

PETROGRAPHY OF SOME LAMPROPHYRIC DIKE ROCKS OF THE COEUR D'ALENE MINING DISTRICT, IDAHO.

By EARL V. SHANNON,

Assistant Curator, Department of Geology, United States National Museum.

INTRODUCTION.

Most of the occurrences upon which the following descriptions are based were examined by the writer in and around the mines of the Coeur d'Alene District in the summer of 1917. Ransome and Calkins¹ had done much work in the region, mapping the dikes in a single color and stating in their text that certain of the rocks were most properly called minettes, while others were nearer kersantite. Later Dr. Joseph B. Umpleby of the United States Geological Survey turned over to the Museum all specimens collected by him in the course of his field work in this region. Inasmuch as other duties have necessitated that publication of results by Doctor Umpleby be indefinitely postponed, descriptions of his material are included in the present paper. There had already been deposited in the United States National Museum the specimens of these rocks collected by Mr. F. C. Calkins in his work in the Coeur d'Alene Region, and permission was kindly extended by him to reexamine these and to redescribe such as might be of interest in connection with the present work. There were thus available specimens from a large proportion of the dikes which occur in the producing area. The descriptions are based entirely upon museum material.

While the following paper contains much rather monotonously descriptive matter, it relates to a group of igneous rocks of uncommon interest. The observations recorded are made as complete as possible for the reason that a great number of the dikes which occur associated with important ore-bodies have been made visible only in mine workings, and the great majority of mines in which they occur have been exhausted and abandoned and their workings rendered permanently inaccessible. Thus the student of this particular district may find here recorded evidence which is no longer obtainable in the field.

These black ferromagnesian rocks have been locally designated by various names as syenite, diorite, diabase, etc. The rock from the

¹Ransome, F. L., and Calkins, F. C., Prof. Paper, U. S. Geol. Survey, No. 62, 1908.

Hecla dike is locally called "black porphyry," a not inappropriate name. The present studies seem to indicate that the hornblendic and the biotitic rocks form two fairly distinct classes and intermediate rocks are somewhat rare. Spessartites are somewhat more abundant than minettes and kersantites and vogesites are quite exceptional.

GENERAL OUTLINE OF THE GEOLOGY OF THE REGION.

The chief aim of the original field work was to endeavor to develop some logical theory in regard to the genetic relation of the lamprophyric rocks to the ore-bearing veins of the district and to the monzonitic rocks which are presumed to have supplied the ore-depositing solutions.

The areal and economic geology of the region have been described in detail by Ransome and Calkins, and it is necessary here only to mention in bare outline the broader features of the areal geology. The district occupies a portion of the large area of pre-Cambrian rocks which covers the greater portion of northern Idaho and north-western Montana. These sediments, which are of Algonkian age, comprise a vast thickness of beds known collectively as the Belt Terrane. In the Coeur d'Alene District these rocks were divided by Calkins into the following members, the divisions being based upon lithologic characters:

Formation.	Thickness.
	<i>Fect.</i>
Striped Peak; red and green flaggy sandstones and shales, top eroded.....	1, 000
Wallace; mainly calcareous shale with some limestone.....	4, 000
St. Regis; green and purple shales and sandstones.....	1, 000
Revet; pure white thick-bedded quartzites.....	1, 200
Burke; greenish sericitic slates and thin-bedded sericitic quartzites.....	2, 000
Prichard; blue-black slates quartzites and argillites, base not exposed.....	8, 000
Total.....	17, 200

The important ore bodies occur mainly in the lower formations, the Prichard, Burke, and Revett, a condition which is probably in some measure influenced by the lithologic character of the formations but is apparently more because, at the time of deposition of the ores, the rocks of the higher formations in very few cases were in a position to be reached by the ore-bearing solutions before their load of dissolved minerals had been exhausted. Most of the areas occupied by the lower formations as exposed at the present surface occupy islandic horsts which are partly surrounded by graben of the higher formations which have been faulted down by gigantic post-mineral faults. If commercial ore-bodies exist in these depressed

blocks they have been dropped downward far beyond the reach of mining exploration.

The igneous rocks are present in small amount. Chief among them is a group of granitic rocks ranging from syenite to quartz-monzonite or quartz-monzonite porphyry in composition, which occurs as a number of small areas which presumably are upward projections of a single small batholith. The intrusion is very long as compared with its width and trends in a northeasterly direction. Calkins states that its exposure is probably the axis of a very old flat anticline which has largely been obliterated by later deformation. This monzonitic intrusion has been regarded by Ransome and others as the most probable source of the metalliferous ores of the district. Hershey¹ discredits the theory that the ore minerals were derived from the igneous rock and applies a modification of the older lateral-secretion theory which implies that the lead and zinc were derived by leaching from a certain narrow horizon in the upper Prichard formation in which these metals were present in some form as an original clastic constituent. In his latest paper, which, unfortunately, is generally inaccessible to the majority of persons who might be interested in the subject, Mr. Hershey contends that the ores are older than the Coeur d'Alene monzonite intrusions, and further that the contact-metamorphism of the Ninemile area is distinctly older than the intrusive rock at present exposed and likewise older than the ores which the metamorphic silicates inclose. His evidence seems to, in part, substantiate these latter conclusions, although his views as to the source of the metallic minerals have met with no general acceptance even upon consideration of his complete evidence.

Ransome believed that the Coeur d'Alene batholith was an upward projection of the continuation of the Central Idaho batholith which he assumed to underlie the entire district. In part from the modified conclusions of both Ransome and Hershey, we may derive the following succession of events:

1. Intrusion of the central Idaho batholith, extending under the Coeur d'Alene region to connect with the Priest Lake batholith to the north, probably with an upward extension beneath the center of the Coeur d'Alene area.

2. A renewed upward advance of the column of magma under the central portion of the Coeur d'Alene district, giving off emanations which produced intense local metamorphism in the overlying rocks.

3. Deposition of the ores by solutions given off by the underlying igneous rock of the Coeur d'Alene.

¹ Genesis of lead-silver ores in Wardner District, Idaho. *Min. and Sci. Press*, June 1, 8, and 15, 1912. Origin of Lead, Zinc, and Silver in the Coeur d'Alene, *Min. and Sci. Press*, Sept. 27 and Oct. 4, 1913. Origin and Distribution of Ore in the Coeur d'Alene, Private Pub., San Francisco, 1916.

4. Continued upward advance of the magma column, giving the Coeur d'Alene batholith as it at present exists.

5. Slight subsidence of the region and intrusion of the lamprophyric dikes.

6. Beginning of long-continued subsidence, giving great structural faults.

As suggested by Stewart¹ the fact that the rocks of the Coeur d'Alene intrusion present some essential differences from the main mass of granitic rock in Idaho indicates that some differentiation had probably taken place before it was intruded.

