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PETROGRAPHY OF THE MICA PERIDOTITE DIKE
AT DIXONVILLE, PENNSYLVANIA

BY

ARTHUR P. HONESS* AND CHARLES K. GAEHRER**

In "The American Journal of Science," the writers called attention to a recently discovered peridotite dike in the coal measures of Western Pennsylvania. Since then, they have made a more thorough chemical and petrographic study of the dike rock, the results of which are presented in this bulletin.

The dike at Dixonville, Indiana County, Pennsylvania, was encountered in 1924 in the underground workings of the Barr Slope Mine of the Clearfield Bituminous Coal Company. Dixonville is a little mining town situated on Dixon Run about ten miles northeast of Indiana, the county seat of Indiana County. The dike has been encountered in at least four places in the mine and appears to strike approximately North 80° East. Its thickness varies in different places from less than two feet near its end to a maximum of 45 feet near the middle.

More recently Mr. Ronald DeChicchis examined the occurrence and reports that a second and thinner dike, apparently a stringer, has been found. The dike has not been found at the surface which may be due to the fact that peridotite weathers readily and dikes of similar character have been found in outcrops only under exceedingly favorable conditions. However, those who have seen the dike in the mine workings, somewhat less than 200 feet below the surface, incline to the view that the magma solidified before it got much higher in the rocks than where it was encountered in the mine workings. The dip of the dike is difficult to determine on account of insufficient exposure.

The rocks intruded by the dike are in the Allegheny formation, Pennsylvanian in age. The coal seam, according to the mine operators and the Indiana folio of the United States Geological Survey, is the "D" coal or Lower Freeport which is overlain and underlaid by a carbonaceous shale. The contacts between dike and coal are quite sharp and there is little evidence of metamorphism. The coal at the point where the dike is 45 feet in thickness is coked slightly for about eight inches adjacent to the dike. The shales adjacent show little effect of the intrusion aside from considerable fracturing. Both the coal and the shales are streaked with calcite and dolomite in the fractures near the dike, and in the outer portions of the dike, where it becomes lighter colored and more calcic, vugs are common, carrying druses of calcite, dolomite, quartz, pyrite, and in one instance, chalcopyrite. There has apparently been no displacement of the strata, as the coal was encountered again at the same elevation after tunneling through the dike.

This area, situated in the northeastern part of the plateau region not far from the Allegheny Front, conforms in geologic structure with the Allegheny Plateau. The rocks are bent into a series of low folds of which the most persistent and pronounced is the Chestnut Ridge anticline. This is one of the strongly developed folds of the Allegheny Plateau and can be traced for miles. The slope of the flanks of the anticline is generally steeper on the west. The strata dip northwestward into the "Lateb" syncline, named from the town of Lateb, in Westmoreland County. This fold has been traced from Indiana to Scottsdale, Pa., and its southward continuation is known as the Uniontown basin. In the northeastern part of the Indiana

quadrange, the Latrobe syncline is split in two by a southward-plunging anticline whose axis extends along Rayne Run. The axis of the eastern fork of the Latrobe syncline passes between Rayne Run and Dixon Run, and rises and trends north-eastward. It is in the trough of this syncline, adjacent to the Chestnut Ridge anticline, that the Dixonville dike is found. This is of great interest, for in Fayette county, about 110 miles to the southwest, a dike is found in a similar relation to the same upfold.1

Megasopic Description

Megascopically, the dike rock is a compact, dark gray to greenish gray, porphyritic type of the peridotite family. Phenocrysts are generally abundant, much more so than in the Fayette County dike. The most striking phenocrysts are those of mica, the larger of which are biotite. One large hexagonal crystal of deep brown color measured 2½ inches by 2 inches. The rock also carries many smaller phenocrysts of plagiopylite embedded in a dark greenish or grey aphanitic groundmass. Some of these are perceptibly chloritized. The rock often has a mottled appearance due to the presence of numerous blotches of serpentine, pseudo-morphous after olivine. Dolomitic carbonate often forms distinct euhedral grains of variable size, resembling, in some few cases, the outline of olivine crystals from which it may have been derived.

