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MISCELLANEOUS MAP SERIES
MAP M-119, SHEET 1 OF 2

GEOLOGIC MAP OF THE DULUTH COMPLEX AND RELATED ROCKS, NORTHEASTERN MINNESOTA

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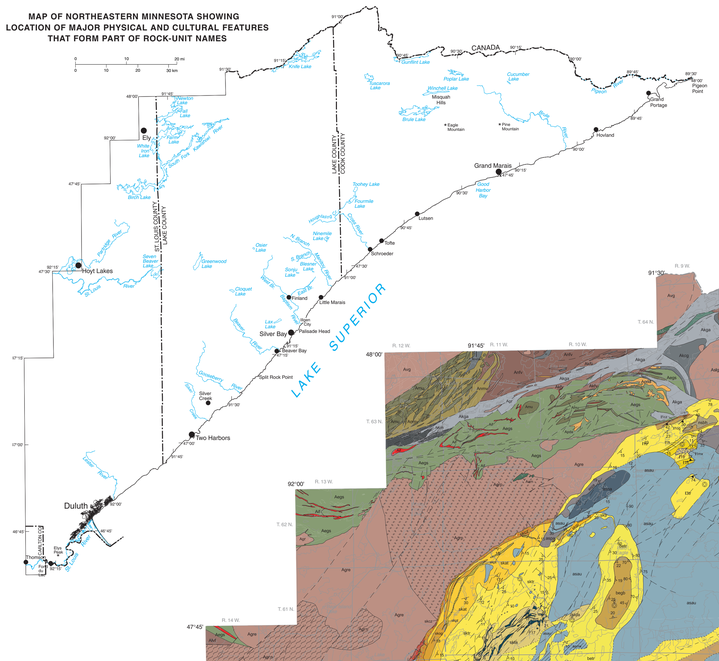
MAP OF NORTHEASTERN MINNESOTA SHOWING LOCATION OF MAJOR PHYSICAL AND CULTURAL FEATURES THAT FORM PART OF ROCK-UNIT NAMES



NOMENCLATURE

Standard geologic terms as defined in the Glossary of Geology (American Geological Institute, 1987) are used where applicable. Map-unit classifications follow recommendations of the Commission on Stratigraphic Nomenclature (American Association of Petroleum Geologists, 1983). Standard terminology is used for rock names based on modal mineralogy; modal definitions have been modified slightly from the classification scheme suggested by Streckeisen (1976). Cumulate rock codes, for example, *ncoi* or *ncr*, indicate mineral phases listed in decreasing order of abundance. Cumulus phases are denoted by uppercase letters, and intercumulus phases are denoted by lowercase letters. Mineral abbreviations used below are

n or *p*	plagioclase
o or *v*	olivine
c or *x*	clinopyroxene
o or *s*	hypersthene
i or *i*	inverted pigeonite
r or *r*	iron-titanium oxide
a or *a*	apatite

For further information on terminology and stratigraphic designations, see Miller and others (2002).

DESCRIPTION OF MAP UNITS

MESOPROTEROZOIC ROCKS

KEWEENAWAN SUPERGROUP—Volcanic and sedimentary rocks formed during the development of the Midcontinent rift system.

NORTH SHORE VOLCANIC GROUP—Suite of stratified volcanic and minor sedimentary rocks exposed in northeastern Minnesota along Lake Superior shoreline; divided into five sequences on the basis of stratigraphic position and magnetic polarity; sequences are further subdivided into individual flows and formational sequences (considerably modified from Green, 1972).

Schroeder–Lutsen sequence—Predominantly olivine-tholeiitic lava flows occupying upper part of volcanic group from Little Marais to Good Harbor Bay; separated from older rocks by unconformity marked by sedimentary units (*nwfa* and *nlwcc*); total thickness 500–1100 m; sequence not radiometrically dated.

- *nwfa* — *Undifferentiated olivine-tholeiitic basalts*—Homogeneous suite; commonly ophitic, aphyric; smooth to ropy, billowing flow tops.
- *nlwcs* — *Dear Yard Lake sandstone*—See Jirsa (1984) for further information.
- *nlwcb* — *Manitou River basalt*—Fine-grained, intergranular, transitional basalt; abundant small plagioclase phenocrysts; flow thickness greater than 100 m.
- *nplbx* — *Pork Bay breccia*—Matrix-supported breccia; pebble- to boulder-sized clasts of intermediate volcanic rocks (mainly basalt) in red, silt- to sand-sized matrix; interpreted as mudflow deposit.
- *ntpph* — *Terrace Point basalt*—Fine-grained, ophitic olivine-tholeiite; sparse plagioclase phenocrysts; thickness in amygdaloid zone more than 100 m; part of Schroeder–Lutsen sequence at northeast; thickness greater than 50 m.
- *nlcrr* — *Cut Face Creek sandstone*—Red-brown, laminated, ripple-marked, cross-bedded volcanic sandstone and shale; marks discontinuity between Schroeder–Lutsen sequence and upper northeast sequence.
- *nlmrr* — *Little Marais conglomerate*—Polymict volcanic conglomerate, subangular cobble- to pebble-supported; sandy to silty matrix; marks angular unconformity between the Schroeder–Lutsen sequence and upper southwest sequence.

