

# MINERALIZATION ALONG THE DIKES OF SOUTHERN VERMONT.\*

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## INTRODUCTION.

The region covered by this study lies in southern Vermont about fifteen miles north of the Massachusetts boundary line. Wilmington, latitude  $42^{\circ} 52' N.$ , longitude  $72^{\circ} 52' W.$ , in Windham country, was about the center of the field of operation. Most of the work done was between the parallels of  $42^{\circ} 45'$  and  $43^{\circ} N.$  and the meridians of  $72^{\circ} 45'$  and  $73^{\circ} W.$  The majority of the work was done in the township of Wilmington, although adjoining townships were partially covered.

The country rock of this region is predominantly a quartz-mica schist which varies greatly both in structure and composition. As regards structure, it is found with both slaty and gneissic forms, although it is typically an ordinary schist. It is much folded into anticlines and synclines, some of which have an axial length of several miles, and it also has profound local contortion and severe crumpling. In composition the range is from almost pure quartz to almost pure mica, with fifty per cent of each as the typical combination. The mica is generally biotite, but it is sometimes accompanied by muscovite, paragonite, and in rare cases, phlogopite. The quartz is almost always colorless or milky, but it is occasionally pink, due to the coloring properties of some compound of iron in minute quantities. The range of composition is further varied by the addition of accessory minerals, the most common of which are feldspar, magnetite, pyrite, and limonite pseudomorphs after pyrite.

The whole region is shot full of semimetamorphosed dikes of diorite and of later quartz or quartz-feldspar dikes, which often cut through the diorite dikes and seem to pay even less attention than they do to the structure of the country rock and its planes of schistosity. The outcrops of the dikes vary in width from a

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few hundred yards to two or three miles. The quartz dikes vary in size within wider limits than do the diorite and send out stringers into the country rock much more extensively. Although nothing is known of the mass or masses of magma in which these dikes originated, it is extremely probable that they came from the same magmatic basin and that they form a series of complementary dikes which, if mixed in amounts proportional to the quantity in which they occur, would give the chemical and general mineral composition of the original large mass. Thus the variation in composition of the dikes is assumed to be due to variation in composition of the magma or sub-magma at different periods:

#### DESCRIPTION OF DIKES.

The typical composition of the diorite is one of nearly 70% of hornblende, about 30% of feldspar with quartz in varying quantities, and some iron-bearing mineral, either pyrite or magnetite, in slight amounts. The range of composition is from an eighty-twenty relation of the essential minerals to one of fifty-fifty, innumerable variations occurring between the two. The rock is generally very fine-grained, with the feldspar and quartz arranged in spheres or circles scattered evenly throughout the rock. At times the feldspar and quartz bunches are so fine that they are discernible only under the microscope. In rare cases the centers of these quartz or feldspar spheres are hollow, but generally they contain biotite, magnetite, pyrite, limonite pseudomorphs after pyrite, or very good hornblende crystals. In a case where biotite occurred in the center of the quartz spheres, a microscopic study of the specimen showed a zonal arrangement of the two minerals. The outer shell of the sphere consisted of quartz with only microscopic crystals of biotite, the next had quartz and biotite in about equal amounts, evenly intermingled, and the center consisted of almost pure biotite. A careful microscopic study of other minerals found in the center of feldspar and quartz bunches would probably show a tendency toward the same sort of zonal arrangement. The same minerals which occur in the centers of the feldspar circles generally occur scattered throughout the diorite itself in minute ill-formed crystals. Only in one or two cases did the biotite occur with sharply defined crystal angles or the magnetite with perfectly triangular octahedral faces.

The acidic dikes and stringers are usually nearly pure milky quartz. Quite often they are of quartz and feldspar in varying proportions, and the feldspar occurs in various-sized blotches surrounded by quartz, into which feldspar stringers sometimes extend. This silicate may be light-gray oligoclase or white albite, but is generally a pink feldspar which has been proved by the petrographic microscope, in all cases studied, to be pink microcline. This bears out Pirsson's theory that the potassic feldspars are pink due to finely disseminated iron oxides because potash does not readily enter into combination with iron. In connection with the results of mineralization found here, it may be interesting to note that he believes the gray color of oligoclase to be due to finely divided ilmenite disseminated through it. Sometimes there is more feldspar than quartz in these dikes, and in one or two places small irregular stringers of practically pure feldspar were found.

#### MINERALIZATION.

The mineralization along these dikes is extensive, as might be expected, but the quartz and quartz-feldspar dikes have a much greater amount of it because the most active volatile constituents of a magma, such as Ti, Cl, F, B, and the hydroxyl and sulphate radicals, seem to accompany the acidic rather than the basic sub-magmas.

Practically the only minerals found in and near the diorite dikes as the result of mineralization are pyrite and magnetite, although some of the unusually large and well-formed biotite crystals which are found in places in the diorite may have been influenced to some extent by mineralizers. The magnetite is usually disseminated through the dike itself in small indistinct crystals of microscopic size, though sometimes it occurs in aggregates of these crystals, and occasionally in single good-sized perfect octahedrons. In the country rock, the magnetite crystals are generally fewer in number, but better developed. The pyrite is almost always in single well-formed cubes of various sizes, both in the dike and in the country rock, but it is much more apt to be concentrated along the contact than the magnetite, and frequently occurs in aggregates of crystals there. Occasionally a large pyrite crystal is found including a smaller one of magnetite. Very often the pyrite is completely altered to limonite pseudomorphs before any other sort of weathering is apparent.