THE LAMPROPHYRE DIKES.

The lamprophyric dike rocks are widely distributed in the Coeur d'Alene region as well as in a large part of the surrounding territory. They are most abundant in the Prichard formation, are common in the lower Burke, and are increasingly rare higher in the series. Those which have reported from the formations above the Burke are doubtful, as they are thoroughly decomposed and may belong to the diabases rather than to the lamprophyres.

As is well known the group of rocks called lamprophyres belongs to the class known as diaschistic or complementary intrusives and results from the tendency of a magma of medium composition to separate into two components by the process of gravitative differentiation, a mafic division containing the majority of the ferromagnesian minerals, and represented by lamprophyres, and a felsic division consisting of the more acidic light-colored constituents of the rock and represented by aplites in the case of a normal granite or granodiorite. The presence of lamprophyric rocks in wide distribution over the Coeur d'Alene region constitutes the strongest argument in support of the assumption that the region is underlain by a granitic batholith. Yet from a batholith of the composition of the granitic rock of central Idaho aplites should be expected to form at least twice as much of the volume of the complementary rocks as lamprophyres. Aplites are not definitely known to occur in the Coeur d'Alene district, although Hershey has mentioned some very much decomposed dikes which may originally have been of aplitic character. As to why lamprophyres should be so abundantly represented while aplites are almost, or quite, absent, the explanation probably lies in the well-recognized fact that mafic magmas are fluid at much lower temperatures than are acidic magmas. It is probable that the lamprophyres did not extend much above the level of the present erosion surface and that they were enabled to reach their present position because they were fluid at temperatures below the crystallizing point of aplites which solidified at much greater depth. The

¹ Journal of Geology, vol. 22, No. 7, p. 684.

mixed character which characterizes many of the dikes may be construed to show that when they reached their present position they had already cooled to the extent of partial crystallization and lumps of solidified material were carried forward mixed with more fluid fused magna in a pasty mass yielding solid bodies of more or less agglomeratic texture.

The age relations of the lamprophyres are rather definitely fixed by the work of Hershey on the age of the Coeur d'Alene batholith in relation to the ores and by the fact that both the ore-bearing veins and the Coeur d'Alene batholith itself are cut by typical lamprophyric dikes. The whole series of events, tabulated above, from the first underlying intrusion to the injection of the lamprophyric dikes must have occupied a relatively short period of time. That the period of mineralization had not entirely closed before the intrusion of the basic dikes is evidenced by the fact that the dikes are all affected by hydrothermal alteration, some of them to an extreme degree.

The lamprophyres occupy narrow dikes rarely more than 10 feet in width and seldom traceable along the strike for more than half a mile. The majority of them strike in a northwesterly direction and dip steeply to the southwest, but exceptions to this rule are abundant. In appearance the rocks are fine-grained, dark gray, greenish, or black, but lighter-colored, coarser grained varieties occur as described below. They are commonly much weathered in surface outcrop, the majority of the dikes being concealed by soil. In weathering they disintegrate to a friable sand along joints and give rounded cobbles which shell off in concentric layers. The weathered rocks are commonly greenish to brown from the development of chlorite and limonite from the alteration of the ferromagnesian minerals. The effects of ordinary weathering do not extend any great distance downward, however, and the altered character of the dikes exposed in cuts and mine workings is from the development of sericite and other minerals indicating the action of thermal solutions.

In the field these rocks may readily be divided into two classes according to the character of the dominant ferromagnesian mineral. The rocks studied may with a few exceptions be called minette or spessartite. The hornblende rocks in the main have plagioclase as the dominant feldspar while most of those which show biotite as the predominant ferromagnesian mineral contain only alkalic feldspar. Kersantites, or lamprophyres composed of biotite and plagioclase, are rare, as is the hornblende-orthoclase rock, vogesite. The most abundant varieties are those consisting of greenish-brown hornblende and twinned lime-soda feldspar. These range from very fine-grained rocks to some which have the texture and appearance of fine-grained hornblende granite. A single specimen of the coarsest

forms might well be classed as a diorite, yet there is every gradation between the coarse forms on the one hand and very fine-grained mafic rocks of typical lamprophyric texture and mode of occurrence on the other. Such rocks to distinguish them from ordinary diorites must be called spessartites (although this name is objectionable, as it has been given also to a mineral of the garnet group). The relationship of the spessartites to the minettes is not clear. They are distinct from each other in composition—so much so in fact as to suggest that they were derived from the parent magma at slightly different periods. No data on the relative age relations of the two types were obtained in the field. There seems to be some evidence, however, showing that a given dike may pass from one rock into the other along its strike. Thus the large spessartite dike at Bailey's Pond apparently continues across the valley, yet on the north side of the river it consists of minette. The same thing occurs at Elk Creek where a typical minette is exposed on the south side of the valley yet where what seems to be the same dike reappears on the north side of the river, scarcely over a hundred yards distant, it is a much decomposed spessartite consisting almost entirely of hornblende with neither biotite nor orthoclase.

The lamprophyres are closely associated with the veins of the sections in which they occur. Around Kellogg almost every one of the large nonproductive pyritic quartz veins has its dike of lamprophyric rock within a few yards of the vein itself. Such relationships are well exhibited in the Lombardy, Teddy, Tillicum, Eldorado, Enterprise, Evolution, and other prospects near Kellogg and a similar relation exists in many of the lead mines of the Canyon Creek and Mullan areas as in the Hecla, Marsh, Moonlight, Morning, Rex, Helena-Frisco, Success, Standard, and other mines. This juxtaposition of dikes and veins argues in favor of the conclusion that they have a common source and also shows that at the time the lamprophyres were intruded, in contrast with the enormous abundance of later fissures, planes of weakness were few in number and igneous injections were constrained to occupy the same general channels followed by the mineralizing solutions.

DETAILED DESCRIPTION OF THE LAMPROPHYRES.

I. BIOTITE TYPE.

Minette, Hecla Mine.—The dike which occupies the same fissure, but is younger than the Hecla vein (see fig. 1), has been described by Ransome, as being chiefly composed of hornblende. Sections were not examined by the writer, and the first specimen which was studied was found on the Hecla dump and does not agree with Ransome's description. Specimens from various parts of the mine

in Mr. Umpleby's collection also fail to agree with Mr. Ransome's description as noted below, the only other rock known from the district which does agree with Mr. Ransome's specimen being the hornblende-quartz rock from Bailey's Pond.

In appearance this rock is essentially like that from the adjoining Marsh mine, being composed of biotite phenocrysts rather sparsely scattered through a rather light granular-looking gray groundmass.

