The Reany Creek Formation Marquette County Michigan

By WILLARD P. PUFFETT

CONTRIBUTIONS TO STRATIGRAPHY

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Description of a new formation of Precambrian age in northern Michigan

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THE REANY CREEK FORMATION MARQUETTE COUNTY, MICHIGAN

By Willard P. Puffett

ABSTRACT

The Reany Creek Formation, a new stratigraphic unit, crops out in a narrow belt north of Dead River in and west of the Negaunee 7½-minute quadrangle, Marquette County, Mich. It is divided into three units: (1) a basal conglomerate, (2) a middle sequence of graywacke and slate containing disrupted beds of arkose and dispersed pebbles and boulders of granitic rock, and (3) an upper unit of arkose, quartzite, slaty graywacke, and conglomerate. Maximum thickness of the formation is 3,000–3,500 feet. The formation unconformably overlies massive greenstone and layered amphibolite of the Mona Schist of early Precambrian age. The upper part of the Reany Creek Formation is faulted against sheared metavolcanic rocks of the Mona Schist.

The middle sequence, which consists of slate and graywacke containing dispersed boulders of granitic rock, is similar in composition to other formations in the Lake Superior region that are believed to be of glacial origin. Chemical composition of the slate is similar to that of the matrix of the Gowganda Formation, reported to be of glacial origin, and to the graywacke and argillite in Timiskaming rocks that contain granitic boulders. All these rocks are distinctly different from average Precambrian slates in that Na_2O greatly exceeds K_2O, CaO is lower, and ferrous iron exceeds ferric iron.

The age of the Reany Creek Formation is not known, but it is presumed to be middle Precambrian because it is intruded by Keweenawan dikes and rests unconformably on lower Precambrian rocks.

The similarities between the Reany Creek Formation in Michigan and the Gowganda Formation in Canada suggest a correlation between these two units.

INTRODUCTION

The Reany Creek Formation is a new stratigraphic unit north of Dead River in the Negaunee 7½-minute quadrangle, Marquette County, Mich. The distinguishing feature of this formation is a chloritic slate containing widely scattered pebbles and boulders of granite and sparse to abundant intraclasts of arkose. Coarse conglomerate occurs locally at the base, and quartzite, arkose, graywacke, and bedded and nonbedded conglomerate occur in the upper part. The formation rests unconformably on rocks of early Precambrian age; the upper part is in fault contact with sheared metavolcanic rocks also of early Precambrian age. Comparison of this formation with formations elsewhere suggests that the Reany Creek Formation is of middle Precambrian age and is in part of glacial origin.

The Reany Creek Formation was mapped in 1966 during the study of the Negaunee 7½-minute quadrangle; this investigation is part of a restudy of the Marquette Iron Range by the U.S. Geological Survey in cooperation with the Geologic Division of the Michigan Department of Conservation. Areas underlain by the Reany Creek Formation west of the Negaunee 7½-minute quadrangle were not mapped in detail.

GENERAL GEOLOGY

The general geology of the area in which the Reany Creek Formation occurs is shown in figures 1 and 2. Dead River basin (fig. 1) is a topographic lowland underlain by metasedimentary rocks of middle Precambrian age and bordered by highlands underlain by lower Precambrian rocks.

The geology in and around the east end of the Dead River basin is shown in figure 2. The Mona Schist, the oldest rock in the area, has been intruded by granitic gneiss in the northeastern part of the area and by syenite-diorite-granodiorite in the southern part. The Michigamme Slate has been deposited on an erosional unconformity that cuts across the granodiorite. Near its east limit, the slate has been folded into a northwest-plunging syncline. A broad zone of shearing, in which the exposed rocks are rhyolite, tuff, and greenstone of the Mona Schist, borders the north edge of the Michigamme Slate and has truncated the granodiorite. The Reany Creek Formation occupies the area between the broad zone of shearing and the greenstones and amphibolites of the Mona Schist to the north. Metamorphism has affected all the rocks in the area shown in figure 2, including the rocks of the Reany Creek Formation and Michigamme Slate, which have been metamorphosed to the chlorite zone by post-Huronian pre-Keweenawan regional metamorphism (James, 1955, pl. 1).

PREVIOUS WORK

The Dead River basin has been studied much less than the Marquette syncline, a few miles to the south, and references to conglomerates within the basin are few. Published maps do not show conglomerate underlying the north flank of the basin. Rominger (1881, p. 13) described conglomeratic rock with bright red granite pebbles in sec.

2, T. 48 N., R. 26 W., near the east end of the area mapped as the Reany Creek Formation. Wadsworth (1893, p. 85, 115) correlated a conglomerate at the Holyoke mine in sec. 2, T. 48 N., R. 27 W. (nearly a mile west of the Negaunee 7½-minute quadrangle) with one in sec. 15, T. 48 N., R. 26 W., and named it the Holyoke Formation. Van Hise and Leith (1911, p. 288) assigned this conglomerate to the base of the upper Huronian (now the Michigamme Slate).

Engel (1954) described conglomerate and slate along the north side of the Dead River Storage Basin between the north central part of sec. 7, T. 48 N., R. 26 W., and the Holyoke mine. He called these rocks the Holyoke Formation, suggested that the formation was in part of glacial origin, and tentatively correlated it with the basal middle Precambrian Fern Creek Formation of Dickinson County, Mich. Engel suggested also that it might be correlative with either the Timiskaming metasediments or the Gowganda Tillite of Ontario, Canada.

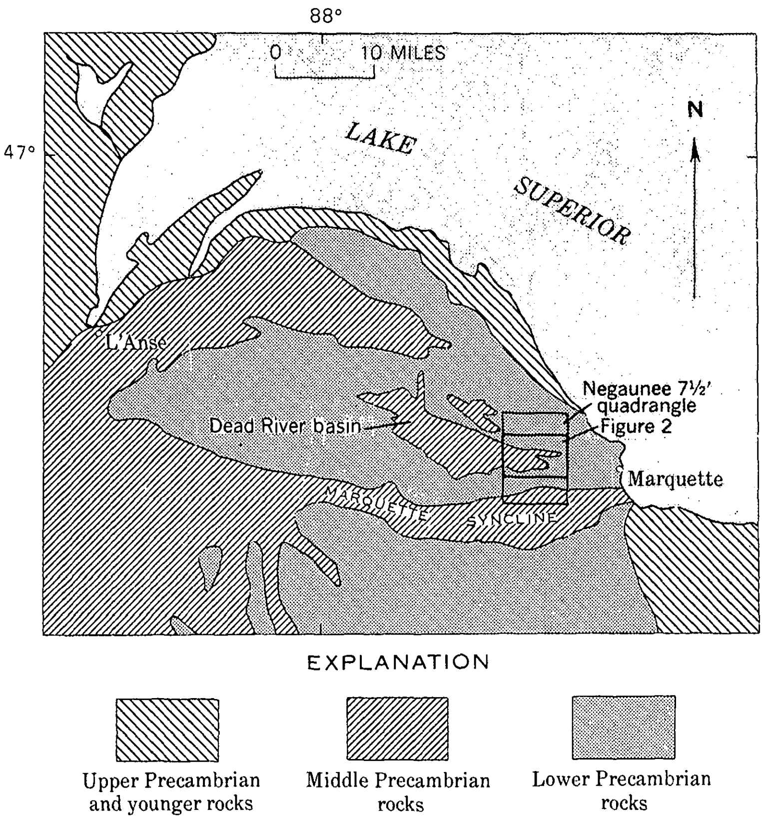

FIGURE 1.—Generalized geology of part of northern Michigan and location of the Negaunee 7½-minute quadrangle.