Evidence of this change will be given under the discussion of the microscopic character of the dike. Several crystals of a platy, light colored pyroxene were found, one of which is a half inch in diameter. The indices of refraction as determined by the immersion method, and the parallel parting indicate that it is diopside. Jet black, glassy phenocrysts of variable size and shape showing perfect conchoidal fracture are rather abundant. They are hard, brittle and slightly magnetic and at first were very puzzling because of their massive habit and exceptional hardness. Upon breaking open several of the larger ones they appeared to be a hardened coal-like substance which might be expected under the conditions of intrusion; but a more careful chemical study shows that these unusual phenocrysts are small segregations of massive ilmenite. (See Fig. 5). However, in the outer portions of the dike occasional graphic blotches may be seen which probably represent metamorphosed coal fragments. A few red garnets, not over four mm. in diameter were found; several in a rock fragment from the inner portion of the dike, and others near the contact. Pyrrhotite occurs sparingly in the less altered portions of the dike, and included angular fragments of red and black shale, which show very little effect of the heat of the magma, are not uncommon. The groundmass is dense and so shot through with carbonate that even under the microscope it is not possible to determine with certainty its original texture and composition.

Microscopic Description

Classification of this rock is made possible only through careful study of the primary constituents and their alteration equivalents. Fresh olivine is not abundant, but occasional phenocrysts partially altered to serpentine throw some light on the changes within the dike following consolidation. The serpentinization, in most cases, has been complete, producing well defined pseudomorphs, and in only a few instances has the alteration been halted along irregular cleavage lines to yield the characteristic mesh structure. (See Figs. 1 and 2 p. 13). The serpentine often is intermixed intimately with a fine grained carbonate, identical with that forming the groundmass of the rock. (See Fig. 2).

Some iron oxide may be observed along the serpentine trenches or collected at the border of the crystal, but this is variable in amount and in general indicates an

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*Associate Professor of Mineralogy, The Pennsylvania State College.
**Instructor in Mineralogy, The Pennsylvania State College.
1 See Bibliography p. 12 for all numbered references.
olivine of fairly low iron content, approaching the forsterite molecule. The presence of microscopic rutile needles and elongated crystals, some of which are beautifully twinned in a geniculate manner, suggests titanium as an original constituent of the olivine, especially since the occurrence of these crystals is wholly restricted to the serpentine pseudomorphs and to those carbonate areas which unmistakably represent original olivine. Also the presence of a few such crystals in the unaltered areas of olivine point to rutile as primary inclusions which have survived the processes of serpentinization and carbonation predominant in the rock.

If the rutile crystals were secondary, formed by the decomposition of other titanium-bearing minerals of the rock, it is likely that the groundmass would also contain them. But such distribution is indeed rare, and where it has been observed, the relation of the carbonate to the serpentine is evident. Other titanium minerals of primary origin, such as perovskite and ilmenite occur, but there is no apparent change to rutile. Hence the occurrence of these yellowish brown needles in the fresh areas of olivine, and their constant association with the serpentine indicate that they are not of secondary origin, but were formed as primary inclusions in olivine. (See Fig. 3, p. 14). Perovskite occurs abundantly as small, well defined, brownish or black crystals, distributed uniformly through the groundmass. (See Figs. 1 and 3). The individual crystals are usually quadrilateral, but penetration groups and aggregates are very common. This mineral is probably a primary constituent which has survived the carbonation of the groundmass without noticeable effect, excepting the definite border of gray to greenish material in some respects not unlike leucocene. Invariably the alteration hand takes the form of the crystal. The pyroxene, present in small amount, is according to index and parting, a diangle, which is partially changed to a gray, fibrous mass, probably bastite. The pyroxene is of platy habit, light green in color and in a single instance was observed to occur as a distinct phenocryst, a centimeter in diameter.