Under the microscope this rock is seen to be composed of large phenocrysts of biotite with accessory iron ore and well-crystallized apatite with occasional much altered phenocrysts of diopside in a groundmass composed chiefly of alkalic feldspar. Among the secondary minerals may be mentioned abundant sericite formed at the expense of the feldspar, infiltrated calcite, and chlorite and secondary amphibole formed from the diopside. The biotite as usual in these rocks is intensely pleochroic in tones of dark and light brown with dark reaction rims and embayed outlines. It occurs in well-formed hexagonal tablets which are markedly parallel in arrangement and are fresh and unaltered.

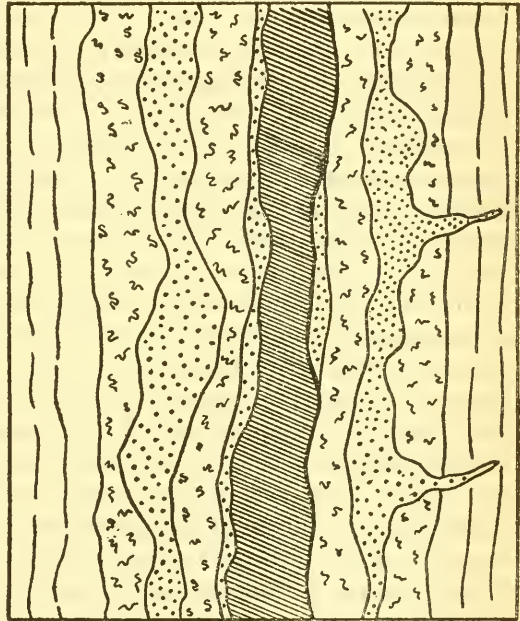


FIG. 1.—DIAGRAM SHOWING RELATION OF DIKE TO VEIN, HECLA MINE. A. DIKE. B. CRUSHED MATERIAL WITH QUARTZ AND ORE. C. GALENA. D. QUARTZITE WALL ROCK. WIDTH OF SECTION 15 FEET.

The iron ore occurs in small scattered grains of euhedral outlines. The apatite, which is abundant and rather late in crystallization, forms well-crystallized stout hexagonal prisms. The groundmass appears to be, in large part, composed of orthoclase, which occurs in lathlike bundles of prismatic fibers which give a rather rolling extinction. This habit of the orthoclase gives the rock a somewhat trachytic texture. Between the orthoclase laths are interstitial areas filled with a material of very feeble birefringence which may be a zeolite or perhaps glass. Scattered throughout the groundmass are innumerable minute needles of granular appearance, high relief, high

birefringence, and approximately parallel extinction. These are too minute for their character to be determined, but they bear some resemblance to the minute rutile needles which make up the so-called sagenite nets. The diopside phenocrysts are rare and usually only small grains and patches of unaltered diopside occur, embedded in a mass of chloritic alteration products. The rock is a very typical minette.

A specimen from halfway between the two oreshoots on the 600-foot level is a holocrystalline very fine grained nonporphyritic aggregate of minute laths of feldspar and chlorite in shreds. The rock is greatly altered and now consists chiefly of chlorite. The original ferromagnesian mineral was clearly biotite although no vestige of unaltered biotite now remains. The feldspar grains, which are very minute, are untwinned and are probably orthoclase. The fabric is regularly dotted with grains of iron ore. Large patches of infiltrated calcite occur and inclusions of clear quartz are abundant. In some cases these inclusions are a single crystal individual but more frequently they are aggregates of interlocking grains, quite evidently fragments of quartzite. The quartz exhibits rolling extinction and other strain phenomena. These inclusions have no reaction rims.

Another specimen from the middle oreshoot on the 900-foot level is fine grained, holocrystalline, and fairly fresh. It contains numerous well-crystallized tablets of pleochroic brown biotite scattered through a ground composed almost entirely of alkalic feldspar having a trachytic texture from being composed of bundles of lath-shaped fibers sometimes curved and divergent and yielding rolling extinction. Iron ore in the usual small euhedrons is scattered throughout the fabric of the groundmass. Grains of augite exceeding the largest biotite phenocrysts in size occur at frequent intervals. These seem much shattered and irregular pieces seem to be detached portions of much larger individuals. They show well-defined cleavage but are much cracked and unaltered augite has progressed along cracks until now only grains of unaltered augite occur embedded in a mesh of alteration products. Occasionally one of these augites shows a sharp crystal boundary lined with grains of iron ore. In one place an inclusion of quartz—a single large rounded crystal individual—has a well-defined rim zone containing feathery crystallizations of magnetite. Infiltrated calcite is common.

A specimen from between the 1,400 and 1,600 foot levels is a moderately fine-grained rock consisting of biotite phenocrysts of the ordinary type in a ground of orthoclase which is now badly sericitized. Iron ore forms scattered grains and apatite is present in stout well-formed crystals. Calcite is very abundant and is in places intergrown with a green secondary mineral resembling chloropal. The section contains numerous inclusions of clear quartz having border

zones crowded with fern-like microlites of hornblende and iron ore. These inclusions are all somewhat rounded and embayed. (See pl. 39, B.)

Minette, Elk Creek.—In a railroad cutting just east of the mouth of Elk Creek is a narrow dike of biotite-lamprophyre, cutting rocks of the Prichard formation. On the south side of the cut, rounded residual lumps of fairly fresh rock remain, although decomposition has taken place along joints. On the north side of the cut the rock is decomposed to a friable sandy aggregate containing flakes of bleached and altered biotite. The dike is perhaps 4 feet wide at the bottom of the cut, but narrows upward to about 8 inches, near the surface.

In appearance this rock is exactly like the rock from the Hecla Mine, being composed of phenocrysts of biotite in a gray ground-mass. Under the microscope the resemblance to the Hecla minette is still more marked, the Elk Creek rock consisting of numerous phenocrysts of biotite with accessory iron ore and well-crystallized apatite in a base of alkalic feldspar. Rarely, much-decomposed diopsides occur. Abundant secondary sericite has developed from the feldspar which is intensely altered. Areas of infiltrated calcite are common and some secondary quartz occurs.

That the composition given above does not make up the whole of the dike at Elk Creek is evident upon examination of a specimen collected here by Mr. Calkins. Although labeled the same and of the same appearance in the hand specimen Mr. Calkins' specimen is markedly different as seen in thin section under the microscope. Here, although the sparsely disseminated biotite phenocrysts are large and conspicuous they make but a small fraction of the whole volume of the rock which is composed of a fine grained holocrystalline aggregate of feldspar and hornblende which is of the usual type. The feldspar is so poorly individualized and so greatly altered that little can be said regarding it other than that it is chiefly orthoclase. Less abundant grains are zoned though not twinned and are probably plagioclase. This abrupt variation may represent an inclusion or a transition toward the spessartite which occurs in the line of strike on the north side of the river. Similar abrupt differences between different parts of the same dike are described elsewhere. Mr. Calkins' specimens may be described as a porphyritic biotite vogue-site. (See pl. 38, A.)