Occasionally inclusions of the schist in the diorite dikes and portions of the schist close to the contact contain good crystals of hornblende and feldspar. The presence of these minerals in the dikes is not due to mineralization, but their occurrence in the country rock is undoubtedly due to it. A further evidence of mineralization along these dikes is in the finding of rare crystals of paragonite and phlogopite, always found close to the contact in the country rock.

Mineralizing gases may by their presence influence crystallization or recrystallization without entering into direct combination, and it is possible, if not probable, that much of the fine crystallization of minerals within the feldspar spheres of the dikes is the result of this influence.

It is along the quartz and quartz-feldspar dikes, however, that the best and most abundant evidences of mineralization may be found. The range of minerals occurring along this class of dikes is much greater than that of the diorite dikes. It includes biotite, muscovite, the hydrous green micas, ilmenite, magnetite, pyrite, tourmaline, actinolite, epidote, hornblende, and others. The mineralization which results in some form of mica is by far the most common, and of these micas, the most common form is biotite. It occurs in good crystals along the contacts and extends into the dikes and country rock either side of the contacts. In the dikes, the crystals are conspicuous by reason of the contrast in color, but in the country rock they merely make the schist look darker and denser near the dike, due to this increase in the amount of biotite. In one exceptional case some beautiful large crystals were found in the very center of a quartz dike. This phenomenon was probably caused by the rapid cooling of the quartz which left cavities where the biotite crystals were formed and were later surrounded by an inflow of quartz in heated aqueous solution.

Muscovite, for some reason, is very rare. In a few cases, it occurs in small flakes with some other true mica, and in only one case it is known to occur in beautiful large and distinct crystals in a quartz dike. Phlogopite is as rare here as in the diorite dikes, but paragonite is more common and occurs with muscovite in several places in the schist, near contacts with the dikes. It also occurs in bunches of fine crystals in the quartz of the dike itself, and in one such occurrence where the crystals are strung out along the contact between the quartz

and the feldspar, it is noticeable that the contact between the quartz and the mica is much sharper than that between the mica and the feldspar. In fact, inclusions of crystals of the mica in the feldspar and the reverse are common, while such a thing is almost never observed in the quartz.

The hydrous green micas are widely found in the schists. Penninite occurs with a pearly lustre and appearance so closely approximating that of biotite that a hasty examination does not disclose the difference. Chlorite is often found and comes both from hornblende and from biotite, as evidenced by its general form and its associations.

Tourmaline is found almost everywhere along the dikes. It generally occurs in small distinct needles disseminated in the country rock near the dikes, but occasionally it occurs in single crystals and in aggregates of crystals whose dark color is sharply contrasted with the white of the quartz matrix. Epidote is not very common and generally occurs in rather a massive form between the country rock and the dike. Large masses of beautifully crystallized actinolite, associated with quartz, are found in such quantity that it must be assumed here, as perhaps for the epidote above, that the largest part of the basic material for the mineral was already present in the country rock and that the mineralizers merely changed its form or perhaps added to it other elements in slight amount.

Ilmenite occurs in medium amounts, almost always within the edges of the quartz dikes themselves, sometimes along the contact, and rarely within the country rock. It is not usually in good crystals, but occurs in plates as much as two inches long. Magnetite is much more common than the ilmenite. As is the case near the diorite dikes, the magnetite is apt to be disseminated through the country rock near the contact in small, imperfect crystals. It also occurs in the quartz-feldspar dikes themselves in good crystals, as well as in aggregates. Pyrite is also very common and has much the same sort of occurrence as does magnetite. It is apt to be better crystallized though, especially in the dikes. In one case it occurs in especially large good crystals scattered through a quartz dike, and the crystals are twinned and ribbed in a peculiar manner.

In several cases it is noticeable that in a quartz-feldspar dike, the contact between the feldspar and the country rock is much less sharp than between the quartz and the country rock.

An analagous difference in type of contact between these two minerals and crystals of mineralization has also been noted, and in one or two cases a pure quartz dike is accompanied by almost no effects of mineralization whatever. It may be that some part of the feldspar acts as a mineralizer itself or that the feldspar as a whole is simply more active when crystallizing than the quartz is. It would take a much more detailed study than this to arrive at any conclusion which could be put forth with any assurance as to its correctness.

#### SUMMARY AND CONCLUSIONS.

To recapitulate: the two types of complementary dikes found in this region in southern Vermont, of diorite and quartz and quartz-feldspar, are accompanied by extensive mineralization. The type of alteration found in the country rock near the contacts is much the same in many respects for both kinds of dike. The quartz and quartz-feldspar dikes, however, have much the longer list of minerals resulting from mineralization since the more volatile constituents of a magma seem to accompany the acidic rather than the basic sub-magmas. The common minerals thus formed are hornblende, actinolite, tourmaline, biotite, muscovite, phlogopite, paragonite, pyrite, magnetite, ilmenite, and others.

There is much undoubted mineralization which, so far as we can see, is associated with no dike at all, but which should serve as a guide for further search for dikes.

The descriptions here given and the problems stated are the result of a preliminary and somewhat superficial study of a region almost wholly unknown geologically except in a very general way. It is evident, however, that the region is a very interesting one and offers an excellent field for the study of the results of metamorphism. The work as yet has been barely started, and it is hoped that further careful study by those interested may solve the problems mentioned and many others unmentioned, but undoubtedly present.

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