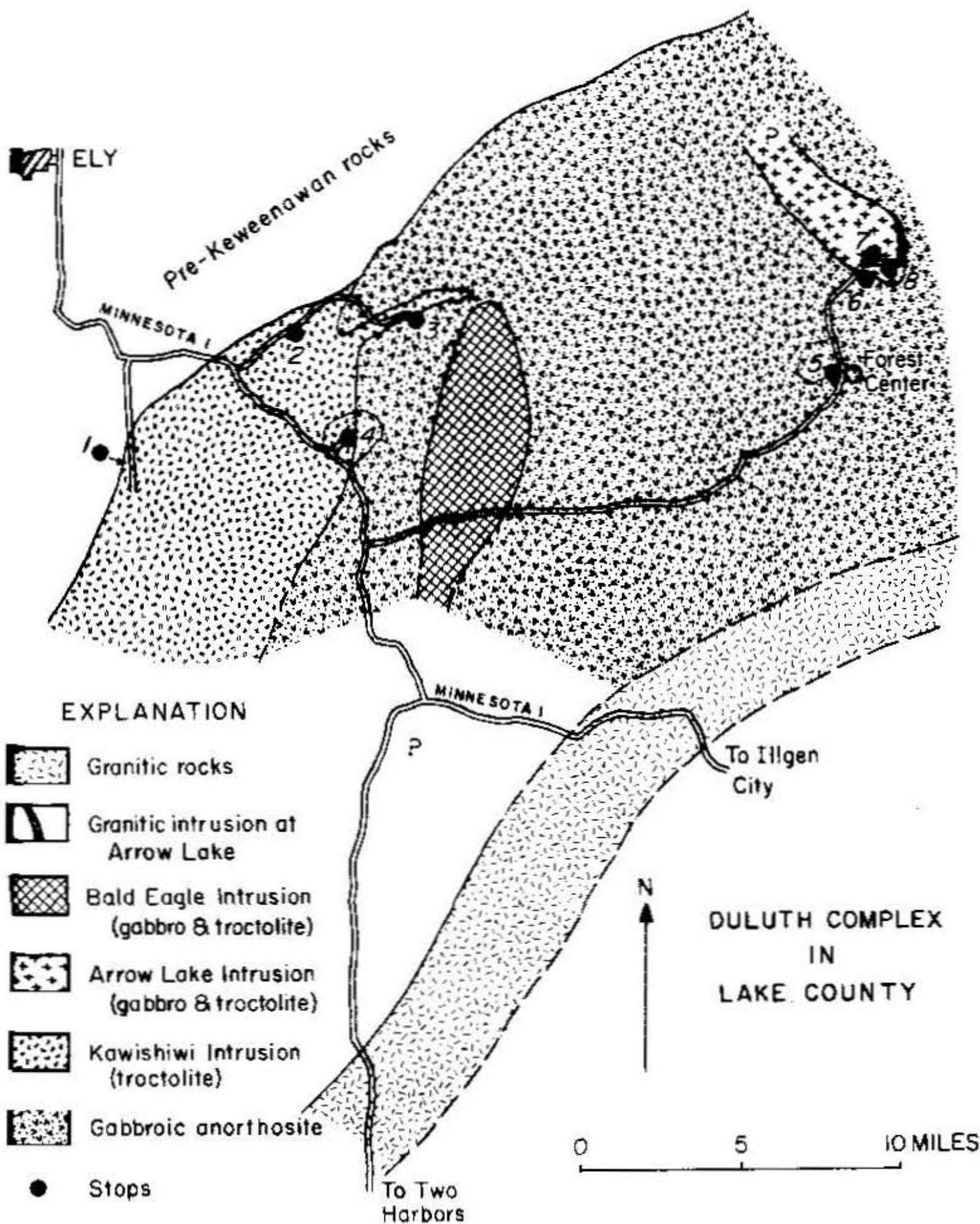


Guide
for
Field Trip
in
The Duluth Complex
near
Ely, Minnesota

Institute on Lake Superior Geology

May 5 and 8, 1968

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Field Trip in Duluth Complex East of Ely, Minnesota

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Introduction

On the accompanying map there are eight stops shown. However, it is unlikely that all stops will be visited and they will not necessarily be visited in the numerical order given. Because of the large number of registrants for the field trip (over 200) it is necessary that several groups visit the outcrops simultaneously and each group will be starting at different outcrops. Hopefully each group will make a minimum of six stops.

