rock is panautomorphic; all the grains are crystalline, approximately the same size, approaching automorphic forms, yet few or none possessing them.

In thin section the appearance of the rock duplicates its megascopic features. By far the most abundant constituent is feldspar. This has decomposed to such an extent that in some spots identification is impossible, and even when freshest its identification is obscured from the large quantity of separated material, which makes the cleavage lines most indistinct. This separated material is, for the most part, kaolin. It is brownish in color and is made up of flakes and needles without any action on polarized light. It is scattered in translucent clouds throughout the mass of the feldspar. This latter mineral gives in some sections parallel extinctions; in others, the angles range from 8° to 18° ; such sections evidently approach the clinopinacoid and show an elongation of the feldspar parallel to the *c* axis. Though generally untwinned, in places albite lamellæ were noted. These small extinctions point to the presence of albite and oligoclase. In some spots, in the neighborhood of larger quartzes, a micropegmatitic development of quartz and oligoclase was seen. Carlsbad twinning was also noted.

Additional to these acid feldspars, another group of plagioclases is present of a much more basic character. These basic feldspars are twinned both according to the albite and Carlsbad laws, hence

advantage could be taken of Michel-Levy's method on sections normal to 010. Extinctions in one part of the Carlsbad twins range as high as 31° , in the other part 15.5° is the observed angle. Evidently the feldspar is entirely different in composition from those already observed and should be classed as a labradorite with composition very close to Ab_3An_4 . The basic labradorite is not nearly so abundant as the more acid substance.

Associated with the feldspars are the following minerals: Amphibole, pyroxene, zircon, quartz, apatite, and magnetite, besides some hydrous iron ore. Of these minerals amphibole is by far the most important and most interesting, owing to its variety. It occurs in at least three different types, ordinary hornblende of deep chestnut-brown color, a light green phase, while a third variety has been derived from the pyroxene with which it is now associated. Of these forms the ordinary variety hornblende is most common. It is strongly pleochroic, the rays vibrating parallel to *C* being a deep chestnut-brown, those parallel to *B* of a similar but lighter shade, while those parallel to *A* are yellowish-green. The absorption scheme is the usual $C > B > A$, but the difference between *B* and *C* is very slight.

The hornblende is generally lath-shaped with jagged or frayed terminations. Sections parallel to 100 and 010 are present. No crystallographic terminations were noted, but basal sections (001) are frequent with prism and clinopinacoidal faces well developed, the macropinacoidal showing as a rule. The secondary hornblende is light chestnut-brown in color. It is generally associated with the unaltered portions of the original pyroxene, whence it has been derived, and crystals of light-brown pyroxene were noted with extinctions as high as 45° , whose edges and corners had completely gone over to hornblende of a markedly darker hue, with extinctions ranging in the neighborhood of 20° .

The third form of amphibole is usually associated with the dark and light brown varieties already described. It occupies in every instance a peripheral position and sometimes has a fibrous radiating structure—though as a rule the structure of the associated hornblende is repeated in the green mineral. Most commonly, its form is that of the amphibole, *i. e.*, lath-shaped, or rather it forms a part of the lath-shaped crystals. Cleavage in its prism zone is well developed. Its pleochroism, bluish-green in the prism zone, with yellowish-green hues normal to this direction, together with its position and other relations, indicate a soda-amphibole of the arfvedsonite group. Evidently we have here a gradual change in com-

position from a normal hornblende to one abnormally high in soda, brought about through contact with a magma, becoming increasingly rich in soda molecules. At times the arfvedsonite mineral is slightly decomposed.

The pyroxene presents nothing novel. Basal sections are rather frequent and exhibit the well-developed prismatic cleavages. It is of the augite variety. This, together with zircon, apatite, biotite, ilmenite, and magnetite, together with a scattering quartz, complete the list of original minerals.

In the vicinity of the amphibole, much iron oxide has separated. It is black in shade and irregular in outline. It has been derived from the hornblende, but the residual mass of this mineral appears perfectly fresh. Clouds of yellow ocher were noted, chiefly in the vicinity of the pyroxene, and from the analysis ilmenite also appears to be quite abundant. Fluid inclusions in the quartz are not uncommon.

The analysis of this rock follows:

ANALYSIS OF QUARTZ MONZONITE. (W. C. PHALEN, ANALYST.)