Mica is abundantly developed and varies in composition from biotite to a weakly pleochroic brown variety of phlogopite. (See Fig. 4, p. 14). The biotite phenocrysts are hexagonal in outline, attain a breadth of 7 mm., though usually smaller, and are undoubtedly the result of crystallization under slowly cooling, before the magma had reached the upper level, where sudden chill put an end to further fractionation. The phlogopite appears in smaller euhedral crystals, having straight or curved contour, and in some cases, attains a breadth of nearly a centimeter. In this section, both varieties are observed to be fairly well preserved, although irregular borders of chlorite are quite commonly developed. (See Fig. 4, p. 14). Small grains of magnetite, some of which are ilmenitic bearing the characteristic leucocene border, are generally distributed through the rock; pyrrhotite occurs sparingly in the less altered portions. The accessories rarely observed are spinel and garnet. Black angular phenocrysts of ilmenite variable in size and shape, and showing perfect conchoidal fracture are widely scattered through the rock, and unusual concentrations of these occur locally. (See Fig. 5, p. 15). Some slate fragments are included in the dike but these show little metamorphism as a result of the intrusion. Other constituents of the rock are due largely to alteration and weathering, and in view of their extensive development will be discussed at some length.

As may be noted from the chemical analyses of this rock (p. 6, Table 1, Column 1), carbonate has been a very important factor in the change which the dike has suffered. Just how much of this has been primary is not clear; but the unusual character of the carbonate in the central portion is suggestive of alteration produced by primary carbonated waters issuing from the dike during the later stages of cooling. It may be true that the outer portion may have carbonate added by infiltration, but the interior is so dense and aphanitic, and so thoroughly charged with carbonate that the rock dissolves freely in warm hydrochloric acid with a violent liberation of carbon dioxide. This alteration is uniform throughout the rock, a fact hardly to be expected in meteoric alteration, which is usually more or less selective. The chlorite borders surrounding the mica further suggest hydrothermal alteration, not to mention the fresh appearing pyrrhotite occasionally observed embedded in the carbonate groundmass. However, a most convincing piece of evidence for hydrothermal change is the fact that the coke and also the shale at the contact are thoroughly charged with dense carbonate, which has been introduced by the heated waters. Fragments of the natural coke taken from the contact effervesce violently when immersed in cold hydrochloric acid. Figure 6, p. 15, shows the introduction of calcite into the contact shale.

Study of the thin sections reveals the presence of several distinct types of carbonate. The first and most abundant is the fine grained, almost structureless calcite variety forming the groundmass of the rock. The second is a massive uniform carbonate, probably dolomite, possessing perfect rhomboedral cleavage and occurring as irregular, rounded to subangular patches, somewhat suggestive of crystal outline, although the writers are unable to say what mineral has been replaced. Unlike the other types of carbonate, these dolomite areas are totally extinguished in a single position, indicating an individual grain or crystal not wholly in keeping with the structure of secondary replacement species. The third form of carbonate occurs as a coarsely granular aggregate, forming pseudomorphs after olivine. Whether it is calcite or dolomitic could not be definitely decided from the small amount of material present. The original constitution of the groundmass is not known, for so complete has been the carbonation that no trace of the pre-existing material can be seen. In the absence of plagioclase feldspar and other calcic minerals, one must look to other sources for the calcium, perhaps a plagioclase glass or melilitite which has been completely destroyed, or from assimilation of underlying, deep seated, Ordovician and Devonian limestones. The carbonate forming the outer portions of the dike is much more extensively developed, and may in part be considered secondary, the result of infiltration. Here it often assumes a coarser texture, commonly shows twinning and is often found well crystallized, associated with quartz, pyrite and chalcedony in druses. But in the interior, it is believed the dense, fine grained aggregate is the result of heated carbonated waters, some of which were probably calcite as a result of assimilation of deep seated limestones, acting upon the original groundmass, itself possibly of calcic nature, subsequent and immediately following consolidation and serpentinization of the olivine. From the tongues and irregular channels of fine grained carbonate leading uninteruptedly from the groundmass into the serpentine pseudomorphs, one may conclude that the replacement has extended even to the serpentine. (See Fig. 7, p. 16).

