Journal of the Minnesota Academy of Science

Volume 32 | Number 3 Article 9

1965

Precambrian Geology in Humboldt Township, Marquette County, Michigan

Peter D. Rowley
University of Texas

Precambrian Geology in Humboldt Township, Marquette County, Michigan[1]

PETER D. ROWLEY[2]
Dept. of Geology, The University of Texas

ABSTRACT—The present study involved investigation of gneissic granite, migmatite, basic dikes, and faults in part of the Southern Complex of Michigan. The average strike of the foliation of the gneissic granite based upon the orientation of feldspar phenocrysts is N. 60° W., the strike of the major dike set is between N. 30° W. and N. 60° W., the average strike of the fault zones is N. 52° W., and a two-mile long body of migmatite trends about N. 57° W.

The known history starts in the early Precambrian, when gneissic granite was emplaced and formed migmatites by incorporation of wall-rock material. Then the rocks were faulted, intruded by dikes, and regionally metamorphosed to the almandine amphibolite facies. After a second period of dike intrusion, hydrothermal solutions that passed upward through the fault and dike fissures caused retrograde metamorphism.

A combined field and laboratory geological study with an emphasis on structural geology and petrology was carried out on a part of the Precambrian gneissic granite of the Southern Complex in Marquette County, Michigan (see Figure 1). The problem area is located in the southern half of Humboldt Township (T. 47 N., R. 29 W.) just north of Republic. The Marquette Iron Range is a few miles to the north and the Republic Iron Range immediately to the southwest.

Since the discovery of iron in 1844, the Precambrian rocks in this area have been widely studied. The Marquette Range and the Republic Range, of the Animikie epoch of Middle Precambrian age, have been mapped in detail, but the great body of gneissic granite that underlies the iron formation has been neglected until recently.

James (1958) recently reviewed the problem of the stratigraphy of the rocks of pre-Keweenawan age in parts of northern Michigan, and placed the granitic rocks of the Southern Complex within the Lower Precambrian system. The mapping of Precambrian granites has been done by Gair and Wier(19 56), Bayley (1959), and James *et al* (1961) in areas respectively 15 miles southwest, 25 miles south-southeast, and 25 miles south of the problem area. The present study adds information of yet another portion of these granite areas in northern Michigan. No attempt was made to correlate rocks of the region studied with the stratigraphy set up by the workers mentioned above. Mechanics of emplacement of the granite is thought to be magmatic; no evidence for granitization was found.

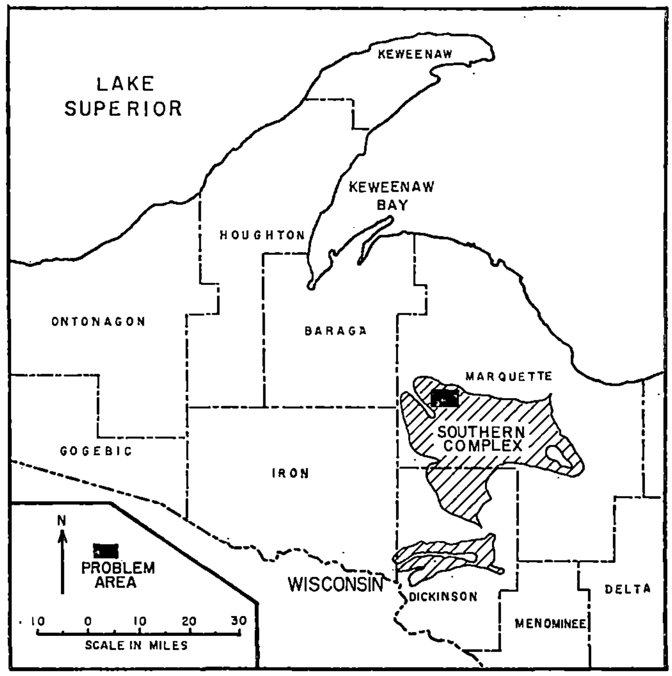

FIG. 1. Location map of a portion of northern Michigan showing location of Southern Complex and problem area.

In the immediate problem area, zones of metamorphism have been mapped by James (1955) and Henrickson (1956) as parts of regional investigations. The area, which lies wholly within the Southern Complex, overlaps the sillimanite and staurolite zone of Henrickson (1956). Thus, the metamorphic minerals correspond mainly to the sillimanite-almandine subfacies of the almandine amphibolite facies of Fyfe *et al* (1958).