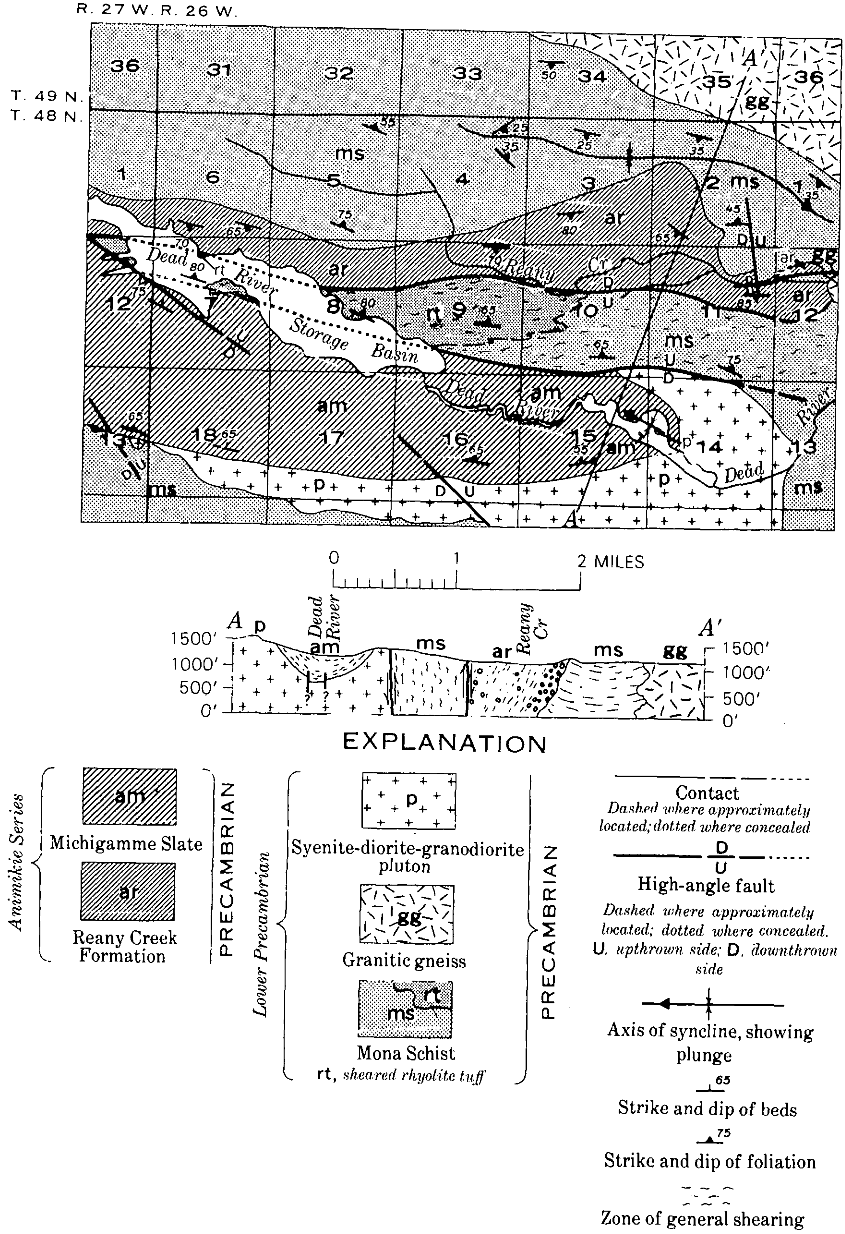

FIGURE 2.—General geology of the east end of the Dead River basin, including the location of the Reany Creek Formation. (For location of area in Negaunee 7½-minute quadrangle, see figure 1.)

The Holyoke Formation, orginally introduced as a stratigraphic name by Wadsworth (1893, p. 85), has never been adopted for use by the U.S. Geological Survey. The rocks described by Engel as the Holyoke Formation are here included in the Reany Creek Formation.

REANY CREEK FORMATION

LOCATION

The Reany Creek Formation is here named for the stream that flows across the formation in the eastern part of the area (fig. 2). The formation crops out north of the Dead River in Marquette County, Mich., in an elongate belt extending west from sec. 12, T. 48 N., R. 26 W., to near the northeast corner of sec. 2, T. 48 N., R. 27 W., about a mile west of the Negaunee 7½-minute quadrangle. The maximum mapped width of the formation is about 1 mile; the average width is about 2,000 feet. Outcrops are generally small and widely separated. Glacial deposits obscure more than 75 percent of the bedrock, and water in the Dead River Storage Basin covers much of the formation west of sec. 8, T. 48 N., R. 26 W. There is no continuous exposure of a complete section of the formation. Some of the best exposures are along a line that extends north from the shore of Dead River Storage Basin about 400 feet west of the east boundary of sec. 7, T. 48 N., R. 26 W. Exposures along this line include arkose and interbedded conglomerate and slate in the upper part of the formation, chloritic slate containing granitic boulders in the middle unit, and coarse conglomerate in the lower unit that is in contact with greenstone of the Mona Schist. This line of exposures, which extends north from the Dead River Storage Basin for about 1,750 feet, is here designated the type section. The top of the formation is not defined since the upper part is in fault contact with sheared felsic rocks of the Mona Schist (p. F13).

GENERAL DESCRIPTION

The Reany Creek Formation is divided into three units: (1) a basal conglomerate, (2) a middle sequence of graywacke and slate with disrupted beds of arkose and dispersed pebbles and boulders of granitic rock, and (3) an upper unit of interbedded arkose, quartzite, slaty graywacke, and conglomerate (fig. 3). The middle sequence is the most widely distributed of the three units; the basal conglomerate is known only from two widely separated areas, and the upper unit crops out only in the western part of the area underlain by the formation. The formation rests on a well-defined unconformity, under which are the massive greenstone and layered amphibolite of the Mona Schist. The upper part is faulted down against the sheared metavol-

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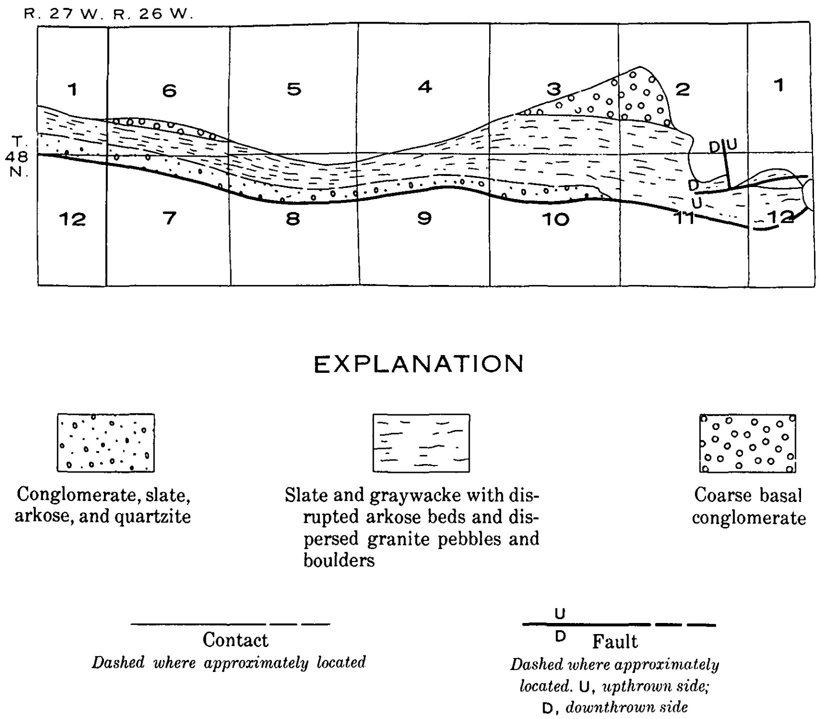


FIGURE 3.—Three subdivisions of the Reany Creek Formation in the Negaunee 7½-minute quadrangle.

canic rocks of the Mona Schist; thus the top of the Reany Creek Formation is not exposed.