All stages of replacement may be witnessed from serpentine practically free of carbonate to almost complete obliteration, when the original pseudomorph is represented by isolated serpentine areas, surrounded by fine grained, variously oriented aggregates of carbonate. According to Benson, experiment shows that carbonated waters have a particularly strong action on serpentine, of may act directly upon olivine itself, and that where magmatic rocks have been converted to carbonates and talc, the change occurred after the alteration to serpentine. Hence, there are two different processes, the first, the formation of serpentine from olivine; the second, the carbonation of the groundmass with partial replacement of the serpentine. There is evidence of these processes to be found in the Dixonville dike. But just how far primary carbonation proceeded without infiltration of secondary material, the writers are not prepared to say. It has been suggested by Bowen that replacement by heated carbonated waters may be very extensive, as exemplified in the Pen District, where primary silicate rocks have yielded to hot carbonated waters, partially or completely, over a considerable area, with an abundant development of calcite,
### Guide For Table I.


III. Limburgite, Syracuse, New York (DeWitt Dike) Analyst, H. N. Stokes. 

IV. Kimberlite-albite, Glenwood Dike, Tompkins County, New York, Analyst, J. H. C. Martens. 

V. Kimberlite-albite, near Ludlowville, New York, Analyst, J. H. C. Martens. 


VII. Peridotite, Gates, near Masontown, Fayette County, Penna., Analyst, M. W. Adams. 

VIII. Peridotite, Willard, Elliot County, Kentucky, Analyst, T. M. Chatard. 

IX. Mica peridotite, Crittenden County, Kentucky, Analyst, W. F. Hillebrand. 

X. Peridotite, Pike County, Arkansas, Analyst, R. N. Brackett. 

XI. Monteclerite albite (melilitic-poor) Isle Cadioue, Quebec, Analyst, H. S. Washington. 

XII. Mellite-biotite, Isle Cadioue, Quebec, Analyst, H. S. Washington. 

XIII. Kimberlite, Lion Hill dike, South Africa, Analyst, P. A. Wagner. 

XIV. Highly micaceous kimberlite from peripheral portion of the Lion Hill dike, South Africa, Analyst, M. Dettrich. 


XVI. Carbonate dike, 40-centimeter dike, Premier Diamond Mine, South Africa, Analyst, Miss H. E. Vassar. 

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dolomite, and siderite. In the rock under discussion, siderite does not appear to be present, but the other two are extensively developed.

From a consideration of these two processes, namely, serpentinization and carbonation, predominant in the rock, a careful study reveals the presence of three distinct types of pseudomorphs as follows:—

First. The serpentine after olivine is the most characteristic, and pseudomorphs of this nature are abundant and of exceptional development. (See Figs. 1 and 3). Second. Other Pseudomorphs after olivine which are composed of a coarsely granular aggregate of carbonate usually bearing the characteristic rutile needles, which may suggest either direct carbonation of olivine, or a later replacement of the serpentine derived from the olivine. That this carbonation is of a different period is evidenced in the sharp contact of the pseudomorph against the carbonate of the groundmass, and in the coarsely granular character of the replacement material.

The third form of replacement may be observed in the massive rounded or subangular phenocrysts of dolomite. See Fig. 3 (d). These often reach a breadth of over two centimeters, are gray in color, and of glassy lustre. The indices of refraction of two of the larger crystals as determined by the immersion method are 1.669, e—1.535 ± 0.03. But these values are not constant, and others may approach magnesite composition.

All of these carbonate areas show a perfect rhombohedral cleavage and uniform extinction, unlike that shown by any of the other replacement carbonate. However, as regards their origin, sufficient evidence is not at hand upon which to base any satisfactory conclusions. In some few cases the outline resembles, in a general way, crystals of olivine, or possibly grains of pyroxene, but usually the dolomite pseudomorphs are not suggestive of any pre-existing mineral and since there is not the least trace of the original constituent, so complete has the carbonation been, it is not easy to arrive at a definite conclusion. Also the absence of rutile needles, so constant and characteristic of the other pseudomorphs, strengthens the view that these irregular forms do not result in all cases from the replacement of olivine. The microscopic study of this rock, then, involves not only the primary constituents, chief of which are biotite and olivine, but also the changes which have been so extensively inaugurated through the agency of silicate and carbonated waters.

In Table 1, p. 6 are given the chemical analyses of sixteen dikes rocks. The key to the numbers is given on p. 7.