Upper southwest sequence—Includes basaltic, intermediate, and minor (less than 10 percent by volume) rhyolitic lava flows extending from Duluth north to Little Marais along shore of Lake Superior; normal magnetic polarity; flows generally greater than 15 m thick; pyroxene phenocrysts indicate eruption of sequence in 1099–1096 Ma (Davis and Green, 1997).

- *nsph* — *Basalt of Spirit Mountain*—Suite of ophitic basalt, intergranular basalt, basaltic andesite, and aphyric rhyolite.
- *nplrp* — *Palisade Head porphyritic rhyolite*—Light-gray to pink, aphanitic; contains small quartz, K-feldspar, and oxidized mafic phenocrysts; thickness about 100 m; U-Pb age 1096.6 ± 1.7 Ma (Davis and Green, 1997).
- *nbst* — *Baptism River basalt*—Mixed suite of subophitic to ophitic basalt, intergranular basalt, basaltic andesite, and rhyolite; includes Silver Beaver rhyolite (unit *nslbr*) in upper part of sequence and Silver Bay porphyritic basalt (unit *nsbp*) in lower part.
- *nslbr* — *Silver Beaver rhyolite*—Light-gray to pink, sparsely plagioclase-phyric to aphyric, microspherulitic, locally flow laminated; thickness 120–150 m.
- *nsbp* — *Silver Bay porphyritic basalt*—Ophitic olivine basalt with as much as 50% large (2–5 cm) plagioclase phenocrysts; thickness 15–20 m.
- *ngrb* — *Gooseberry River basalts*—Ophitic, subophitic, and intergranular basalt flows, generally aphyric.
- *nphb* — *Two Harbors basalts*—Mostly aphyric, intergranular basalt flows; some have well-developed flow-top breccia.
- *nlmb* — *Larsmont ophitic basalt*—Homogeneous, aphyric, ophitic, olivine-tholeiitic flows; compositionally uniform.
- *nsrb* — *Sucker River basalts*—Ophitic to subophitic basalt flows; mostly aphyric.
- *nlwb* — *Lakewood basalts*—Mixed suite of predominantly intergranular basalt with some ophitic basalt, terranostic, icelandite, and rhyolite; more evolved compositions in lower part of suite.
- *nlkb* — *Lakeside lavas*—Mixed suite of intergranular, plagioclase-phyric, and ophitic basalt, basaltic andesite, icelandite, and rhyolite; U-Pb age 1098.4 ± 1.9 Ma for icelandite (Davis and Green, 1997).
- *nlef* — *Leif Erickson Park lavas*—Mixed suite of intergranular, plagioclase-phyric and ophitic basalt, basaltic andesite, and icelandite flows; locally recrystallized by Duluth Complex.

Lower southwest sequence—Sequence of lava flows truncated on east by Duluth Complex; primary reverse magnetic polarity reset in vicinity of the complex; total thickness less than 400 m; sequence not radiometrically dated.

- *nsjb* — *Ely's Peak basalts*—Intergranular, ophitic, and plagioclase-phyric basalt flows; basal flow is augite-phyric and locally pillowed. Basal section includes the Nopeming Sandstone, a crossbedded, quartz arenite with minor siltstone similar to the Puckwunge Sandstone beneath Lower northeast sequence.

Upper northeast sequence—Mixture of basaltic, intermediate, and abundant (greater than 50 volume percent) rhyolitic lava flows exposed along shore of Lake Superior from Hovland to Good Harbor Bay; normal magnetic polarity; total thickness about 3.8 km; U-Pb zircon ages (Davis and Green, 1997) indicate eruption of sequence began about 1100 Ma.