Augite-Minette, Marsh Mine.—In the upper levels of the Marsh Mine at Burke, two small dikes are exposed. On the No. 1 tunnel level there is exposed one very much decomposed dike, about 6 inches wide, which consists of much bleached and altered biotite phenocrysts in a pasty or sandy brownish-green matrix. This dike, somewhat wider and less decomposed, is crossed by the raise between the

No. 1 and No. 2 tunnels, and on the level of the No. 2 tunnel it is quite fresh, has a width of about 2 feet, and cuts cleanly across the vein on this level and the level below. On the No. 1 level below the tunnel one dike cuts cleanly across the vein, while the other is deflected along the vein for some feet and dies out. (See fig. 2.) Below this level these two unite to form a single dike, which gradually widens with depth. Two specimens studied came from the old sheave-way above the inclined shaft, on the level of the No. 2 tunnel. One specimen was taken from the center of the dike and the other from the contact with the inclosing slaty rocks of the Burke formation.

In the hand specimen the rock from the Marsh dikes is dark gray in color and porphyritic from the development of numerous bright brownish-black phenocrysts of biotite in an almost aphanitic gray groundmass. The individual phenocrysts of biotite average about 2 mm. in diameter and are not well crystallized. No other minerals can be distinguished with the unaided eye. The rock is quite fresh, but where altered it assumes a brownish color and becomes friable, the groundmass being completely altered before

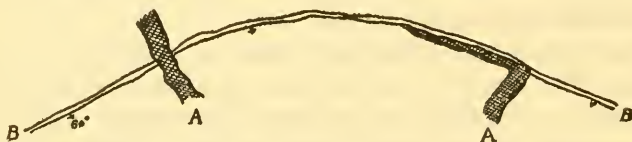


FIG. 2.—SHOWING RELATION OF DIKES (A) TO VEIN (B) ON NO. 1 LEVEL OF MARSH MINE.

the biotites are attacked. The dikes are cut by numerous joints which appear to follow no regular system. The rock has a rather marked tendency to cleave parallel to the walls of the dike, due to a flow structural arrangement of the biotite phenocrysts. The material from the border of the dike is finer grained; the biotites are slightly smaller, averaging about 1 mm. in diameter, are somewhat better crystallized, and are more markedly arranged parallel to the walls, thus emphasizing the cleavage of the rock.

Under the microscope the rock is seen to consist essentially of biotite and augite, with accessory apatite and iron ore in an unindividualized glassy base. Among the secondary minerals may be mentioned abundant sericite which has developed in the ground mass and also probably opal, tridymite, and some zeolites which have developed in the augite. The biotite is of the type characteristic of lamprophyres, with intense pleochroism in tones of dark and light brown, deep embayments, and dark colored resorption rims. It is usually entirely fresh and the phenocrysts are remarkably free from inclusions. The augite, which equals or exceeds biotite in amount, occurs in large phenocrysts with rather poor crystal outlines which

are commonly merely spongy shells inclosing a large amount of the material of very low refraction and double refraction which may include opal, tridymite, and zeolites. The augites which are near diopside in composition, are commonly colorless but frequently have a narrow, faintly pleochroic border of a pale green color which shows some admixture of the aegirite molecule. There are clearly two generations of the colored constituents of the rock. The apatites, which are often of large size, are late in crystallization and often contain dust-like inclusions, especially along the vertical axis. The iron ore occurs in abundant small euhedral grains in the groundmass. The flow structure of the rock is very marked. The groundmass is mostly colorless to brownish glass but in places it acts feebly on polarized light. The rock from the border of the dike has smaller biotites and the augites are even more spongy than in the main mass of the dike and the groundmass is more completely glassy. This glassy groundmass contains much dust-like material which by its dispersion gives the glass a brownish color suggesting kaolin.

Since classifications are based upon the character of the feldspar, and there is no feldspar present in uncrystallized base of this rock, it is difficult to say whether the rock should be classed with the minettes or the kersantites. The aegiritic rims of the augites and the faintly double-refracting patches in the groundmass give the rock an alkalic appearance in thin sections and it is placed with the majority of biotitic lamprophyres studied in the minette class. In consideration of the abundant presence of augite the rock may be termed an augite-minette.

Minette, Senator Stewart Mine, Kellogg.—A specimen of very dense lamprophyric rock from the Senator Stewart mine, in Deadwood Gulch, near Kellogg, is intensely altered as seen in thin section and only the original texture is preserved in the secondary minerals. Apparently it was much like the glassy minette from the Marsh Mine. It shows the usual fabric of biotite laths in what appears to have originally been an alkalic glass, but which is now deep green in color, and almost opaque. It is dotted with small grains of iron ore. Large scattered fragments of broken and irregular outline are now quartz, but appear to have originally been augites.

Olivine-augite-minette, Kellogg.—On the north side of the river, on the Kellogg-Wallace road, just east of Kellogg, there are exposed a number of small lamprophyre dikes. These are directly across the valley from the Bailey's Pond locality described below, and in the field were supposed to represent the continuation of the same dikes. Microscopic study of the largest and freshest dike at this locality, however, shows the mineralogic composition to be entirely unlike anything exposed on the south side of the river. There are at

least four dikes exposed here, cutting quartzitic rocks of the Prichard formation, three of which are about 4 feet in average width. These three dikes, while completely decomposed, resemble the dark spessartites of the Bailey's Pond side. The fourth, which is the westernmost, is somewhat fresher in appearance. At the level of the road it is about 8 feet wide, but it narrows upward. On the surface it is traceable for about one-fourth of a mile in a north-westerly direction, and may connect with dikes in Italian Gulch, which are in the line of strike.

In the hand specimen this rock is fine-grained and of a greenish-gray color. The most abundant megascopically distinguishable mineral is micaceous and of a greenish color. Small white grains, presumably feldspar, are visible under a lens. The rock is tenacious but has a tendency to cleave parallel to the walls of the dike.

Under the microscope the rock is equigranular except for rare phenocrysts now consisting entirely of serpentine which is clearly secondary after olivine. The other original minerals are colorless augite, biotite, and orthoclase with accessory iron ore and apatite. The rock is very much altered. Among the secondary minerals the most abundant is chlorite, which has developed at the expense of the original biotite. Calcite in infiltrated patches and secondary quartz are abundant. Epidote occurs in places as an alteration product of biotite and sericite is common in the feldspar. The olivine phenocrysts are now represented by masses of serpentine, dotted with iron ore which are commonly surrounded by a rim of biotite and augite.