Field Work

Field work occupied eight weeks in the summer of 1963. Most of the area was covered by compass and

[1] This study was supported by a National Science Foundation Undergraduate Research Participation Grant. The writer is deeply grateful to Dr. Eiler L. Henrickson of the Carleton College Geology Department for proposing the problem and for help at every stage; and to Dr. Duncan Stewart of the Carleton College Geology Dept., for much advice and encouragement. Thanks is also given to Mr. William R. Pasich of the Research Lab, Jones and Laughlin Steel Corporation, Negaunee, Michigan, for chemical analyses; Dr. James W. Villar of the Research Lab, Cleveland-Cliffs Iron Company, Ishpeming, Michigan for suggestions in the field work; and Mr. Kenelm C. Winslow of the Cleveland-Cliffs Iron Company, Ishpeming, Michigan, for aerial photo coverage. Criticism of the manuscript by Dr. J. Hoover Mackin of the Dept. of Geology, University of Texas, Austin, Texas, is much appreciated.

[2] B. A., Carleton College, 1964. Now at The University of Texas as a teaching assistant working toward his M.A. and Ph.D. degrees. Thesis work, under the direction of J. Hoover Mackin, concerns the use of ignimbrites to interpret the structural history of a part of the High Plateaus of southwestern Utah.

pace traverses on an enlarged (500 feet equals one inch) 7½ minute Republic, Michigan quadrangle, U.S.G.S. topographic map series. Studied and mapped were numerous dikes, a number of fault zones, bodies of migmatite, and the granite itself.

The area is typical continental glacial drift topography with hills of resistant granite rising slightly above swampy plains underlain by glacial drift. Outcrops are mostly limited to road and railroad cuts and the tops and flanks of hills.

The fresh granite is light pink to white and contains abundant feldspar phenocrysts that are usually from one to three inches long. A well-defined alignment of phenocrysts averages about N. 60° W.; there is a tendency for this alignment to trend more to the north as one goes south through the problem area. This alignment is the surface expression of a foliation that has a less well defined, steeply northeastern dip. Jointing in the granite trends predominantly north-northwest, north-northeast, and northeast; most of the dips are near-vertical.

Enclosed within the granite are a number of migmatite bodies. These are areas of "mixed rock," seen as layers and lenses of alternating granite and schist, with folds, stringers, swirls, and ptygmatic structures common. The migmatites are thought to be remelted, drawn out, and partly assimilated blocks incorporated in the granite of the Southern Complex. One of the best outcrops of migmatite, showing a fold about 50 feet across, is on the east side of highway M-95 in the NW¼, NE¼, Sec. 29; here it is cut by a younger dike and possible fault.

Most of the migmatite bodies occur in an elongated area that can be traced for about two miles in an almost straight N. 57° W. trend from the E½, NE¼, Sec. 29, in the southeast to an outcrop in the NE¼, NW¼, Sec. 19 in the northwest. The belt is less than 1000 feet wide and is believed to terminate at the southwest end; there is no indication that it stops at the mentioned outcrop in the northwest. The strikes of the individual layers and lenses correspond closely to the trend of the body as a whole. The body has a fairly rapid gradation into the surrounding granite. Reconnaissance along the northeastern border of the Republic Range reveals migmatites similar in nature but larger in size.

Twenty fault zones were found cutting the granite; these faults appear as schistose zones, individually a few inches to two feet wide, often with a darkened or schistose development of the granite on either side of the fault. Slickensides commonly plunge at low angles. Two prominent fault zones, where a number of the individual schistose planes are observed, are located in the SE¼, SE¼, Sec. 20, and N½, SE¼, Sec. 31. The faults range in strike from N. 13° W. to N. 87° W.; the average strike is N. 52° W. The relative movements were not ascertained.