General Geologic Relations

General mapping of the geology in northeastern Minnesota over the past few years has shown the Duluth complex to be a series of anorthositic, gabbroic, troctolitic, granodioritic, and granitic intrusives. These intrusives outcrop in an arcuate pattern extending about 150 miles north-eastward from Duluth towards the northeastern tip of Minnesota. Older granites, schists, greenstones, and slates occur along the basal contact on the northwest; and Keweenaw flows form the upper contact to the south-east. Radiometric dating of zircons from rhyolitic flows and granitic fractions of the Duluth complex (Silver and Green, 1963 and personal communication) indicate that the intrusives and the flows are essentially contemporaneous to within experimental errors at 1120 ± 15 million years.

Stops 1, 2, 3, and 4 are located in the Gabbro Lake 15 minute quadrangle for which a detailed geologic map is available through the Minnesota

Geological Survey. Stops 5, 6, 7 and 8 are located in the Forest Center 15 minute quadrangle where some preliminary mapping has been accomplished but no geologic map is available.

A tabulation of modes for the various units of the Gabbro Lake Quadrangle is included. About 400 thin sections have been studied and counts of 1500 or more points in each thin section have been used as a basis for the modal estimates. In most of the rock units there is a substantial variation of the mode about an average but in general each type can be distinguished from another on textural differences.

The oldest intrusive and most extensive unit of the Duluth complex in the two quadrangles is gabbroic anorthosite (80 to 90% plagioclase). A small mappable unit of anorthositic gabbro (70 to 80% plagioclase) occurs in the Gabbro Lake quadrangle as a unit within the gabbroic anorthosite. In all of these plagioclase-rich units the only cumulate-type mineral is plagioclase of about An_{65} to An_{75} composition. The remainder of the minerals are interstitial. The abundance and textural relations of the various interstitial ferromagnesian phases often may be used as a basis for distinguishing smaller units within the gabbroic anorthosite.

Cross-cutting structural relations based on detailed observations of smaller units within the gabbroic anorthosite and planar plagioclase orientation in small areas, indicate that the gabbroic anorthosite consists of a number of intrusions.

Intrusive into the gabbroic anorthosite are at least three major troctolitic to gabbroic intrusions and other smaller intrusives. In the Gabbro Lake quadrangle, from Bald Eagle Lake to the south is a major intrusive which is differentiated from a troctolite margin to a gabbro core. Layering and planar plagioclase orientation indicate this intrusion to be

cone-shaped in cross section. Also, in the Gabbro Lake quadrangle, south-east of the Kawishwi River is a major troctolite intrusion with a dike-like appendage to the northeast. The major part of this intrusion forms a basin-like structure about 6 miles across. Many anorthosite knobs occur throughout the area of this intrusion. Some of these appear to be lenses but others may be inclusions. Further east in the Forest Center Quadrangle occurs a third major intrusion which consists in part of gabbro and in part of troctolite. Detailed petrologic studies of this intrusion have not yet been accomplished. Structurally this has steeply dipping layers near the margins and rather flat central portions. A finer-grained, well-banded margin indicates extensive assimilation of the surrounding gabbroic anorthosite. The eastern margin of this intrusion is formed, in part, of granite with inclusions of finer grained hornfels presumably from the margin of the intrusion.