BASAL CONGLOMERATE

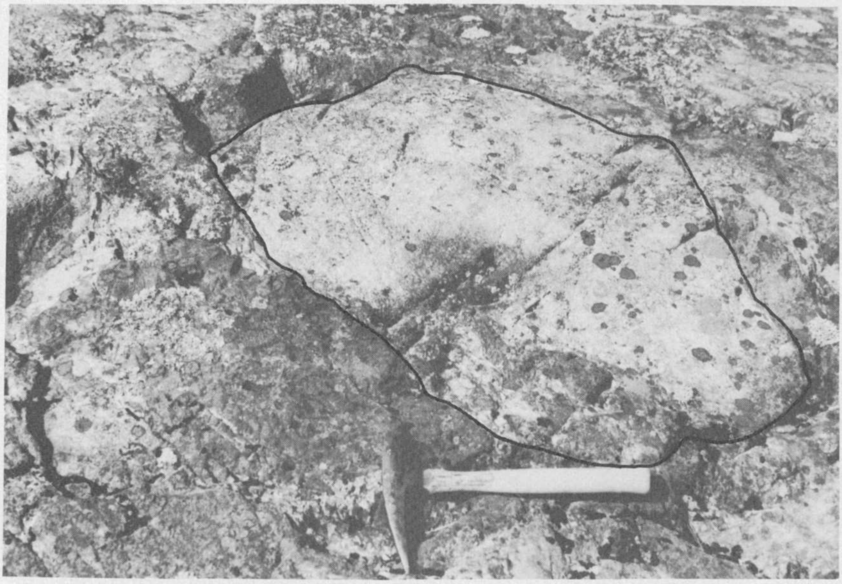
The eastern lens of conglomerate (fig. 3) is about 7,500 feet long. The beds dip 65°–85°S., and the calculated maximum thickness of the lens is nearly 2,000 feet. The best exposure of the conglomerate extends about 800 feet northwestward on a conspicuous hill 2,800 feet east and 500 feet north of the southwest corner of sec. 2. The conglomerate contains many rounded and angular boulders of granitic rock and greenstone in a matrix of poorly sorted coarse-grained arkose that is subordinate in volume to the boulders. The granitic rock in the boulders is light gray to reddish gray and ranges from pegmatite to fine-grained felsic porphyry. Some boulders are as much as 25 inches in diameter, but more commonly the boulders are about half this size. There are a few clasts of vein quartz as much as 2 inches in diameter and a few of chert-magnetite rock less than 2 inches across. The arkosic matrix is tightly cemented, is poorly sorted, and contains large angular grains of feldspar and chloritized mafic minerals, quartz grains, and rock fragments including a chert-magnetite rock, vein quartz, a quartz-feldspar rock, and metabasalt. All the rock types represented in the boulders occur in about the same proportion in the smaller fragments of the matrix. Bedding or foliation is obscure, and there is no systematic gradation in size of boulders from the base of the unit upward.

Widely separated outcrops of conglomeratic arkose and graywacke are in the south-central part of sec. 3, near the west limit of the eastern lens. The arkose and graywacke contain fragments of granite and vein quartz that are about 12 inches in diameter near the base of the lens; clast size decreases upward, and near the top of the lens, clasts average about 1 inch in diameter. The graywacke is fine grained to medium grained, is tightly cemented, and commonly breaks conchoidally. It consists of angular to subangular grains of sericitized plagioclase, rather fresh microcline, angular to subrounded quartz grains, fragments of igneous rocks ranging in composition from basalt to granite, and fine-grained pyrite and magnetite. Feldspar is equal to or more abundant than quartz. The matrix of the graywacke is a cloudy claylike material and chlorite; the chlorite has corroded the margins of many of the quartz grains. In the east-central part of sec. 3, thin quartz-chalcopyrite veins and sparingly disseminated chalcopyrite occur within the graywacke.

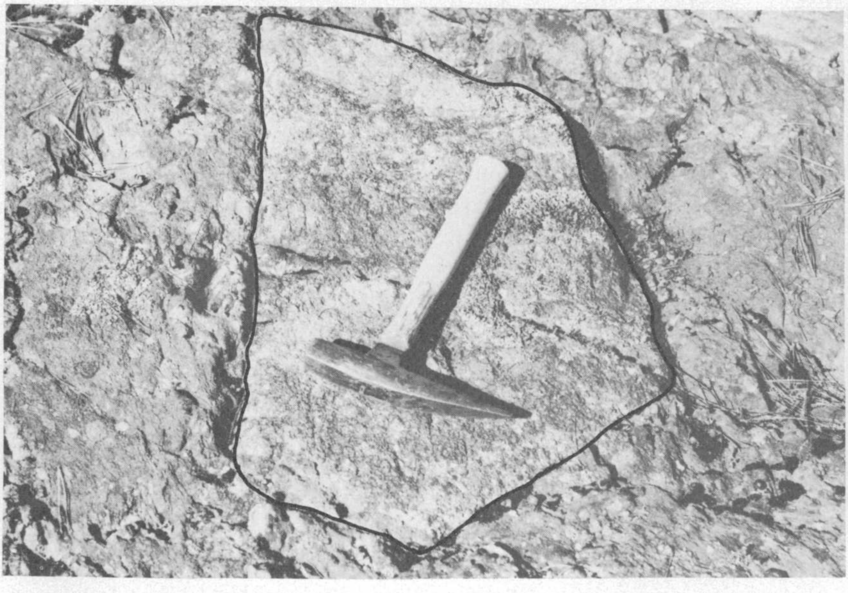
The contact between the conglomerate of the Reany Creek Formation and the amphibolite of the Mona Schist is not exposed, but it apparently coincides with a drainage line in the west-central part of sec. 2 and the central part of sec. 3. There is a large angular discordance between the base of the conglomerate and the well-defined layering in the amphibolite. The curving trend of the contact suggests that the conglomerate was deposited in a U-shaped valley at least 2,500 feet deep.

The western lens of conglomerate (fig. 3) is well exposed near the crest of a steep slope in the southern third of sec. 6, T. 48 N., R. 26 W. The lens is about 3,800 feet long and has a maximum thickness of 250 feet. The west limit of the lens is well exposed at the top of a steep slope in the southeastern part of sec. 1, T. 48 N., R. 27 W., but the east limit is less well defined. Conglomerate less than 100 feet thick is possibly concealed in a covered interval at the base of steep greenstone cliffs in sec. 5.

The western conglomerate lens is composed of boulders of granitic rock and greenstone in a chloritic matrix. A boulder 10 feet long was reported by Engel (1954); however, most of the boulders are 1–4 feet in diameter and, regardless of size, range from well rounded to very angular (fig. 4). The western conglomerate differs from the eastern conglomerate in containing more greenstone and more chert-magnetite rock and in having a chloritic rather than arkosic matrix.



A



B

FIGURE 4.—Granitic boulders in basal conglomerate of the Reany Creek Formation, SW¼ sec. 6, T. 48 N., R. 26 W. *A*. Rounded boulder. *B*. Sharply angular boulder.

The unconformity at the base of the western conglomerate has truncated northwest-trending dikes of metadiabase and beds of crystal tuff in the Mona Schist. At least three Keweenawan (upper Precambrian) diabase dikes strike northeastward across the conglomerate and extend into the underlying greenstone.

GRAYWACKE AND SLATE WITH DISRUPTED BEDS OF ARKOSE AND DISPERSED BOULDERS OF GRANITE ROCK (MIDDLE UNIT)

The middle unit is the most widespread of the three units of the Reany Creek Formation. The best exposures are in the NW¼ sec. 12, T. 48 N., R. 26 W., and along a steep slope west from the southwest corner of sec. 5, T. 48 N., R. 26 W.

SLATE

Slate is the most common rock in the middle unit. It is pale olive green, is thinly foliated, and lacks evidence of bedding. It contains a few angular grains of cloudy feldspars and rounded to angular grains of quartz sparingly dispersed in a matrix of chlorite, sericite, and an unidentified cloudy claylike material. Two samples of this rock were chemically analyzed (table 1), and the results are discussed later in this report (pp. F16–F18).

GRAYWACKE

Dark-gray-green graywacke forms a few outcrops. Bedding is generally obscure, but in a small exposure near the center of sec. 12, thin alternating layers of slate and graywacke resemble varves. Small rounded pebbles of granite, generally less than an inch in diameter, occur in an outcrop less than 20 feet from the interlaminated exposure. The graywacke is composed of angular to subrounded grains of cloudy plagioclase, relatively fresh microcline, quartz, some margins of which are corroded by chlorite, fragments of chloritized mafic rock, and relatively fresh quartz-feldspar rock fragments, all dispersed widely through a matrix of chlorite, sericite, and unidentified claylike material. Detrital zircon was identified in some thin sections.