Numerous basic dikes cut the granite, migmatite, and, in at least one case (N½, SE¼, Sec. 31), a fault. Over 130 dikes were found. Dikes are probably much more common than the number observed in outcrop would indicate, since they are less resistant to erosion than the granite. The width varies from a couple inches to 180

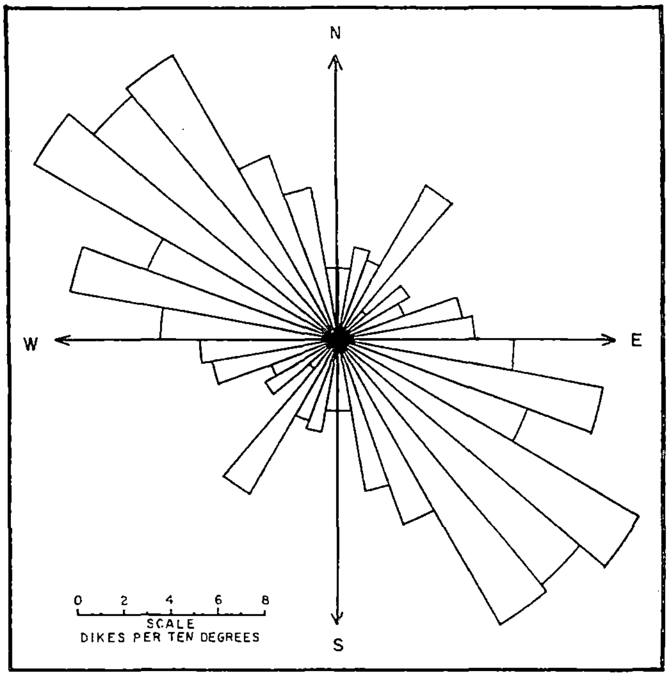

FIG. 2. Plot of strikes of dikes in problem area. Scale indicates number of dikes radial from center per ten degrees of compass bearing.

feet (SE¼, NE¼, Sec. 29), with the smaller dikes being much more common; over half the dikes seen are less than 5 feet wide, and only 14 are greater than 25 feet in width. The dikes are commonly vertical; where the dip is not vertical, usually in the case of the smaller dikes, it is very steep, with no constant compass direction. A conjugate dike system can be plotted (see Figure 2) consisting of a major set trending between N. 30° W. and N. 60° W., and a minor set perpendicular to it. No connection was found between size of dike and its strike, nor between petrology and strike. Most of the dikes have been metamorphosed, although there are a few dikes that are younger than this metamorphism.

Often extending out from the contacts with the larger dikes into the granite wall rock up to a distance of a few feet, the normal granite is finer grained and more gneissic, and the feldspars are bright red. This may be due to contact metamorphism. Blocks of the granite up to a couple feet in diameter, enclosed in the dikes, also exhibit a reddening of the feldspar crystals.

Petrology

Laboratory work consisted principally of the examination of 46 thin sections. The following description is a summary of the work detailed in Rowley (1964).

The granite consists mainly of large crystals of microperthite (microcline and albite) in a groundmass of quartz and biotite, with accessory minerals. Common occurrence of sutured boundaries of quartz and feldspar indicates a period of metamorphism younger than the emplacement of the granite. This period of metamorphism is believed to be the same as that studied by James (1955) and Henrickson (1956). Other minor constituents of the granite are low temperature alteration minerals; most noticeable is penninite, which replaces biotite.

The migmatite is made up of silicic rock layered with amphibolite. The silicic parts are believed to have been originally of granite composition, but on partial assimilation of more basic blocks have changed to a rock containing more equidimensional, finer-grained, and more calcic feldspars. The plagioclase of the silicic layers grades from An_{15} to An_{50} and is granoblastic with quartz of undulose extinction. The layers of amphibolite consist of poikiloblastic hornblende, plagioclase (An_{40} to An_{50}), and undulose quartz, with biotite often at the edges of the layers. When well developed, hornblende is idioblastic over all other essential constituents. The minerals are of medium grain size (usually less than three millimeters) and the texture is schistose. There are minor amounts of fine-grained low-temperature alteration products, which are believed to be caused by retrograde metamorphism; these include such minerals as sericite, chlorite, clinozoisite, and epidote, and with leucoxene and sphene often replacing ilmenite. Other accessories are apatite, zircon, magnetite, and pyrite.

Fault zones are almost entirely of very schistose chlorite, sometimes buckled. Mashed lenticular quartz grains and biotite may be important, and leucoxene, apatite, and epidote are accessories. These minerals grade into granite on either side of the fault zones.