SiO ₂	67.27
Al ₂ O ₃	13.67
Fe ₂ O ₃	1.83
FeO	2.49
MgO	1.72
CaO	1.90
Na ₂ O	2.79
K ₂ O	5.80
H ₂ O above 100° .....	.45
H ₂ O below 100° .....	.08
TiO ₂	1.70
P ₂ O ₅ .....	.16
MnO .....	.19
	100.05

PART II

INTRODUCTION

During the preparation of this article a new rock classification has appeared, based on the chemical relations which obtain in igneous rocks.¹ It was decided by the writer to incorporate the principles of this classification into the body of this present theme, in so far as they were applicable, but on maturer thought this was deemed inadvisable for the following reason. It was held that to introduce so much of an entirely new nomenclature into an article where an old and familiar group of names must of necessity predominate at

¹ *Quantitative Classification of Igneous Rocks*, by Cross, Iddings, Pirsson, and Washington. Chicago, 1903.

the present time must only tend to obscure and to detract attention from the main topic at issue. At any rate, with this idea in view, it was decided to append a second chapter, devoted chiefly to the discussion of the rock analyses and their interpretation in the light of the work already alluded to.

UMANAK ISLAND

Granite (Cat. No. 75,480).—Directly back of the low-lying expanse which has been described as stretching a mile back from the coast¹ there rises, to a height of 3700 feet, a typical nunatak, composed of granite. An analysis of this granite, comprising the boss, follows, and with it an analysis of graphic granite from Omeo, Victoria, Australia, by A. W. Howitt.

ANALYSIS OF GRANITE—OMEOSE

	(1)	(2)
SiO ₂	76.03	70.91
Al ₂ O ₃	12.02	15.32
Fe ₂ O ₃ .....	.69	trace
FeO .....	.68	—
MgO .....	.18	.07
CaO	1.61	.58
Na ₂ O	2.97	2.31
K ₂ O	5.72	10.07
H ₂ O .....	.20	.51
TiO ₂ .....	.28	—
	100.38	99.77

NOTE.—1. Greenland granite, W. C. Phalen, analyst. 2. Graphic granite, Omeo, Victoria, Australia, A. W. Howitt, analyst. *Trans. Roy. Soc. Victoria*, XXIV, pt. II, p. 120, 1888.

COMPOSITION IN TERMS OF STANDARD MINERALS

	(1)	(2)
Quartz	34.38	18.00
Orthoclase	33.92	59.49
Albite	24.63	19.39
Anorthite	2.78	1.67
Ilmenite .....	.61	—
Magnetite .....	.93	—
Diopside	1.57	.66
Wollastonite	1.39	—
H ₂ O .....	.20	.51
	100.41	99.72

According to the quantitative scheme of classification the rock works out to an omeose, a rock very high in silica and potash, granitic in every respect.

¹ See page 186.

It will be noted that the analyses show rather wide discrepancies, only the wide ranges in the ratios involved in the classificatory scheme allowing them to be placed in similar subdivisions; thus, for example, in the Greenland rock, the ratio Q:F is 0.6, in the graphic granite from Omeo it is 0.22. The ratio between the alkalis and lime in the former case is 15.5, and that between the potash and soda is 1.9; these respective ratios in the type omeose being 30 and 4.

Diorite (Cat. No. 75,481).—The diorite has been described as forming a series of horizontal dikes in the granite and as varying in texture from a very fine grain to a pegmatitic facies. The lower dike material has been chosen as a type of the magma, from which all the diorites have come for the reasons stated on page 190 of this article. Its analysis, therefore, is given with that of von Lasaulx's doleritic lava from Auvergne, the diorite having worked out to an auvergnose.

ANALYSES OF DIORITE—AUVERGNOSE

	(1)	(2)
SiO ₂	47.80	48.57
Al ₂ O ₃	18.24	19.47
Fe ₂ O ₃ .....	.35	—
FeO	9.27	13.53
MgO	8.08	4.25
CaO	11.44	10.86
Na ₂ O	2.24	1.33
K ₂ O	*.45	.82
H ₂ O above 100° .....	.58	.48
H ₂ O below 100°	—	
TiO ₂	1.46	—
P ₂ O ₅ .....	.24	—
MnO .....	.55	.76
	100.70	100.07

NOTE.—1. Diorite (Auvergnose) Greenland, W. C. Phalen, analyst. 2. Doleritic lava from Auvergne, A. v. Lasaulx, analyst. *Neues Jahrbuch f. Min., Geol. u. Pal.*, 1869, p. 657.