The pyroxene, which is colorless and unaltered in thin section, is near diopside in composition, and is perhaps the most abundant mineral of the rock. It forms prismatic individuals with poorly developed form and barely perceptible cleavage. Biotite occurs in thin laths and tablets, pleochroic in tones of dark and light brown. There now remain only ragged remnants of the original biotite surrounded by chlorite. The orthoclase, which is greatly sericitized, forms poorly individualized interlocking grains. Iron ore is abundant in small grains and apatite occurs in the usual prismatic crystals. Quartz is abundant in the interstices, but it is all clearly secondary. The rock thus has no features in common with the spessartite of the Bailey's Pond side.

Augite Minette, Murray Hill.—Another rock, collected by Doctor Umpleby and examined only in thin section. Contains an unusual number of sharp euhedral crystals of augite in a groundmass composed of biotite and orthoclase. The augite is for the most part clear and colorless but the crystals have at times a narrow faintly pleochroic pale-green border of aegirite-augite. The orthoclase is of the peculiar type composed of bundles of prismatic fibers. It is

somewhat sericitized. Interstitial quartz grains which occur frequently may be secondary. (See pl. 37A.)

Lamprophyre, Grouse Tunnel, Grouse Gulch.—This rock is megascopically one of the coarsest of the lamprophyres. It is of medium-gray color, having feldspar in excess of ferromagnesian minerals, and has prominent black spots which apparently are small aggregates of hornblende. Under the microscope it appears as a comparatively coarse holocrystalline aggregate of feldspar with slightly subordinate ferromagnesian minerals consisting of hornblende and biotite in about equal amounts. The feldspar consists of both orthoclase and plagioclase, the former slightly in excess.

Olivine-Kersantite, Spring Gulch.—Just west of the mouth of Spring Gulch on the south side of the river near Osburn, two parallel dikes are exposed a few feet apart, cutting rocks of the Prichard formation. These dikes were examined by the writer, but in the following description Mr. Calkins' specimens and sections were utilized. Only the largest and freshest dike is represented. In the hand specimen the rock is dark gray to black, fine grained and non-porphyrific, showing under a lens small flakes of biotite and brown spots which may represent serpentinized olivines. Under the microscope it shows the usual trachytic aggregate of plagioclase laths with predominant biotite and accessory hornblende as the ferromagnesian minerals. The plagioclase is in well-defined laths, characteristically zoned and twinned. Sericitization is well advanced in all cases, beginning with the more basic cores of the crystals and progressing outward. Augite is common in disseminated ragged crystals and large pseudomorphic areas of both talc and serpentine, dotted with iron ore, which are in this case surrounded by a rim of biotite, clearly represent original olivine. The usual accessory apatite and iron ore are present.

Minettes, other occurrences.—Other much decomposed biotite-lamprophyre dikes occur in the district, especially near the Enterprise Prospect, near the mouth of Polaris Gulch, and near Raven, on Prichard Creek. A typical fresh rock of this type is exposed in the workings of the Moonlight claim above Burke, but it was not studied in thin section.

II. HORNBLLENDE TYPE.

Odinite, Hecla Mine.—Ransome¹ describes the dike which accompanies the Hecla Vein as occupying the same fissure as the lode and having an average width of two feet but in places reaching 7 feet. It is not quite simple, but branches and pinches out to be succeeded by another dike a few feet to one side. The dike is clearly younger than the ores and sends out minute branches which occupy little fissures

¹ Prof. Paper, U. S. Geol. Survey, No. 62, p. 176.

in the ores, and is more glassy at the borders than in the center. The ores are not noticeably metamorphosed.

In its freshest condition the rock of this dike is dark greenish-gray and fine grained, the only minerals recognizable to the unaided eye being small prisms of hornblende, specks of pyrite, and scattered grains or granular inclusions of quartz up to an inch in diameter. The microscope shows a holocrystalline aggregate of abundant phenocrysts of hornblende in a groundmass of the same mineral, with a calcic-plagioclase in minute laths. Larger phenocrysts, possibly augite, have been completely altered to calcite, serpentine, and secondary amphibole. The rock appears originally to have had some glass in the groundmass, but it is now altered to chlorite. The quartz inclusions are much corroded and embayed and are usually surrounded by reaction rims in which spherulitic quartz appears in the groundmass. The rock is probably an odinite, hornblende being too abundant for kersantite, in which biotite is the principal dark mineral. The quartz grains are presumably not original but are inclusions derived from the quartzose sediments through which the dike was intruded.

No other rocks of this character have been seen from this mine. This suggests that the Hecla dike may not be as simple as is generally supposed and lamprophyric magmas of two types may have been injected into the fissure at slightly different periods.

Hornblende-quartz rock, Bailey's Pond.—At the side of the old road, at Bailey's Pond, south of the river, a short distance east of Kellogg, there are several lamprophyric dikes. Four or five narrow black dikes averaging each about 2 feet in thickness outcrop almost horizontally, one above another, along the face of the cliff. These are almost aphanitic in texture and are very much altered but appear to have originally been spessartites. In weathering they characteristically give rounded cobbles resembling water worn boulders. The uppermost dike appears originally to have been somewhat larger than the others but here there are clearly two dikes intruded into the same fissure. The dark mafic rock is in places shattered, forming a breccia cemented by the later much more feldspathic rock. In other places the later intrusion has followed the bottom contact or the top contact or sometimes both giving a central layer of the dark rock sandwiched between two layers of the more feldspathic rock the contact in all places being clean-cut with no mingling of the two materials. The dark rock of this dike in the hand specimen looks fresher and more completely crystalline than that of the dikes below. It is a fine-grained equigranular rock of dark greenish-gray color, which to the unaided eye shows numerous glittering prisms of black hornblende. Megascopically it is indistinguishable from the typical fresh spessartites of the Standard and other dikes.

Under the microscope this rock is seen to consist almost entirely of hornblende and quartz, feldspar being entirely absent. Biotite forms ragged and much resorbed phenocrysts now almost entirely altered to chlorite. The biotite differs from the ordinary biotite of the

lamprophyres of this region in that in color it ranges from pale greenish-brown to deep brownish-green. The quartz forms interlocking grains which are relatively free from inclusions. Small well crystallized apatites are sparingly scattered through the rock and occasional large phenocrysts of diopside occur surrounded by hornblende in parallel position. Iron ore seems to be absent. Among the secondary minerals, the most important is chlorite, formed at the expense of both the biotite and hornblende. Areas of infiltrated calcite, small masses of epidote and abundant ragged grains of pyrite make up the list.