The basic dike rocks all look alike in hand specimen, being predominantly medium to fine grained, usually with distinct schistocity parallel to their strike and dip. The rock type of the great majority of the dikes is an amphibolite, with an almost identical petrology to the amphibolites of the migmatites. The poikiloblastic hornblende illustrates concretionary growth, and where biotite is present this concretionary growth is further emphasized by the growing hornblende crystals having pushed biotite aside. The xenoblastic plagioclase, often with carlsbad twinning, is most commonly An_{40} to An_{50}. Quartz is nearly all metamorphic, being in subrounded forms without undulose extinction. Biotite is often present, most commonly at the edge of the dike or when the dike is narrow. The most important accessories are apatite, zircon, magnetite, ilmenite, and pyrite. Thus, the assemblage is typically high almandine amphibolite zone. The schistocity and appearance of chilled margins in these metamorphic dikes is taken as mimetic growth, preserving the original dike texture.

Superimposed on this assemblage of minerals is another assemblage that represents minerals of lower temperatures of formation; that is, the dikes show the same retrograde metamorphism as the migmatites. The minerals are sericite, calcite, epidote, clinozoisite, and quartz replacing plagioclases; chlorite (mostly penninite) replacing biotite; and leucoxene and sphene replacing ilmenite.

Relict minerals and structures, which indicate that the regional metamorphism did not go to completion, are seen under the microscope. One type of relict mineral seen in many dikes is zoned plagioclases. These plagioclases are seen by their more heavily sericitized centers, a feature that is believed to indicate a more calcic composition in the center, relict from the unmetamorphosed dike. Even more meaningful, although only found in thin sections from the wider dikes, are large plagioclase phenocrysts, often over an inch in length, which are heavily saussurized, and are interpreted as relicit minerals. Another feature restricted to the wider dikes is a somewhat hazy palimpsest structure, noted as small clusters of hornblende crystals. Under low power, these clusters are often aligned, and the size of each cluster is just slightly smaller than the size of the above mentioned relict plagioclases. Each cluster is taken as relict after a mafic mineral, probably a pyroxene crystal, of the original dike before metamorphism took place; these clusters illustrate the small distances of ionic diffusion of mafic constituents involved in even these high temperatures of metamorphism.

A few unmetamorphosed dikes are present in the problem area. One 55-foot wide dike that was examined is diabase made up of augite and plagioclase (An_{50} to An_{70}) in an ophitic texture. Magnetite and minor alteration minerals such as sericite and uralite, are present.

The red color in the granite adjacent to the dikes is due to the presence of hematite dust that clouds the feldspars (see Poldervaart and Gilkey, 1954). The feldspars in this gneiss are micro-antiperthite and plagioclase (An_{10} to An_{20}), believed to be a result of replacement of the original microperthite and microcline of the original granite by more calcic constituents from the intruded dike. Much of the quartz of the gneiss wall rock has undulose extinction and sutured edges. Lower temperature effects are indicated by a high degree of sericitization, and replacement of much of the biotite by penninite. There is also a decrease in size and lineation of the plagioclase crystals of the granite. The petrology of the granite xenoliths incorporated in the dikes is much like the petrology of the rocks of the contact zone with the exception that, in the case of the xenoliths, there is no microcline, and there is more development of metamorphic (nonundulose) quartz, sometimes in the form of a myrmekitic texture.

Conclusions

The oldest rock type in the area is the gneissic granite; foliation is believed to be a primary flow structure. In intrusion, basic wall rocks were incorporated in the granite, forming migmatites in what is thought to be much the same manner as proposed in the classic work of Adams and Barlow (1910) on migmatites in the Laurentian granite of the Canadian Shield. This wall rock is thought to have been a basic igneous rock, since the mineralogy of the metamorphic rocks now present indicates sufficient potash for an igneous rock, and shows a close resemblance to the dike petrology.

The intrusion of the granite was followed either immediately or in a later period of deformation by faulting. The first dike intrusion ensued, strictly following joint planes in the case of the small dikes, and in the case of the larger dikes, modifying these openings by forcing aside the walls. The intrusion of these dikes, probably taking place at great depth, may have brought about slight metamorphic effects in the adjacent granite; however, this effect may be due to the later regional metamorphism. The composition of the dikes was probably gabbroic with plagioclase phenocrysts; pyroxene crystals were foliated parallel to the dike intrusions, with chill zones near the contacts with the granite wall rock.