ARKOSE

Pinkish-gray medium- to fine-grained firmly cemented arkose forms thin beds in the lower part of the slate-graywacke unit and interclasts of small knots and rootless folds in many exposures elsewhere. The grains in the arkose are tightly packed and fairly well sorted. Clouded feldspar is about twice as abundant as quartz. Zircon, leucoxene, chloritized mafic minerals, and carbonates are accessories. In composition, the arkose differs from the graywacke chiefly by the smaller proportion of matrix to rock fragments.

Arkose beds, a few inches to about a foot thick, are interbedded with greenish-gray chloritic slate in a few small outcrops near the south edge of the SW¼ sec. 2, T. 48 N., R. 26 W. In part, the arkose beds are folded and broken resulting in an intermixture of slate and arkose. In one exposure (fig. 5), beds of arkose and slate are draped over a granite boulder about 22 inches in diameter. A few hundred feet east of this exposure the arkose beds are folded and broken, but there are no boulders.

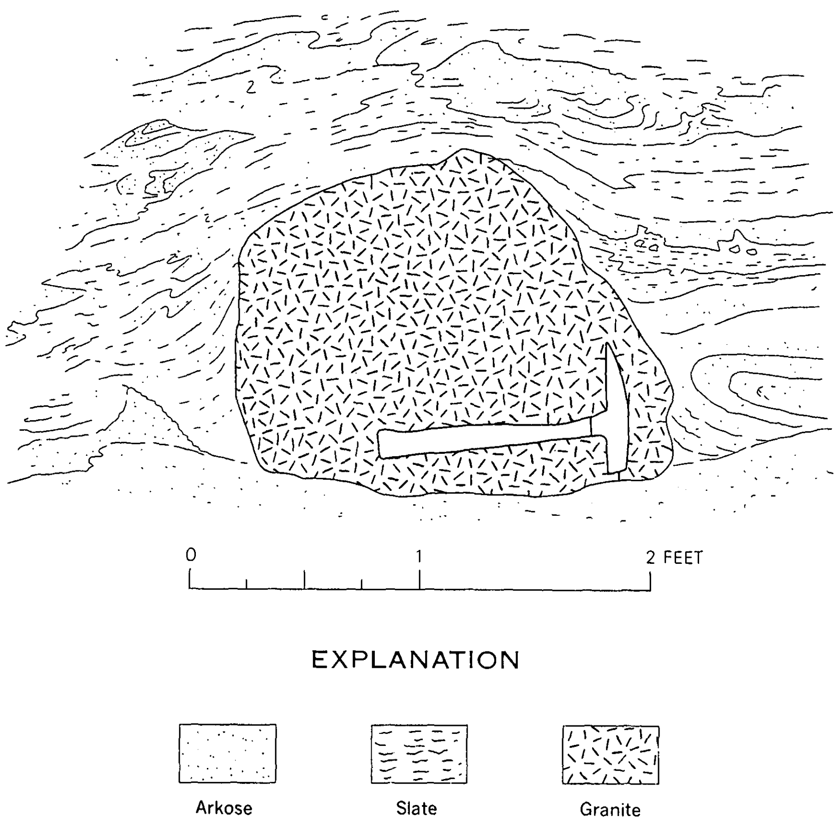


FIGURE 5.—Sketch (from photograph) of granite boulder surrounded by disrupted beds of arkose and chloritic slate. Outcrop is about 2,000 feet east of southwest corner of sec. 2, T. 48 N., R. 26 W., and is near the base of the middle unit of the Reany Creek Formation. Symmetrical draping of beds over the boulder possibly resulted from compaction during lithification of sediments deposited after emplacement of boulder; however, the overturned beds in lower right of sketch suggest forceful emplacement of the boulder into preexisting beds. Beds below boulder appear to be undisturbed. Distortions in arkose beds above boulder resulted from slump. There are no other granite boulders in the exposure; the outcrop extends a few feet to the left and right from the limits of the sketch.

The method of emplacement of the granite boulder is uncertain, but it could be attributed to gravity movements such as slumping or mudflows; however, the surrounding rocks, even though folded and broken, do not appear to have been sufficiently disrupted for such an origin. Perhaps the boulder was ice rafted, and the sediments now forming the slate and arkose were deposited over it. Overturned arkose beds near the lower part of the boulder could have resulted from lateral displacement of the boulder, either at the time of original emplacement or later.

Near the east boundary of sec. 1, T. 48 N., R. 27 W., small rootless folds of arkose a few inches in diameter are widely scattered in the slate on and near the crest of a steep slope. These fragments of arkose appear similar to the arkose exposed in sec. 2, and thus it is assumed that they are of intraformational origin. There is a general decrease in size and abundance of the arkose intraclasts upward from the base of the slate. Evidence of bedding in some of the larger fragments indicates they were formerly part of a bed or series of beds (fig. 6). However, bedding is not common in the smaller pieces of arkose; possibly they were never part of extensive beds, but were deposited as isolated small pods in what is now slate. The folded and broken fragments of arkose may have resulted from slumping, mudflows, slip folding within the slate, or possibly from disruption of beds by ice in a till-like deposit.

Features somewhat similar to the disrupted beds and fragments of arkose have been reported in the Gowganda Formation. Schenk (1965, p. 312–314) described formerly well-laminated interbedded argillite and quartzite in the Gowganda Formation that have been extremely swirled, although the laminae in the surrounding rocks are undisturbed. He ascribed these features to deformation caused by slumping.

A. T. Ovenshine (written commun., 1967) described rootless folds of medium- to coarse-grained poorly sorted pink arkose dispersed through finer grained sediments in the Gowganda. He could not attribute these folded inclusions to tectonism, because the enclosing beds dip only a few degrees and no secondary planar structures are found. He also noted that similar features have been found in permafrost soils.

DISPERSED GRANITIC MEGACLASTS

Granitic pebbles and boulders, ranging from less than an inch to as much as 22 inches in diameter, are widely dispersed in the slate and graywacke and are the distinguishing feature of the Reany Creek Formation. The pebbles and boulders can be found in most outcrops even if the exposure is only a few square feet in area. In some large outcrops, however, careful search is required to find one or two granitic

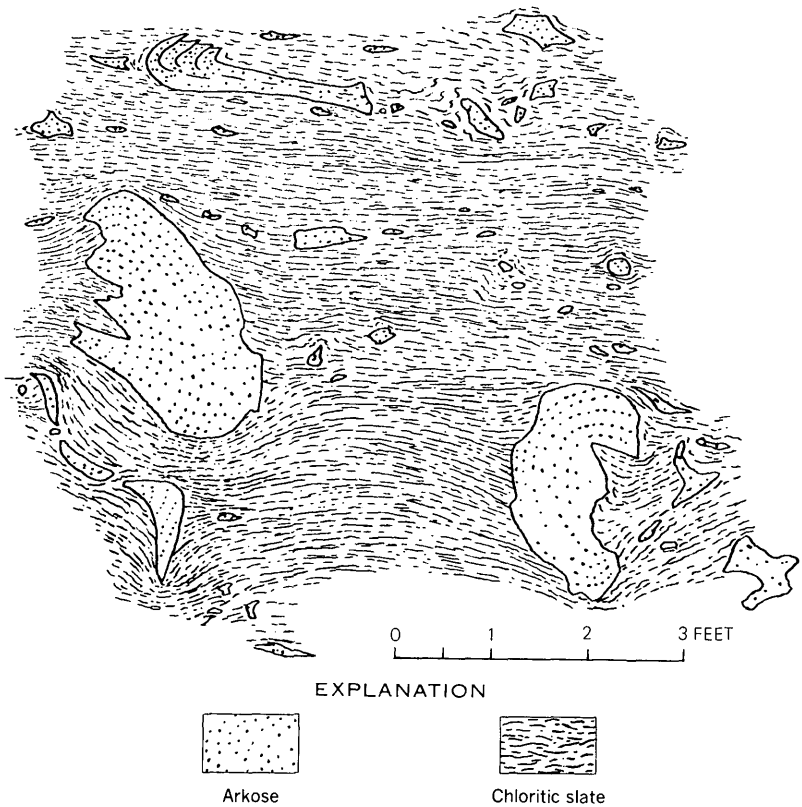


FIGURE 6.—Sketch of outcrop of slate containing broken beds of arkose from near the base of the middle unit of the Reany Creek Formation. Outcrop is near the top of a steep slope in the SE¼ sec. 1, T. 48 N., R. 27 W. Well-defined bedding is evident in larger fragments of arkose; it is at a high angle to the foliation in the slate and is oriented differently in each fragment.

clasts in an outcrop area of as much as several hundred square feet. Some boulders, as much as several inches in diameter, appear completely isolated from other megaclasts. Where several pebbles and boulders are found in a small area, they commonly are crudely alined parallel to the foliation in the slate. Most of the larger boulders are round, but some are subangular to angular. There is no systematic change in size or abundance of the granitic boulders along or across the strike of the formation. Moreover, sedimentary features in the slates surrounding these boulders provide no clues as to their origin. Ice rafting seems to be the most reasonable method of emplacement; however, no striated boulders have been found.