The occurrence of peridotite dikes in the Appalachian region has been known for many years. A dike here and a dike there have been described from time to time in geological literature since the first report of such an occurrence was made by Lardner Vanuxem in 1837 concerning the dikes at Ludlowville, New York. Since that time, intrusions of rock of very similar character have been found in Manhattan, Syracuse and Ithaca in New York State; in Fayette county, Pennsylvania; in Elliott and Crittenden counties, Kentucky; in Hardin county, Illinois, near the Ohio River; in Riley county, Kansas; and in 1924, at Dixonville, Indiana county, Pennsylvania.

When these dikes are plotted on a map, it is a striking fact that they seem to lie along a rather definite curved line extending from the New York State occurrence through Pennsylvania and Kentucky to Southern Illinois. This line might even be projected westward to include the Riley county, Kansas, dike. Several different names have been used by different authors for these intrusives but while they show some variation in chemical and mineralogical composition and in texture, their similarities are more marked than their differences. It was extremely interesting to find that the new Pennsylvania occurrence at Dixonville lies on this line between the Fayette county dike and the New York dikes. That such unusual types of igneous rock should be distributed over so wide a territory in such an apparently regular manner immediately challenges one's speculations as to the reason for it. Even the Montereigen province of Quebec is not far removed from the northeastern extremity of this line. It is also interesting that at the northwestern end of the line of dikes we find this province of aulite rocks, certainly a closely related type; and near the southwestern end, the peridotite dikes of Pike county and Scott county, Arkansas, which have been considered differentiates of the alkaline rocks of the Arkansas province.

In 1915, J. H. Gardner described a zone of disturbance, 500 miles long, beginning with the Bald Hill uplift just east of the Ozarks in Missouri and southern Illinois and continuing through Kentucky, as the Rough Creek uplift and Dividing Ridge-Kentucky River fault, across the Cincinnati arch to the Compton anticline which joins in West Virginia with the Warfield anticline and Chestnut Ridge anticline. The latter fold extends into Pennsylvania as far as Clearfield, as a very prominent structural feature. Gardner noted the fact that along this zone of disturbance, at various localities, some of them a great distance apart, are to be found these intrusives.
trusions of peridotite. He suggests that the pressure which caused this line of stratigraphic disturbance affected the rocks to remote depths and concludes that the intrusions were due to the same forces which affected this whole region and initiated this line of disturbance at the time of the Appalachian revolution.

The investigations of Ruelemann and R. T. Chamberlin indicate that the original trend lines of Pre-Cambrian orogeny have influenced the formation and position of many subsequent features of North American geology. Among these are the general direction of the Paleozoic epicontinental seas, the present general strike of the rock formations, and the main physiographic features of the continent. One of Chamberlin's lines of Appalachian folding and fracture is this line of disturbance pointed out by Gardner, and to which these ultra-basic intrusives seem so closely related. It is interesting to note, then, that the curved line of peridotite intrusives occurs along a zone of disturbance in the rocks which extends in general conformity with the trend lines of Pre-Cambrian orogeny, apparently foredoomed millions of years beforehand to this position in conformity with the general framework of the continent.

W. R. Jillon has suggested that a common origin exists between these dikes and some rather unusual structures, which he calls, isotherusts, in Wells Creek Basin, Tennessee, at Jetha Knob, Kentucky, and Serpent Mound, Ohio. He considers these isotherusts phases of incipient volcanic activity and that, together with the peridotite dikes he favors these as evidence of the intrusion of ultra-basic material from a great isostatic magma underlying this great area at depths of but a few thousand feet.

Both H. S. Washington and Professor J. F. Kemp consider these dikes the surficial extensions of a much larger reservoir of magma which underlies this area. They may be the basic and fluid differentiates of a vast series of mafic magmas distributed in depth under this area. None of the acid phases of such a magma has been discovered unless those more acid types found associated with mica peridotites and alunites in Arkansas and in the Montereign province of Quebec may be considered a part of this deep seated magmatic reservoir. This is, however, impossible of substantiation at present, although an intensely interesting speculation. The Arkansas intrusives are certainly Upper Cretaceous in age while those of the Appalachian region are generally considered post-Carboniferous and a part of the activity of the Appalachian revolution.