Following this came a period of regional metamorphism, assigned a post-Animikee, pre-Keweenawan age by James (1955) and Henrickson (1956); the problem area was in the almandine amphibolite zone. The granites were the least affected, as there was only a dissolving along the boundaries of the constituents to give them a sutured character; the dikes and possibly the fault zones were changed into amphibolites. The migmatites, although themselves formed during the original granite intrusion, asssumed their present mineralogies at this time.

The next event was the intrusion of the unmetamorphosed dikes. This was followed by a period of retrograde metamorphism, assigned to hydrothermal solutions, noted in the presence of low temperature alteration minerals in the rocks throughout the area. The rocks of the dikes and faults show the greatest alteration; this indicates that the entrance of the solutions was up through the dike and fault fissures.

Conclusions from the study of this limited area appear to fit the regional picture of Precambrian igneous rocks as developed by Gair and Wier (1956), James (1958), Bayley (1959), and James *et al* (1961). Extended mapping and possibly radiometric age dating will be needed to tie in the exact stratigraphy of the different areas and to determine the true significance of the similarity of structural trends found in the area studied here.

References

ADAMS, F. D., and BARLOW, A. E., 1910. Geology of the Haliburton and Bancroft areas, Province of Ontario. *Memoir No. 6,* Canada Geological Survey.

BAYLEY, R. W., 1959. Geology of the Lake Mary quadrangle, Michigan. *U. S. Geol. Survey Bull.* 1077.

FYFE, W. S., TURNER, F. J., and VERHOOGEN, J., 1958. Metamorphic reactions and metamorphic facies. *Geol. Soc. America,* Mem. 73.

GAIR, J. E., and WIER, K. L., 1956. Geology of the Kiernan quadrangle, Michigan. *U. S. Geol. Survey Bull.* 1044.

HENRICKSON, E. L., 1956. A study of the metamorphism of the Upper Huronian rocks of the western portion of the Marquette District, northern peninsula, Michigan. *Unpub. Ph. D. thesis,* University of Minnesota.

JAMES, H. L., 1955. Zones of regional metamorphism in the Precambrian of northern Michigan. *Geol. Soc. America Bull.,* 66: 1455-1488.

JAMES, H. L., 1958. Stratigraphy of pre-Keweenawan rocks in parts of northern Michigan. U. S. Geol. Survey Prof. Paper 314-C.

JAMES, H. L., CLARK, L. D., LAMEY, C. A., and PETTIJOHN, F. J., 1961. Geology of central Dickinson County, Michigan. *U. S. Geol. Survey Prof. Paper 310.*

POLDERVAART, ARIE, and GILKEY, A. K., 1954. On clouded plagioclase. *Am. Mineral.,* 39: 75-91.

ROWLEY, P. D., 1964. Geological investigation of a portion of the Southern Complex, northern peninsula, Michigan. *Unpub. Independent Study paper,* Dept. of Geology, Carleton College, Northfield, Minnesota.

Learned Societies Around the World

Republic of South Africa

Royal Society of South Africa. Founded 1877. Conducts scientific research and promotes exchange of ideas and experience between research workers in all fields. Maintains an excellent library. Publication: Transaction.

Suid-Afrikaanse Akademie vir Wetenskap en Kuns. Founded 1909. Established for advancement of Afrikaans language, literature, art, science, and technology. Divided into two sections: (1) languages, literature, and arts; and (2) natural sciences and technology. Maximum membership of 300 (150 to each section). Number of associated members is unlimited. Publications: Tydskrif vir Wetenskap en Kuns (semi-annual). Tegnikon (quarterly). Hertzog-Annale (annual).

South African Association for the Advancement of Science. Founded 1903. Organizes a one-week conference each year. Publications: papers read at the annual conference as well as essays and articles by its members in its journal, South African Journal of Science.

Associated Scientific and Technical Societies of South Africa. Founded in 1920. Promotes and represents the interests of the scientific, technological, and professional societies in South Africa. Fourteen societies are members of this institution which has its headquarters in Kelvin House, Johannesburg. Publication: Annual Proceedings in which all lectures given during course of a year are reproduced.