INTERBEDDED ARKOSE, SLATE, GRAYWACKE, CONGLOMERATE, AND QUARTZITE

The upper unit in the Reany Creek Formation (fig. 3) consists of interbedded arkose, slate, graywacke, conglomerate, and quartzite. The outcrops south of it are of sheared metavolcanic rocks of the Mona Schist against which the Reany Creek Formation has been faulted. The only exposure of the contact between the two formations is in Reany Creek about 1,000 feet north of the center of sec. 10, T. 48 N., R. 26 W. The easternmost exposure of this unit is in Reany Creek in sec. 10; other outcrops are in a belt 500–800 feet wide that extends west to the edge of the area shown in figure 2.

ARKOSE

Beds of massive pinkish-gray arkose crop out south of Reany Creek in the north-central part of sec. 9, T. 48 N., R. 26 W.; on the north edge of the county road on the north side of Dead River near the east border of sec. 7; and in a small southeast-draining valley at the north edge of Dead River Storage Basin, about 1,500 feet west of the east edge of sec. 7, T. 48 N., R. 26 W. Foliated coarse-grained pinkish-gray arkose is exposed on the north and south edges of Dead River Storage Basin in sec. 1, T. 48 N., R. 27 W. In the easternmost exposure of arkose in sec. 9, feldspar is dominant over quartz, as it is in the disrupted beds of arkose in the slate-graywacke unit, but to the west in secs. 1 and 7, the arkose contains as much as 75 percent quartz.

CONGLOMERATE

Conglomerate is exposed along the north shore of Dead River Storage Basin in sec. 7, T. 48 N., R. 26 W.; near the east boundary of sec. 1, T. 48 N., R. 27 W.; and in Reany Creek north of the center of sec. 10, T. 48 N., R. 26 W.

Several beds of conglomerate, 1–3 feet thick and separated by 3–5 feet of chloritic slate and coarse-grained graywacke, are exposed on the shore of Dead River Storage Basin west of a small inlet 300 feet west of the east edge of sec. 7. A photograph of one of the beds is shown in figure 7. The beds are relatively well sorted, being composed of clasts ranging from 3–5 inches in diameter; the matrix of chloritic slate forms only a very small percentage of the beds. A few large boulders, some as much as 15 inches in diameter, occur along the beds. In some places, the beds abut such boulders, and in other places, layers of the smaller sized material bend around the large boulder. The most common boulders are light-gray medium-grained granite, but there are also large clasts of greenstone and a few boulders of fine-grained quartzite.

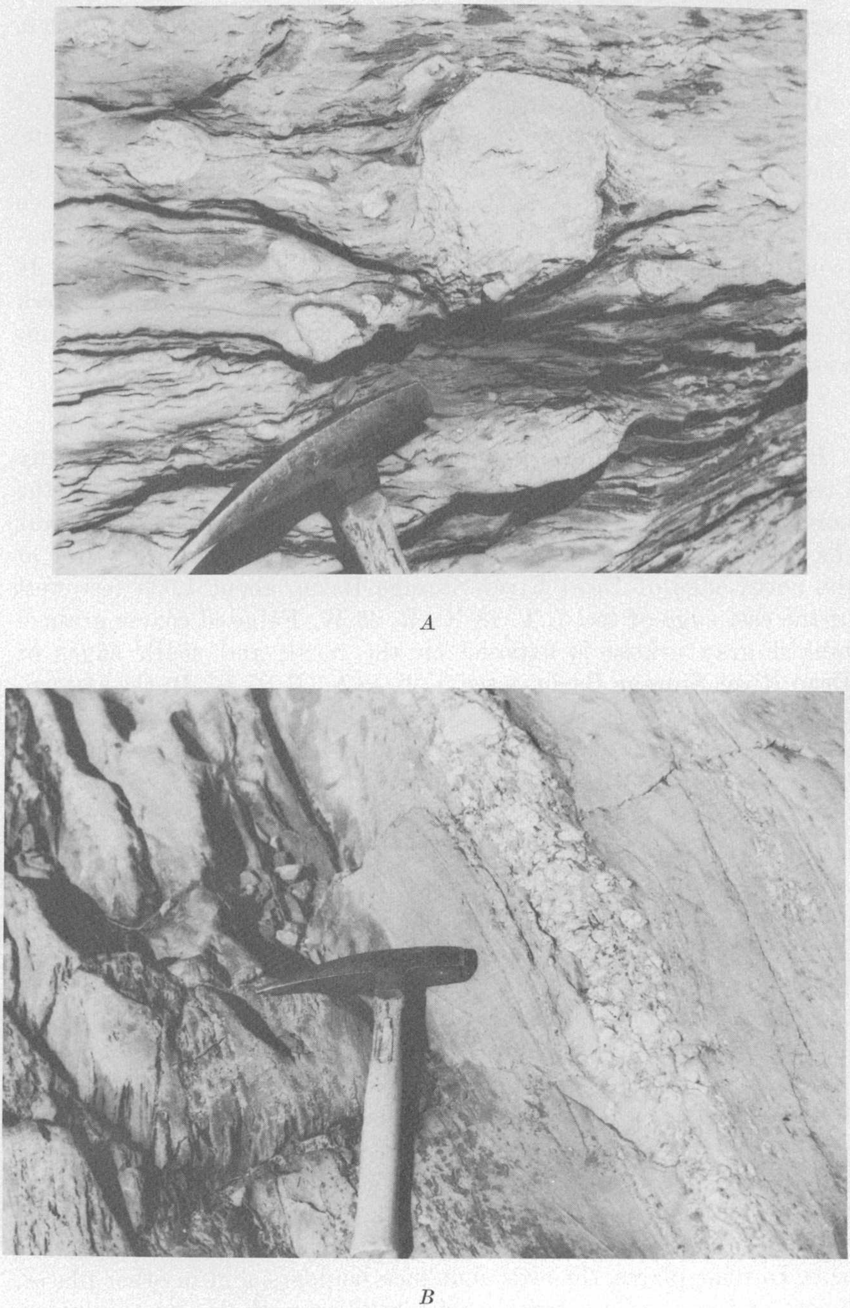


FIGURE 7.—Conglomerate in the upper part of the Reany Creek Formation. Exposed along the north shore of the Dead River Storage Basin in the NE¼ sec. 7, T. 48 N., R. 26 W. *A*. Nonbedded dispersed conglomerate with slaty graywacke matrix. *B*. Interbedded conglomerate and graywacke.

The conglomerate east of the small inlet in the northeast corner of sec. 7 is not bedded, but consists of pebbles and boulders of granite that are broadly dispersed throughout a chloritic slate matrix containing a few thin lenses of gray fine-grained quartzite. The distribution of the pebbles and boulders appears to be random, and the exposure has the general aspect of an indurated till. The foliation in the slate is bent or compressed near the margins of many of the larger boulders, but there is no definite evidence of penetration such as might be expected from ice-rafted erratics dropped into soft sediment. (Figure 7*A* is from this locality.)