Economic Mineral Occurrences

Several smaller intrusions such as a norite in the Gabbro Lake quadrangle and troctolite dikes also occur but are not shown on the accompanying sketch map and will not be discussed here. Various assemblages of copper, iron, and nickel sulfides occur near the basal contact of the troctolite intrusion southeast of the Kawishwi River. Other economic mineral occurrences are known to exist in other parts of the Duluth complex but the only one to be discussed here is near the Kawishwi River. The surface expression of these occurrences is the typical brown oxidized zone or gossan. These occur in a roughly linear zone parallel to the basal contact of the gabbro although not at the base, usually a few hundred feet from the contact. The gossans do not seem to occur in

the anorthositic rocks but rather in the troctolite including the dike-like appendage of troctolite mentioned earlier.

The troctolite in the vicinity of the sulfides usually contains many inclusions some of which appear to be fine grained gabbro, others are hornfels which may have been part of the Virginia formation or iron formation, and still others are gabbroic anorthosites. Within the gabbroic and troctolitic rocks the sulfides occur with various combinations of types and sizes of silicate minerals. In some cases the host is very plagioclase rich and in others quite olivine rich. In some cases the host is very coarse-grained and in others quite fine-grained. In nearly all cases, however, the sulfides appear to fill the interstices between the plagioclase and olivine grains.

Average Modes of Units in the Duluth Complex, Gabbro Lake Quadrangle

Plagioclase	78.26	87.44	87.96	65.56	65.67	67.55	68.57	70.25	63.65	93	57.3	42.2
	Anorthositic Gabbro (30) ago	Noritic Anorthosite (37) agh	Gabbroic Anorthosite (176) agu	Basal Contact Zone of Gabbroic Anorthosite (17) agu	Contact Zone of Gabbroic Anorthosite with Troctolite (12) agu	Norite (6) n	South Kawishiwi Augite Troctolite (13) sat	South Kawishiwi Polkilitic Troctolite (27) spt	Dike of South Kawishiwi Intrusion (48) st	Anorthosites in South Kawishiwi Intrusion (4) sa	Margin of Bald Eagle Intrusion (12) bt	Central Zone of Bald Eagle Intrusion (7) bg
Augite	8.80	2.63	2.83	5.80	5.00	3.91	9.73	4.89	8.63	1	2.1	46.0
Hyperssthene	1.28	6.09	1.74	2.85	0.59	23.90	2.02	0.64	1.08	1	tr	tr
Olivine	3.32	0.24	3.92	13.73	6.17	tr	14.82	19.31	22.42	2	13.2	8.3
Opauques	3.01	1.34	1.30	3.93	1.94	3.06	1.34	2.18	3.40	2	5.3	1.0
Biotite	2.64	1.07	.96	3.48	.37	1.25	1.97	.60	tr	tr	tr	tr
Symplectite	2.25	0.55	tr	4.33	--	tr	1.30	tr	tr	--	20.8	1.7

Numbers after each rock type indicate number of thin sections from which average mode was calculated.

Letters after each rock type indicate unit symbol on Geologic Map of Gabbro Lake Quadrangle.

Individual Stops

- Stop #1 This gossan zone near base of South Kawishiwi troctolite intrusion shows inclusions and a variety of textures.
- Stop #2 Reasonably fresh surfaces of sulfide can be found in this test pit from which INCO took a bulk sample. Again a variety of textures and minerals can be seen.
- Stop #3 Contact between gabbroic anorthosite and dike-like appendage of troctolite. Banding and inclusions may be seen in the troctolite which is laced with pegmatitic veins. The complex nature of the contact also may be seen.
- Stop #4 Gravity influenced the settling of olivine to produce gradational layering. This outcrop in the middle of the troctolite basin shows several such cycles of gradational layers.
- Stop #5 Two or three types of gabbroic anorthosite occur here. In fact, an inclusion of one type in another may be seen. Similar outcrops form a monotonous pattern of gabbroic anorthosite over tens of square miles in this area.
- Stop #6 The fine-grained margin of this intrusion shows effects of assimilation of the surrounding gabbroic anorthosite.
- Stop #7 Well banded zone of this intrusion indicates the complex nature of the intrusion and suggests the dynamics involved.
- Stop #8 The granitic eastern margin of this intrusion has some inclusions at the south end of the outcrop. The granite extends nearly a mile to the north but ends about one to two hundred yards south of the road.