The hornblende is very pleochroic in tones of greenish brown. The prisms of hornblende which are in part well bounded by crystal planes show well-developed cleavage and are very frequently twinned parallel to (100). The extinction angle, measured from the twinning plane, is near 16° . This brownish hornblende is apparently a variety intermediate between common and basaltic hornblende very near the latter as in the other spessartites described below. In this rock, however, cores of brown hornblende are frequently surrounded by an outer fringe of common green hornblende in parallel position.

This quartz-hornblende rock is very unusual in composition and its mode of occurrence would suggest that the unusual composition might be due to alteration of a contact-metamorphic nature incident upon the intrusion of the later more feldspathic rock into the same fissure. Opposed to this hypothesis, however, is the fact that the altered rock equals in amount the later rock, which might have caused the alteration. Furthermore, where these magmas are in contact with the inclosing sediments, they have nowhere exerted any noticeable metamorphic influence. The rock from the Hecla Mine described by Ransome as consisting chiefly of hornblende with a large amount of included quartz gives a reasonable explanation of the peculiarity of the Bailey's Pond quartz-hornblende rock. In all probability it is the same as the "odinite" of the Hecla dike—a magma consisting entirely of ferromagnesian minerals which derived and absorbed a large amount of silica from the quartzitic rocks through which it was intruded. This derived quartz became thoroughly diffused and recrystallized as a part of the fabric of the rock instead of remaining as recognizable inclusions as in the Hecla dike.

Bailey's Pond, Spessartite.—The rock which is intruded into the same fissure forming a mixed dike with the one described above varies greatly from place to place in texture and appearance. Perhaps the most abundant type is medium-grained equigranular and of a dark gray color but showing, under a lens, a "pepper-and-salt" aggregate of glittering black hornblende prisms and grains of feldspar. In other parts of the dike this rock is porphyritic from the development of numerous phenocrysts of white feldspar averaging

3 mm. in diameter. From the rather basic form described the rock varies to types which are almost white and consist of scattered prisms of hornblende in a feldspathic base. In places near the lower contact there is a very marked lamination, the rock consisting of layers of feldspathic material alternating with layers composed almost entirely of prismatic hornblende. This may be due to flow structure, segregated bunches of mafic minerals having been drawn out into lines. The fact that this lamination is represented only at the bottom contact where the dike is almost horizontal makes it interesting to consider the possibility that these alternating laminae may be due to crops of crystals of ferromagnesian and of feldspathic minerals separating alternately from the mass of the dike and sinking through the still fluid magma to the bottom. The most acid phase of the rock is somewhat pegmatitic in character and clearly represents an acid residuum which concentrated in patches as the last material to crystallize.

Under the microscope the main mass of the dike is seen to consist of a beautifully trachytic aggregate of laths of plagioclase and prisms of greenish-brown hornblende. Small shreds of pleochroic brown biotite are now almost entirely altered to chlorite. The feldspar, which is the most abundant mineral, is a plagioclase which occurs in beautiful laths characterized by the rarity of twinning on the albite law, the majority of the crystals being simply twinned once. In the main mass of the rock the feldspars are all beautifully zoned and range in composition from basic bytownite, $Ab_{16} An_{84}$, at the center to acid andesine, $Ab_{70} An_{30}$, at the peripheries. Where the rock contains porphyritic phenocrysts of feldspar, these are usually even more basic than in the main mass of the rock, ranging down to pure anorthite in the center. These beautifully zoned phenocrysts frequently show carlsbad, albite, and pericline twinning in the same individual. Occasionally there are inclusions of quartz which reach 3 mm. in diameter, each inclusion being a single crystal individual. These are commonly surrounded by rims of hornblende and frequently have a small patch of chlorite in the center. The quartz contains lines of fluid inclusions. The hornblende is in prisms which are somewhat ragged and frayed at the ends but which, in cross sections, are sharply euhedral. The hornblende is frequently twinned parallel to (100). It is a basaltic variety, pleochroic in pale to dark greenish brown. In the coarsest-grained acid phase of the rock the minerals present are the same as in the main mass of the dike—plagioclase, hornblende, and some biotite. The hornblende is pale to dark brown, lacking the greenish tinge of the finer-grained rock. The biotite, which is much altered to chlorite, is also pleochroic in brown tones. It is present only in rare shreds. The feldspar, which is greatly kaolinized, is not so basic as in the

main mass of the rock. The feldspar phenocrysts are zoned and show albite and carlsbad twinning. They range in composition from oligoclase-albite, $Ab_{02} An_8$, at the peripheries to bytownite-anorthite, $Ab_{17} An_{83}$, at the cores. Quartz and micropegmatite are common in the interstices of this rock.

Spessartite, Eldorado claim.—At the portal of the tunnel of the Eldorado claim, a prospect opening on a small barren vein in the Prichard formation on the north side of the river, about a mile east of Kellogg, a small amount of quarrying has been done on a broad exposure of lamprophyric rock. This may be in the form of a neck or stock as it can not be traced in any direction from this exposure. There is some evidence that narrower dikes of ordinary more basic lamprophyre may radiate outward from this mass and the quartz-pyrite vein developed in the tunnel terminates at the igneous rock in a suggestive manner. In the hand specimen the rock is fairly coarse granular and consists of equal parts of white to pale flesh colored feldspar and greenish hornblende. Occasional large poikilitic biotites occur and small veinlets of pegmatitic material were seen. Under the microscope the rock is a coarse aggregate of hornblende and feldspar. The larger feldspars which are badly sericitized internally are plagioclase. Smaller grains appear to be orthoclase. The hornblende is of the usual type. Large chlorite patches dotted with iron ore and surrounded by hornblende rims appear to represent original augite. Dots of iron ore and a few long prismatic apatites occur. (See pl. 38 B.)

Spessartite, Lombardy claim.—The first 70 feet from the portal of the lower tunnel of the Lombardy claim in Italian Gulch north of Kellogg are in a peculiarly equidimensional mass of lamprophyric rock precisely like that last described on the Eldorado claim. There is evidence that one or more dikes of finer grain and more mafic composition may extend outward from this mass. The Lombardy vein, carrying some lead and great masses of cupriferous pyrite and pyrrhotite, also extends outward from this igneous mass. Megascopically the rock of this occurrence is indistinguishable from that of the Eldorado claim and the microscopic character is similar. The feldspar, which is much altered, appears to be a rather basic plagioclase. The hornblendes which are sharply euhedral show some incipient alteration to green chlorite but are for the most part fresh with well-developed cleavage. They are as usual pleochroic in tones of light to dark greenish brown but have borders of green hornblende. The rock contains large areas of calcite. Associated with these are patches of serpentine with hornblende rims which are probably altered olivines. Biotite occurs rarely and in the form of small tablets. Scattered stout well-formed prisms of apatite and grains of iron ore occur. Quartz is absent.

Other coarse spessartites.—Certain dikes which accompany the Osburn fault throughout a large part of its length closely resemble these coarse spessartites, but they are enormously decomposed.