QUARTZITE

Fine-grained gray feldspathic quartzite is exposed 1,000 feet west and 1,800 feet south of the northeast corner of sec. 8, T. 48 N., R. 26 W., and north of the arkose in the northeastern part of section 7. Large lenses of very fine grained light-gray quartzite occur in chloritic slate on the north border of Dead River Storage Basin along the east boundary of sec. 7. In all these exposures, the quartzite is relatively massive, bedding is indistinct, and there is a suggestion that it forms lenticular bodies.

Fine-grained gray and light-gray quartzite, with some thin interbeds of sericitic slate, crops out near the crest of a hill on the south side of Dead River Storage Basin in sec. 1, T. 48 N., R. 27 W. This quartzite is included within the Reany Creek Formation; however, no conglomerate beds are exposed on this hill, and future work may show that this quartzite south of the storage basin is not part of the Reany Creek.

THICKNESS

The thickness of the Reany Creek Formation can be determined only within broad limits. The estimated thickness of different parts of the formation are as follows: The eastern basal conglomerate is 1,800–2,000 feet thick; the western basal conglomerate is 250 feet thick; the middle unit is about 600 feet thick at the west boundary of the Negaunee 7½-minute quadrangle and about 1,000 feet thick in the eastern part of the quadrangle; and the upper conglomerate, arkose, and quartzite is 300–400 feet thick. Maximum thickness of the formation in the quadrangle is between 3,000 and 3,500 feet.

CHEMICAL COMPOSITION

The slate in the middle member of the Reany Creek Formation is similar in chemical composition to the slates containing boulders in other Precambrian formations in the Lake Superior region (table 1), but differs from average Precambrian slate (table 2). The slates containing boulders have a high $Na_2O:K_2O$ ratio but a low $Fe_2O_3:FeO$ ratio; they are low in CaO. This composition, which is similar to that of sandstone (graywacke) of a eugeosyncline (Middleton, 1960, p. 1017), suggests deposition from a source in which mechanical weathering was predominant and chemical weathering was minimal. The high Na_2O content of the slate of the Reany Creek Formation might be due either to source rocks rich in Na_2O (table 3) or to postdepositional albitization.

TABLE 1.—*Chemical analyses, in weight percent, of slate from the Reany Creek Formation compared with graywacke and argillite from other dispersed conglomerates of Precambrian age*

	1	2	3	4	5	6	7	8
SiO_2	63.7	65.6	61.98	61.68	58.82	61.54	70.0	61.0
TiO_2	.53	.52	.60	.49	.73		.6	.4
Al_2O_3	15.9	15.2	17.20	16.48	16.46		13.2	18.0
Fe_2O_3	1.0	1.3	1.42	1.73	1.10		1.0	1.2
FeO	4.6	3.7	4.49	5.61	7.20		3.9	4.6
MnO	.03	.11	.10	.09	.09		.1	.1
MgO	3.2	3.4	3.27	3.18	4.92		2.9	4.0
CaO	.85	.57	1.00	.53	.76	.84	.7	1.4
Na_2O	4.5	4.2	5.27	3.99	4.03	4.73	4.0	3.2
K_2O	2.3	2.4	2.04	2.62	1.60	2.84	1.2	2.3
H_2O^+	2.6	2.5	2.70	2.95	3.73		2.0	3.6
H_2O^-	.00	.02	.10	.08	.11		.1	.1
CO_2	.35	.15		.12	.01		Trace	
P_2O_5	.16	.15		.20	.17			Trace
SO_3				.01	.02			
Cl				.01	.03			
F				.05	.04			
S				.11	.05			
BaO				.04	.00			
C				.00				
Total	100	100	100.17	99.97	99.87		99.7	99.9

1. Reany Creek Formation. Slate with widely dispersed pebbles and boulders of granite. SE¼SE¼ sec. 6, T. 48 N., R. 26 W. Sample No. P-310a-66. Lab. No. W-167403. U.S. Geological Survey Rapid Rock Analysis. P. Elmore, L. Artis, G. Chloe, H. Smith, S. Botts and J. Glenn, analysts.
2. Reany Creek Formation. Slate with widely dispersed pebbles and boulders of granite. SW¼NE¼ sec. 11, T. 48 N., R. 26 W. Sample No. P-642a-66. Lab. No. W-167404. U.S. Geological Survey Rapid Rock Analysis. P. Elmore, L. Artis, G. Chloe, H. Smith, S. Botts, J. Glenn, analysts.
3. Gowganda Formation. Matrix of boulder conglomerate. Section 4, Thompson Township, Ontario, Canada. M. F. Conner, analyst (Collins, 1925, p. 66).
4. Cobalt Series (Gowganda Formation). Varved argillite. Wells Township, Ontario, Canada. L. N. Tarrant, analyst. (Pettijohn and Bastron, 1959, p. 595).
5. Cobalt Series (Gowganda Formation). Varved argillite. Olive Township. M. Balazs, analyst. (Pettijohn and Bastron, 1959, p. 595).
6. Cobalt Series (Gowganda Formation). Argillite from Lily Lake in the Gowganda district, Ontario, Canada. Partial analysis. (Wilson, 1913, p. 139).
7. Timiskaming graywacke, near Porcupine Lake, Ontario, Canada. H. B. Wiik, analyst. (MacPherson, 1958, table 1, p. 76).
8. Timiskaming argillite, Ogden Township, Ontario, Canada. H. B. Wiik, analyst. (MacPherson, 1958, table 1, p. 76).

The two analyzed samples of slate from the Reany Creek Formation are from outcrops nearly 4 miles apart—one from near the southeast corner of sec. 6 and the other from about 1,000 feet northeast of the center of sec. 11. Both outcrops are of uniformly fine grained chloritic slate containing widely scattered granitic boulders. Semiquantitative analyses of the two samples are given in table 4, together with spectrographic analyses of two samples of argillite from the Gowganda Formation. The trace-element content of the two formations is similar except for the higher Ba and Cu content of the Reany Creek Formation.

TABLE 2.—*Average chemical composition, in weight percent, of slates and argillite in dispersed conglomerates and of other pelitic rocks*

	1	2	3	4	5
SiO_2	64.6	60.83	56.30	58.10	60.64
TiO_2	.53	.61	.77	.65	.73
Al_2O_3	15.5	16.71	17.24	15.40	17.32
Fe_2O_3	1.1	1.42	3.83	4.02	2.25
FeO	4.2	5.77	5.09	2.45	3.66
MnO	.07	.09	.10	-----	-----
MgO	3.3	3.79	2.54	2.44	2.60
CaO	.71	.76	1.00	3.11	1.54
Na_2O	4.3	4.43	1.23	1.30	1.19
K_2O	2.3	2.09	3.79	3.24	3.69
H_2O^+	2.6	3.13	3.31	5.00	3.51
H_2O^-	.01	.10	.38		.62
CO_2	.20	.07	.84	2.63	1.47
P_2O_5	.16	.18	.14	.17	-----
SO_3	-----	.02	.28	.64	-----
Total	99.58	100.00	96.84	99.15	99.22

1. Average Reany Creek Formation (average of 1 and 2, table 1).
2. Average Gowganda Formation (average of 3, 4, and 5, table 1).
3. Average Precambrian slate, 33 analyses (Nanz, 1953, p. 58).
4. Average shale (Clarke, 1924, p. 34).
5. Average slate (Eckel, 1904, p. 26).