However, J. E. Spurr in his treatise on ore magmas considers these basic dikes derivatives of a single highly specialized magma. He, also, considers the Pike county Arkansas dikes a part of the same magma, and since they are of known post-Cretaceous age, he assumes a like age for the similar dikes in Kentucky, Illinois and elsewhere along this zone of basic intrusion. Thus, he considers their intrusion coincident with the major magmatic period in the Rocky Mountain province and that the forces which produced the Rocky Mountain post-Cretaceous uplift affected slightly the whole Misissippi basin as far as the Appalachians. Extrusive and well developed penneiplanation was achieved in Cretaceous times, and the subsequent uplift and dissection of this penneiplan is generally assumed to have accompanied the great orogenic movements at the close of the Cretaceous.

W. N. Benson in his paper on the tectonic conditions accompanying the intrusion of basic and ultra-basic rocks indicates that dikes of this type are frequently formed in practically unfolded or slightly folded regions, with perhaps fracturing and faulting, but not tangential pressure. It would seem, then, that, although highly speculative, we must also entertain the suggestion that it is entirely possible that these dikes may have accompanied the diastrophic disturbances which affected the Appalachian region at the close of the Cretaceous and that the Arkansas and Appalachian intrusions are of the same age.

CONCLUSIONS

The authors have made a survey of the literature on the dikes of the Appalachian region and closely related dikes, and have reviewed some of the more recent opinions of the problems which are involved in an intrusion of this kind. They have also made a microscopic study of the petrography of the rock and have available a chemical analysis of the rock made in the chemical laboratories of The Pennsylvania State College by Professors T. W. Mason and Harry Geist. As a result of this work already presented in detail, the authors believe that the dike is a mica peridotite intruded in a very fluid condition with its magmatic or intrusive forces about spent. The rock is considerably altered by serpentinization, chloritization and carbonation. The carbonation is believed to be, at least in part primary and representing the last phases of the magmatic activity when the rock was attacked by rising magmatic carbonated waters.

The Dixonville dike undoubtedly belongs to the same period of magmatic activity as the other dikes of the Appalachian region which lie in a rather definite zone of crustal and igneous activity extending from New York to Illinois. It is believed to be one of the rare upward intrusives of a deep seated peridotitic magma of large extent. Fluorine is apparently a prominent mineralizer in all these dikes for apatite is found as an important constituent in many of them and mica is a conspicuous component in virtually all occurrences. No apatite was found in the Dixonville dike but micas, both biotite and phillogpite, occur as prominent phenocrysists. Perovskite is also an unusual mineral which is distributed in microscopic crystals throughout these dikes and is reported from virtually all of them. The parent magma was apparently an alkaline phase of the peridotite family, for many of the dikes, notably some of the New York dikes and some of the Arkansas dikes, carry melilitite. The presence again of so much mica, even in those dikes in which either melilitite did not form or was destroyed by the later phase of carbonation, indicates an unusual peridotite with alkaline tendencies because of the relative amounts of mineralizers, principally fluorine.

The Dixonville dike, then, in all its phases, is another link in the rapidly forging chain of evidence which indicates that a close relationship exists geographically, structurally, chemically and petrographically between these unusual intrusives of the Western Appalachian and Mississippi valley province.

Acknowledgment

Acknowledgment is due to Mr. Herbert Wardrop and other officials of the Barr Slope Mine at Dixonville, Pa., for courtesies extended to the authors during their visit to the mine. Helpful suggestions from Professors C. H. Smyth and A. H. Phillips of Princeton University, bearing on the petrographic problems, are also gratefully acknowledged.

DEPARTMENT OF GEOLOGY AND MINERALOGY
THE PENNSYLVANIA STATE COLLEGE

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BIBLIOGRAPHY


Figure 3
Typical porphyritic texture of the interior of the dike showing pseudomorphs of serpentine after olivine. Inclusions of rutile (marked r) can be seen in the serpentine. Perovskite is well developed as small quadrilateral crystals. The large black triangular mineral is probably ilmenite. The complete carbonation of the groundmass is clearly visible.

Figure 4
A phenocryst of mica showing border of chlorite.
Figure 7
Olivine phenocryst partially altered to serpentine revealing subsequent carbonation of the serpentine. The carbonate of the olivine channels can be traced without interruption to the carbonate groundmass of the rock. (See C).