COMPOSITION IN TERMS OF STANDARD MINERALS

	(1)	(2)
Orthoclase	2.78	5.00
Albite	18.86	11.00
Anorthite	38.09	44.76
Ilmenite	2.89	—
Magnetite .....	.70	—
Apatite .....	.31	—
Diopside	14.56	7.83
Hypersthene	5.01	25.62
Olivine	16.96	5.45
H ₂ O .....	.58	.48
	100.77	100.14

Though the analyses show such discrepancies, especially so as regards the content of the iron oxides and magnesia, the ratios involved in the placing of the rock in its classificatory position are very close. The auvergnose from the type series of von Lasaulx however, would, strictly speaking, be placed in the sodi potassic subrang of the rang auvergnase, owing to a ratio value between the alkalis of 0.61, this ratio, in the Greenland rock, being 0.2.

NUGSUAKS PENINSULA

On page 195 there is described a rock (Cat. No. 75,488), which has been referred to as lying loose just back of Kaersut. Such material is not regarded as having very great petrographic value. Nevertheless, since the type is rather limited, so far as its exposures in the earth's crust are known, it was deemed worthy a partial analysis to ascertain its classificatory position. From the results of this chemical examination, which follow, it will be seen that the rock is very basic, that it belongs to class IV, the dofemane class, section four of the order hungarare, and to the domagnestic subrang of section one in the permirlic rang of this order. Its name therefore is custerose.

PARTIAL ANALYSIS OF PERIDOTITE—CUSTEROSE

	(1)	(2)
SiO ₂	42.63	46.03
Al ₂ O ₃	6.88	9.27
Fe ₂ O ₃	3.33	2.72
FeO	7.27	9.94
MgO	29.36	25.04
CaO	5.90	3.53
Na ₂ O	1.26	1.48
K ₂ O .....	.14	.87
MnO .....	.36	.40
NiO .....	.27	—
Cr ₂ O ₃ .....	.05	—
H ₂ O	—	.64
P ₂ O ₅	—	.17
	97.45	100.09

NOTE.—1. Partial analysis of peridotite (custerose), Greenland, W. C. Phalen, analyst. 2. Analysis of peridotite, near Querida, Silver Cliff, Custer Co., Col., L. G. Eakins, analyst. Cross, 17th Ann. Rep. U. S. G. S., pt. II, p. 284, 1896.

There remains but one rock, quartz monzonite, whose microscopic analysis is given on p. 206. This rock, whose chemical analysis is given as follows, proves to be a dellense.

ANALYSIS OF QUARTZ MONZONITE—DELLENSE

	(1)	(2)
SiO ₂	67.27	68.36
Al ₂ O ₃	13.67	13.24
Fe ₂ O ₃	1.83	1.29
FeO	2.49	3.39
MgO	1.72	1.15
CaO	1.90	2.51
Na ₂ O	2.79	2.05
K ₂ O	5.80	5.34
H ₂ O above 100° .....	.45	} 2.63
H ₂ O below 100° .....	.08	
TiO ₂	1.70	—
P ₂ O ₅ .....	.16	—
MnO .....	.19	.27
	100.05	100.23

NOTE.—1. Quartz monzonite—Greenland, W. C. Phalen, analyst. 2. Glassy andesite—Dellen, Sweden, H. Santesson, analyst. F. Suenonius, Andesite from Helsingland, Sweden, *Geol. För. Förh.*, x, 1888, p. 273.

COMPOSITION IN TERMS OF STANDARD MINERALS

	(1)	(2)
Quartz	22.32	26.83
Orthoclase	34.47	31.14
Albite	23.58	17.29
Anorthite	7.51	11.12
Apatite .....	.34	—
Ilmenite	3.19	—
Magnetite	2.55	1.86
Diopside .....	.88	1.18
Hypersthene	4.68	7.98
Water .....	.53	2.63
	100.05	100.08

From the analysis of this quartz monzonite, it will be seen that the silica is rather high. This is explained in part by the presence of free quartz. Low lime indicates a small amount of basic feldspar. The high content of titanitic acid is worthy of mention.

In the main, the analysis agrees fairly well with that of the type rock from Sweden. Notable differences occur, however, in the content of ferrous oxide, water, and titanitic acid; the differences in the first and third substances, however, do not suffice to alter the classificatory position, since in rocks of the first three classes these oxides do not have the weight which they possess in similar divisions of classes four and five.

NOTE.—In conclusion, I wish to express my appreciation of the many courtesies extended to me during the course of this work by Dr. G. P. Merrill, Dr. Wirt Tassin, and Mr. Chas. Schuchert, of the U. S. National Museum, and by Dr. David White of the United States Geological Survey.

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