TABLE 3.—*Chemical analyses, in weight percent, of lower Precambrian rocks in the Negaunee 7½-minute quadrangle*

[U.S. Geological Survey Rapid Rock analyses. P. Elmore, H. Smith, L. Artis, G. Chloe, S. Botts, and J. Glenn, analysts]

	1	2	3	4
SiO_2	72.9	49.7	64.0	65.3
TiO_2	.23	.77	.62	.43
Al_2O_3	14.6	15.8	15.1	15.2
Fe_2O_3	.67	2.3	.82	1.0
FeO	.66	9.6	4.8	1.6
MnO	.04	.02	.04	.06
MgO	.56	6.6	3.5	2.5
CaO	1.4	7.0	2.2	1.8
Na_2O	5.0	3.7	3.0	3.6
K_2O	2.9	.70	2.2	5.1
H_2O^+	.58	2.7	2.8	1.2
H_2O^-	.15	.00	.00	.06
CO_2	$<.05$	.31	.18	1.8
P_2O_5	.13	.06	.20	.41
Total	100	99	99	100

1. Granitic gneiss. SW¼NE¼ sec. 35, T. 49 N., R. 26 W. Sample No. P-226-66. Lab. No. W167842.
2. Layered amphibolite, Mona Schist. SE¼SW¼ sec. 4, T. 48 N., R. 26 W. Sample No. P-676a-66 Lab. No. W167400.
3. Sericite, chlorite, quartz-feldspar schist, Mona Schist. SW¼SW¼ sec. 18, T. 48 N., R. 26 W. Sample No. P-173C-65. Lab. No. W167405.
4. Granodiorite. SE¼SE¼, sec. 15, T. 48 N., R. 26 W. Sample No. P-213-64. Lab. No. W164096.

Pettijohn and Bastron (1959, p. 596–598) suggested that the sodic nature of the argillites of the Cobalt Series is due to postdepositional changes. They compared the $Na_2O:K_2O$ ratio with that of average detrital sediments and found it is similar to that of graywacke. The sodic nature of the graywacke is regarded as an original characteristic inherited from its source rocks, but they believed the pelitic rocks of the Cobalt Series should contain about 4–5 percent CaO if they were the result only of glacial abrasion of the average rock of the Canadian Shield. They concluded that the high $Na_2O:K_2O$ ratio and low CaO content indicate postdepositional albitization of the detrital plagioclase that resulted in loss of CaO and addition of Na_2O.

TABLE 4.—*Semiquantitative spectrographic analyses of slate from the Reany Creek Formation compared with spectrographic analyses of argillite from the Gowganda Formation*

[Results of semiquantitative spectrographic analyses are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value about 30 percent of the time. Elements looked for but not detected in the semiquantitative spectrographic analyses: Ag, As, Au, Bi, Cd, Eu, Ge, Hf, Hg, In, Li, Nd, Pd, Pr, Pt, Re, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W. Elements looked for in the spectrographic analyses but not found: Ag, As, Au, Bi, Cd, Ce, Ge, Hg, In, Nb, Pd, Pt, Re, Rh, Ru, Sb, Sn, Ta, Te, Th, Tl, U, W. Dashes (----) indicate element looked for but not detected]

	1	2	3	4
B	----	----	0.002	0.002
Ba	0.1	0.1	.03	.02
Be	----	----	.0002	.0002
Co	.002	.0015	.002	.002
Cr	.02	.015	.02	.02
Cu	.02	.01	.006	.0006
Ga	.001	.001	.001	.001
La	.005	.003	.005	.007
Mo	.0003	.0003	----	----
Nb	.0005	.0007	----	----
Ni	.007	.005	.004	.006
Pb	.0007	.0003	.0005	.0006
Sc	.0015	.0015	.002	.002
Sr	.02	.015	.005	.01
V	.02	.015	.009	.02
Y	.001	.001	.003	.003
Yb	.0001	.0001	.0001	.0002
Zn	----	----	.02	.01
Zr	.015	.015	.009	.01

1. Reany Creek Formation. Slate. Sample No. P-310a-66. Lab. No. W-167403. W. B. Crandell, analyst.
2. Reany Creek Formation. Slate. Sample No. P-642a-66. Lab. No. W-167404. W. B. Crandell, analyst.
3. Gowganda Formation. Varved argillite, Cobalt Series, Wells Township, Ontario, Canada. Harry Bastron, analyst (Pettijohn and Bastron, 1959, p. 595).
4. Gowganda Formation. Varved argillite, Cobalt Series, Olive Township, Ontario, Canada. Harry Bastron, analyst (Pettijohn and Bastron, 1959, p. 595).

The high Na_2O content of the slate in the Reany Creek Formation may be mainly the result of rapid mechanical weathering, with only minor chemical weathering, of source rocks in which the $Na_2O:K_2O$ ratio is high. Lower Precambrian rocks similar to those in the Negaunee 7½-minute quadrangle probably were the source for much of the sediment in the Reany Creek Formation. The analyses given in table 3 show that the $Na_2O:K_2O$ ratio is high in all samples except the granodiorite and that CaO exceeds Na_2O only in the layered amphibolite. If rocks similar to those given in table 3 were the main source rocks for the slate of the Reany Creek Formation, then postdepositional albitization, as suggested by Pettijohn and Bastron (1959, p. 596–598) for the Gowganda Formation, might not have been necessary to produce a Na_2O-rich sediment. To obtain a Na_2O-rich sediment from Na_2O-rich source rocks, however, a rather specialized environment would be required, in which chemical weathering would have to be inhibited to prevent leaching of the Na_2O. A glacial environment, such as that postulated for the Gowganda Formation (Collins, 1925; Schenk, 1965; Wilson, 1913), might have prevailed during deposition of the Reany Creek Formation, and this environment could have allowed the retention of Na_2O in the slate.

ORIGIN

The broad range of rock types in the Reany Creek Formation indicates a variety of depositional conditions, but the same general environment probably prevailed during most of Reany Creek time. The coarse basal conglomerate required a source area with high initial relief, the well-sorted beds of arkose and quartzite represent fluvial deposits, and the very fine grained slate must have accumulated in either deep water or a restricted basin that had virtually no currents. The beds of conglomerate suggest torrential fluvial conditions; possibly they are outwash from glaciers. The boulders widely dispersed through the slate required a somewhat unique transporting medium, such as ice rafting. The disrupted beds of arkose in slate possibly resulted from slumping on an unstable slope. The local concentrations of pebbles and boulders in slate, which grossly resemble till, suggest glacial conditions. A rugged coastline from which glaciers extended into the sea over a relatively steep submarine slope could well have been the environment in which the sediments of the Reany Creek Formation accumulated.

The distinctive lithology of the middle sequence of the Reany Creek Formation—slate and graywacke with widely dispersed boulders of granitic rock—and the till-like deposits of pebbles and boulders in slate in the upper part are the most significant features in determining the origin of the formation. Precambrian formations in Canada with similar lithologies are believed to be of glacial origin (Collins, 1925, p. 73; Dott, 1961, p. 1303, Wilson, 1913, p. 140), and it is here suggested that the Reany Creek Formation is at least in part of glacial origin.

The glacial origin of some pebbly mudstones has been questioned in recent papers by Crowell (1957, 1964) and Dott (1961). They suggested that turbidity currents dispersed the coarser material in the fine-grained sediments. According to Dott (1961, p. 1301), the most convincing evidence for glacial origin is a widespread and polished pavement beneath till-like deposits. Striated boulders have been considered supporting evidence, although Winterer (1964, p. 175) has shown that these are not always of glacial origin. Crowell (1964, p.

88) considered the best evidence for Precambrian glaciation to be the presence of megaclasts that clearly have been dropped into bottom sediments; moreover he stated that a glacial pavement is rarely preserved in a terrestrial environment.

Large clasts can be dispersed in fine-grained sediments by processes other than by ice rafting. Turbidity currents, mudflows, submarine slumping, thrust faults, and collapse of submarine escarpments can result in mixtures of fine and coarse material. Most of these dispersing processes produce features that aid in determining the origin of the anomalous boulders and pebbles. Some of these features include sole markings, convolute bedding, graded beds, and lenses consisting of poorly sorted mixtures that include fragments of the enclosing rocks. None of these features, however, are found in the Reany Creek Formation.

A glacial origin for at least part of the Reany Creek Formation is postulated because of the presence of widely dispersed pebbles and boulders of granitic rock in a matrix of slate and graywacke and because of the lack of evidence for any other origin. Also, most of the larger clasts are of a granitic rock type that is not known to be in contact with the Reany Creek Formation, unless possibly under Pleistocene deposits in the eastern part of the area; thus this feature fits Mansfield's (1907) criterion that conglomerates of glacial origin contain boulders from a distant source. Other factors supporting a glacial origin are largely negative in nature. Because of an absence of obvious bedding surfaces, no determination can be made that megaclasts were dropped into and deformed soft bottom sediments. The contact of the Reany Creek Formation with the underlying formation is exposed at only a few places, and the nature of the surface on which the Reany Creek Formation rests cannot be determined. The disrupted beds of arkose in the lower part of the slate-graywacke unit could have resulted either from overriding glacial ice or from slump along steep submarine slopes.