Spessartites, Standard Dike.—One of the most interesting rocks studied was that which intersects the Standard vein in the Greenhill-Cleveland Mine, near the center of the Standard-Mammoth ore shoot. Specimens were collected from this dike on the 1,200-foot and 2,000-foot levels of the mine. On the 2,000-foot level the dike cuts squarely across the ore body, bulging slightly in the vein. On the 1,200-foot level the dike is deflected along the vein for about 20 feet. These relations are shown in figures 3 and 4. This dike coincides in dip with the pitch of the ore shoot and it can be traced upward to the No. 5 tunnel, 2,500 feet vertically, above the 2,000-foot level.

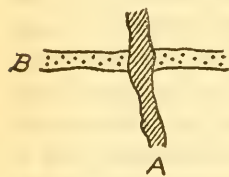


FIG. 3.—SHOWING RELATION OF DIKE (A) TO VEIN (B) ON 2,000 FOOT LEVEL OF STANDARD-MAMMOTH MINE.

In the hand specimen this is a dark-gray equigranular fine-grained rock, showing minute needles of hornblende and white grains of feldspar under a good lens. That from the deep levels of the mine is quite fresh, but material from the No. 5 tunnel is altered to a friable sandy brownish-green aggregate. The fresh rock is cut by numerous joints which divide it into sharp-edged rhombic or tetrahedral blocks.

Under the microscope the rock is seen to be composed of prisms of pleochroic greenish-brown hornblende with accessory and not very abundant iron ore in small scattered grains, occasional small apatites, and minute shreds of biotite in a beautifully crystallized trachytic groundmass composed of twinned laths of plagioclase. In the rock from the 1,200-foot level there also occur occasional large phenocrysts, which were apparently originally olivine but which are now entirely altered to talc. These are commonly surrounded by a rim of hornblende prisms. They do not occur in the rock from the 2,000-foot level. The hornblende, which is well crystallized, is intensely pleochroic in tones of deep brownish-green and pale greenish-brown. It is frequently twinned parallel to (100). The extinction angle measured from the twinning plane is around 12 degrees. This is near basaltic hornblende grading toward common hornblende. The plagioclase shows broad twinning lamellae and ranges in composition from anorthite, Ab_6An_{94} at the center to labradorite, Ab_1An_{19} , at the peripheries. There is a gradual shading from center to border with no distinct zones. The rock from the 1,200-foot level may well be called an olivine-spessartite in view of the original occurrence of olivine. The rock from the 2,000-foot level is a typical spessartite.

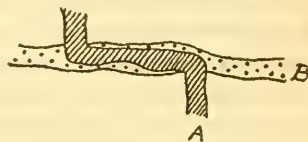


FIG. 4.—SHOWING RELATION OF DIKE (A) TO VEIN (B) ON 1,200 FOOT LEVEL, OF STANDARD-MAMMOTH MINE.

Peculiar interest attaches to a rock which forms a very small branch from the Standard dike into the quartzite of the footwall on the 1,200-foot level of this mine. In the hand specimen the rock is seen to consist of small, greenish grains in an aphanitic black base, the whole looking like an ordinary basalt. It is clearly a result of sudden cooling on the magma which composes the larger dike.

In thin section the rock is seen to have originally consisted of abundant large well-crystallized phenocrysts of olivine and smaller prisms of augite, in a matrix consisting of glass completely filled with minute prismatic laths of augite. Scattered rather large grains of iron ore also occur. The olivine is now entirely changed to aggregates of fibrous talc, no vestige of the original substance remaining. The original cracks, typical of olivine, are now preserved by dotted lines of iron ore. The augite phenocrysts are almost as completely altered to chlorite with some secondary silica. Some of the original pyroxene still unaltered was identified as near diopside by its extinction angle. Many of the large olivines have been shattered and the parts slightly separated from each other, the intervening space being filled by the material of the groundmass. The minute lath-like microlites of augite were identified by their rather high index of refraction, moderately high birefringence, extinction, and square cross section. They show none of the alteration which marks the large augite phenocrysts.

This rock apparently indicates that the magma, which upon crystallization in the larger dike gave a typical spessartite, when intruded contained abundant crystals of olivine and augite. With slow cooling these phenocrysts, by reaction with the magma, were changed to hornblende as evidenced by the talcoid pseudomorphs surrounded by hornblende rims in the main dike on the 1,200-foot level. On the 2,000-foot level at some 800 feet greater depth, where cooling presumably was slower, the olivines were more completely resorbed and no vestige of them now remains. Whether this change is due to absorption of silica from the walls of the fissure by the magma in its upward progress is not clear, but it forms an interesting hypothesis.

Spessartite, Reeder Gulch.—This rock, one of the few of those described which came from the Murray region, forms a very long dike exposed in the mouth of Reeder Gulch by the side of the Golden Chest mill. Megascopically it is a very light-colored rock of nonvitreous chalky appearance and fine grain, but with widely spaced phenocrysts of very black biotite. Under the microscope it exhibits two materials of very different texture but of the same mineralogical composition. The contact between these is sharp, one being fine and the other coarse grained, and both consisting of hornblende prisms and laths of plagioclase. The coarser portion contains large aggregates of radiating prismatic epidote, especially

along the contact with the finer-grained phase which is free from epidote. This is one of the types of agglomeratic intrusion referred to elsewhere. (See pl. 39 A.)

Spessartite, Rex Mine Ninemile.—A specimen collected by Doctor Umpieby and examined only in thin section, shows a holocrystalline fine-grained nonporphyritic lamprophyre, consisting in large part of prismatic hornblende, with less abundant plagioclase. The hornblende is not so well crystallized as is usual in these rocks. The plagioclase is zoned, but twinning is rare. The rock contains frequent patches of serpentine suggestive of original olivine, in each case surrounded by a rim of hornblende. The rock is very similar to that of the Standard dike.

Olivine-augite vogesite, Frisco Mine.—This rock, which cuts sharply across the ore body on the 1,600-foot level of the Frisco mine west of the shaft, is seen under the microscope to be composed of large phenocrysts of augite, rather sparsely scattered through a fine grained holocrystalline groundmass consisting of the usual green-brown hornblende and feldspar. The augites are perfectly fresh and show well-developed cleavage. Occasionally there is a suggestion of very pale green color and barely perceptible pleochroism indicating some admixture of the aegirite molecule. The feldspar is in such minute and poorly characterized altered individuals that its character must remain in doubt. While the appearance resembles twinning it is probable that it is orthoclase of the fibrous character noted elsewhere—an assumption supported by the alkalic appearance of the augites. Sparsely disseminated large phenocrysts now consisting entirely of talc dotted with iron ore are surrounded by hornblende and represent original olivine. (See pl. 37B.)