The environment at the time of deposition of the Reany Creek Formation is believed to have been a rugged coastline bordered by steep submarine slopes. Piedmont glaciers on the highlands are envisaged as having fingers that extended toward the sea, gouging out U-shaped valleys that were later filled with coarse conglomerate. At the coastline or at the "buoyancy line" (Carey and Ahmad, 1961, p. 873), subglacial streams deposited arkosic sand that oversteepened the upper submarine slopes, causing local slumping. Icebergs are believed to have carried boulders out to sea and dropped them into fine-grained bottom sediments. The environment was probably similar to that along modern coasts in subarctic regions.

CORRELATION AND AGE

The age of the Reany Creek Formation is indicated by its lithology, its mode of origin, its relationship to rocks of early Precambrian age, and its chemical composition. Comparison with other formations in the Lake Superior region suggests that the Reany Creek Formation is of middle Precambrian age, is in part of glacial origin, and is possibly correlative with tillite in the Gowganda Formation of Ontario, Canada. The correlation cannot be precise, however, because the Reany Creek Formation is not in contact with other known sedimentary formations of Precambrian age, and no radiometric dating has been done on it or adjacent formations.

It is not definite that the Reany Creek Formation is post early Precambrian in age, but the marked unconformity between it and the Mona Schist and the presence of Keweenawan dikes suggest a middle Precambrian age. Alternatively, the Reany Creek Formation could conceivably be equivalent to the Timiskaming, that is, older than the Animikie Series, but younger than other pre-Animikie lower Precambrian rocks in the area.

Evidence for glacial action in other Precambrian rocks in Michigan is described by Murray (1955, p. 344). He reported striations, gouges, grooves, polishing, and friction cracks in the Michigamme Slate near L'Anse, Mich., about 35 miles northwest of the Dead River basin. He did not indicate that any till-like sediments overlie the striated surfaces. At the present time, the evidence of glaciation reported by Murray does not seem to be related to that suggested by the sediments in the Reany Creek Formation.

J. E. Gair (U.S. Geological Survey, 1962, p. A24) described pebbles and cobbles of granite that may have been ice rafted and deposited in thinly layered, possibly varved, muds of the Wewe Slate (Animikie Series) in the Marquette syncline. This occurrence is about 10 miles southeast of outcrops of the Reany Creek Formation, but at the present time, the two formations cannot be correlated. It is of interest that the deposits of the Marquette syncline show evidence of possible glaciation in Precambrian time, and future work might prove that the deposits are broadly synchronous with those of the Reany Creek Formation.

The dispersed conglomerate in the Reany Creek Formation is similar to that described in the Fern Creek Formation of Dickinson County, Mich. (Pettijohn, 1943), the Gowganda Tillite of the Cobalt Series in Canada (Collins, 1925; Schenk, 1965), the Timiskaming Series in Ontario, Canada (Collins, 1937), and parts of the Knife Lake Group in northern Minnesota (Leith and others, 1935, p. 8; Grout and others, 1951, p. 1035).

It is doubtful that the Reany Creek Formation can be correlated with the Knife Lake Group. Leith, Lund, and Leith (1935, p. 16) thought it highly improbable that the Knife Lake Group ever extended south of Lake Superior. Grout, Gruner, Schwartz, and Thiel (1951, p. 1075) stated that the correlation of the Knife Lake Group with the Huronian is not certain and that the relation of the Knife Lake Group to the Timiskaming cannot be ascertained until the relations of the Timiskaming beds to the older and younger rocks are better understood. Goldich, Nier, Baadsgaard, Hoffman, and Krueger (1961, p. 154) believed that the Knife Lake represents a sedimentary cycle of the Timiskaming period. It now seems probable that the Knife Lake Group and the Timiskaming are pre-Huronian in age and thus older than the Gowganda Formation.

The Fern Creek Formation is lithologically similar to the Reany Creek Formation, and both formations rest unconformably on rocks of early Precambrian age. The granitic gneiss on which the Fern Creek Formation rests may correlate with the granitic rocks that intrude the Mona Schist. Young (1966, p. 209) suggested that the Fern Creek Formation is correlative with the Cobalt Group—the group that includes the Gowganda Formation on the north side of Lake Huron. Frarey (1966, p. 998) believed that such a correlation is very unlikely and, on the basis of published isotope dates, suggested that the Huronian in Canada belongs to an earlier cycle than the Animikie Series in Dickinson County, Mich.

The Reany Creek Formation crops out about 50 miles north of the Fern Creek Formation and about 160 miles west of the nearest outcrop of the Cobalt Series (fig. 8). The total length of outcrop of the Reany Creek Formation is about 7 miles. It hardly seems justified to project it over the distance required to connect it with either the Fern Creek Formation or the Gowganda Formation.

The Reany Creek Formation has, however, many features similar to those in the Gowganda Formation. Significant lithologic similarities include the irregularly shaped rootless folds of arkose and the dispersed pebbles and boulders of granite in slate. The chemical composition of the slate in the Reany Creek Formation is almost identical with that of the argillite and matrix of the boulder conglomerate in the Gowganda. Both formations rest unconformably on rocks of early Precambrian age. Wilson (1913, p. 123) reported that the general succession in the Cobalt Series is from basal conglomerate through graywacke, argillite, and arkose to an upper conglomerate. This succession is like that found in the Reany Creek Formation. Schenk (1965, p. 311) reported that in the Gowganda Formation of Vogt Township, Ontario, massive conglomeratic graywacke and laminated argillite-

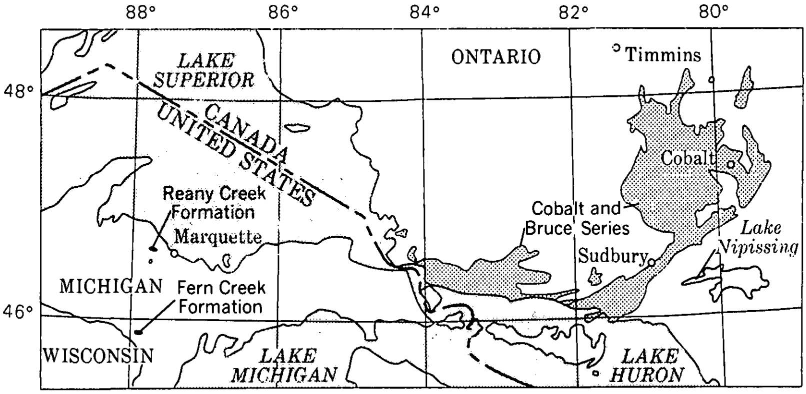


FIGURE 8.—Areas underlain by the Cobalt Series in Canada and the Reany Creek and Fern Creek Formations in Michigan.

quartzite alternate through at least 10,000 feet of strata; each of the two rock types appears three times, so the formation is divisible into six members. The base of the formation is represented in places by a seventh member—granitic conglomerate. Possibly, the tripartite Reany Creek Formation, including the well-developed basal conglomerate, corresponds to Schenk's lower three members of the Gowganda Formation. The Cobalt Series in Canada trends nearly due west near the southeast tip of Lake Superior (fig. 8), and an extension of this trend would possibly include the area underlain by the Reany Creek Formation.

The lithologic and chemical similarities between the Reany Creek Formation and the Gowganda Formation seem sufficient to suggest a tentative correlation. To correlate them, however, would suggest reassignment of some strata in northern Michigan to the Huronian, and James (1958, p. 34–35) has concluded that the middle Precambrian rocks in northern Michigan should be assigned to the Animikie Series and not to the Huronian. Refinements in radiometric dating techniques will certainly be an aid in resolving correlation problems, but at present there are no meaningful radiometric ages to assist in the correlation of the Reany Creek Formation with formations near Lake Superior in Canada.

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