Vogesite, lower part of R. R., E. Fork of Ninemile Creek.—This rock, which was collected by Calkins, is a good example of the agglomerate or mixed dike so common among these rocks. In the hand specimen it is quite plainly made up of two kinds of rock, one a rather coarse granular aggregate of hornblende and feldspar forming inclusions in a matrix of darker colored material composed of hornblende prisms in an indeterminate grayish base. The thin section which evidently was cut from the latter portion of the specimen shows phenocrysts of hornblende of the usual type in a very fine grained ground apparently consisting of minute grains of orthoclase. Large patches of chlorite surrounded by rims of hornblende suggest original augite. Quartz in interstitial grains is common. Iron ore in scattered grains is the only other prominent accessory.

Other lamprophyric dikes.—The lamprophyric dikes are present over the whole of the Coeur d'Alene district and surrounding territory. There is scarcely anywhere an artificial exposure of Prichard formation rocks which does not contain one or more of the dikes and

to describe each one separately is impossible. The above descriptions, it is believed, cover the main types. The present paper is intended as a more or less purely petrographic contribution which is prepared to pave the way for a discussion of certain evidence regarding the problems of ore genesis and modes of vein formation which, it is hoped, may be published later. The portion of the conclusions of the present work which applies to the problem of vein formation may be summarized as follows:

1. Lamprophyric dikes in such widespread occurrence substantiate the conclusion that the district is underlain by a granitic batholith.

2. The fact that complementary aplite dikes failed to reach the position of the present erosion surface gives some evidence as to the depth at which this mass must lie.

3. The coincidence in position of dikes and veins indicates a common source and argues a paucity of planes of weakness at the time of their formation.

4. The dikes are later in all observed cases than the veins with which they are associated, yet they are all more or less affected by a hydrothermal alteration which is traceable to the dying stages of vein-forming activity proving that the dikes and veins belong substantially to the same general period.

EXPLANATION OF PLATES.

PLATE 37.

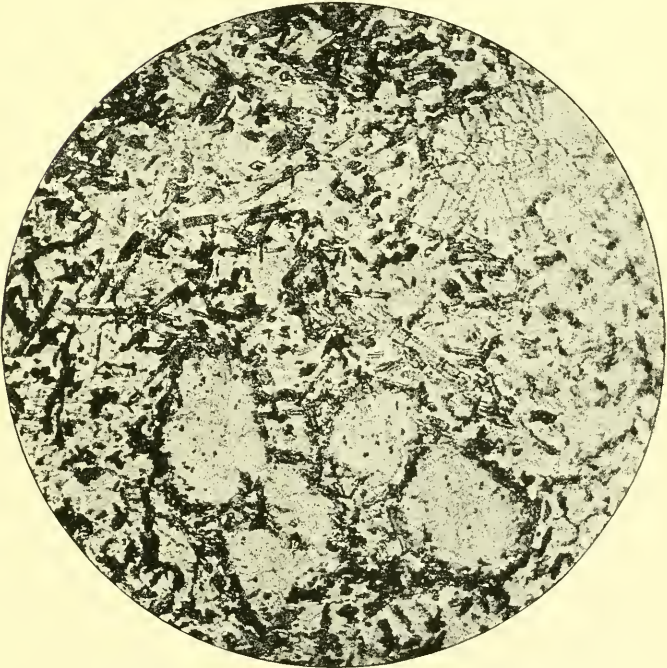
- A. Augite-Minette, Murray Hill. Abundant phenocrysts of biotite with scattered larger augites in a groundmass of orthoclase. Ordinary light. Magnified 30 diameters.
- B. Olivine-augite vogesite, Helena-Frisco mine. Shows areas of talc, pseudomorphous after olivine dotted with iron ore and surrounded with reaction rims of hornblende together with large crystals of augite in a groundmass of hornblende and orthoclase. Ordinary light. Magnified 30 diameters.

PLATE 38.

- A. Porphyritic biotite vogesite. Variant of Elk Creek dike. Large biotite phenocryst in a mass composed of hornblende and orthoclase. The large clear areas showing well-defined cleavage are calcite of obscure origin. Ordinary light. Magnified 30 diameters.
- B. Spessartite, Eldorado Claim. Very coarse aggregate of prismatic hornblende and feldspar. White patches are holes in section. Ordinary light. Magnified 30 diameters.

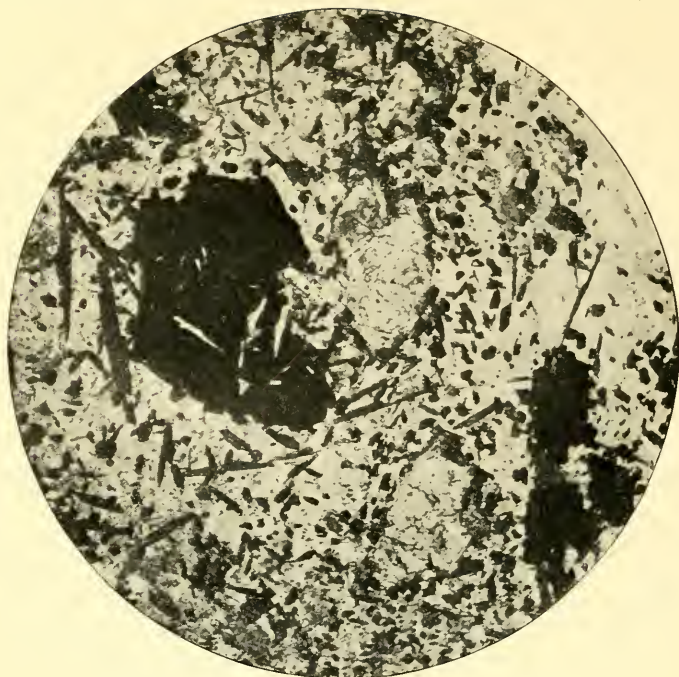
PLATE 39.

- A. Spessartite, Reeder Gulch. Showing contact of coarse and fine grained aggregates of hornblende and feldspar with large area of radiated epidote. Ordinary light. Magnified 30 diameters.
- B. Minette, Hecla Mine. Shows inclusion of quartz surrounded by a reaction rim in an aggregate of biotite and orthoclase. Ordinary light. Magnified 30 diameters.



AUGITE-MINETTE AND OLIVINE-AUGITE VOGESITE.

FOR EXPLANATION OF PLATE SEE PAGE 495.



PORPHYRITIC BIOTITE VOGESITE AND SPESSARTITE.

FOR EXPLANATION OF PLATE SEE PAGE 495.



SPESARTITE AND MINETTE.

FOR EXPLANATION OF PLATE SEE PAGE 495.