- *nghs* — *Good Harbor Bay andesites*—Red-brown, aphanitic to fine-grained, porphyritic andesite flows; contains small plagioclase, clinopyroxene, and magnetite phenocrysts.
- *nbwb* — *Breakwater basalt*—Intergranular, porphyritic transitional basalt; contains small phenocrysts of plagioclase, clinopyroxene, magnetite, and olivine; thickness about 110 m.
- *ngpr* — *Grand Marais porphyritic rhyolite*—Light-gray to pink; contains phenocrysts of quartz, K-feldspar, and oxidized mafic minerals; thickness about 150 m.
- *nvcb* — *Crotthville basalt*—Mixed suite of intergranular to ophitic aphyric basalt, porphyritic basalt, and basaltic andesite.
- *npmf* — *Pincushion Mountain trachybasalt*—Gray, intergranular to subophitic, porphyritic; sparse to abundant tabular plagioclase phenocrysts, especially in upper part.
- *ndtr* — *Devil's Track rhyolite*—Tan to pink, mostly aphyric, massive to flow-banded, locally microspherulitic or diktytaxitic; thickness about 250 m.
- *nmhr* — *Maple Hill porphyritic rhyolite*—Light-gray to tan; contains phenocrysts of quartz, K-feldspar, plagioclase, and oxidized mafic minerals; thickness about 70 m.
- *nrcb* — *Red Cliff basalts*—Ophitic to subophitic olivine tholeiitic basalt flows, some plagioclase-phyric.
- *nkcr* — *Kimball Creek rhyolite*—Light-gray to pink, aphanitic to finely granular, sparsely porphyritic, locally diktytaxitic rhyolite; small phenocrysts of plagioclase and oxidized mafic minerals; thickness about 370 m.
- *nsrd* — *Marr Island lavas*—Mixed suite of intergranular and ophitic basalt, basaltic andesite, icelandite, and rhyolite.
- *nmbb* — *Naniboujou basalts*—Mixed suite of intergranular to subophitic basalt and basaltic andesite, mostly aphyric.
- *ndfv* — *Devil's Kettle porphyritic rhyolite*—Pink to light-gray, aphanitic; contains quartz, K-feldspar, and phenocrysts of oxidized mafic minerals; thickness 235 m; U-Pb age 1097.7 ± 1.7 Ma (Davis and Green, 1997).
- *nbrv* — *Brule River lavas*—Interbedded flows of porphyritic rhyolite and basalt; U-Pb age 1100.2 ± 2.2 Ma for rhyolite near base (Davis and Green, 1997).

Lower northeast sequence—Includes intermediate, and rhyolitic lava flows exposed along shore of Lake Superior from Hovland to Grand Portage; normal magnetic polarity; flows average about 3 km; U-Pb zircon ages suggest eruption at about 1108 Ma (Davis and Green, 1997).

- *nhvl* — *Hovland lavas*—Mixed suite of intergranular basalt, basaltic andesite, icelandite, and rhyolite; commonly plagioclase-phyric, some glomeroporphyritic; U-Pb age 1107.7 ± 1.9 Ma (Davis and Green, 1997).
- *nprr* — *Rock porphyritic rhyolite*—Reddish to tan, aphanitic; contains quartz, K-feldspar, and oxidized mafic phenocrysts; thickness about 70 m; U-Pb age 1107.9 ± 1.8 Ma (Davis and Green, 1997).
- *ndrb* — *Duranda Bay basalt*—Brown, aphanitic and fine-grained, sparsely plagioclase-phyric flow; thickness about 90 m.
- *ngpb* — *Grand Portage basalts*—Intergranular transitional basalt and basaltic andesite flows; commonly plagioclase-phyric; upper part exposed in sequence from augite-phyric and pillowed basal flow at Grand Portage.

Miscellaneous rock types—Volcanic and sedimentary rocks of unknown stratigraphic position because they are either poorly exposed or dislocated due to faulting or intrusion.

- *nabh* — *Nonmagnetic basaltic hornfels*—Fine-grained, strongly granoblastic, locally meta-amygdaloidal; oxide-rich olivine gabbroic to gabbronoritic mineral assemblage; subdued aeromagnetic signature.
- *nbrh* — *Mafic basaltic hornfels*—Fine-grained, strongly granoblastic, locally meta-amygdaloidal; oxide-rich olivine gabbroic to gabbronoritic mineral assemblages; strong aeromagnetic signature.
- *nich* — *Intermediate hornfels*—Fine-grained, granoblastic; quartz-bearing mineral assemblages of intermediate composition.
- *nich* — *Interflow sedimentary hornfels*—Fine-grained, granoblastic; relict bedding commonly preserved; oxide gabbro mineral assemblage; strong localized aeromagnetic highs.
- *nmu* — *Undifferentiated volcanic rocks*—Normal magnetic polarity.
- *nmb* — *Undifferentiated basalt*—Normal magnetic polarity.
- *nmvb* — *Ophitic basalt*—Normal magnetic polarity.
- *nmi* — *Intermediate volcanic rock*—Normal magnetic polarity.
- *nmib* — *Icelandite*—Normal magnetic polarity.
- *nmfi* — *Undifferentiated felsic to intermediate volcanic rocks*—Normal magnetic polarity.
- *nmr* — *Rhyolite*—Aphyric; normal magnetic polarity.
- *nmpr* — *Porphyritic rhyolite*—Quartz- and K-feldspar-phyric; normal magnetic polarity.
- *nmvi* — *Volcaniclastic rocks*—Unsorted, variably bedded, tuffaceous, typically polymictic; normal magnetic polarity.
- *nmvu* — *Undifferentiated volcanic rocks*—Reverse magnetic polarity.
- *nmbu* — *Undifferentiated basalt*—Reverse magnetic polarity.
- *nmvi* — *Intermediate volcanic rocks*—Reverse magnetic polarity.
- *nmr* — *Rhyolite*—Reverse magnetic polarity.
- *nmfi* — *Rhyolite with basaltic inclusions*—Aphyric to feldspar-phyric rhyolite with centimeter-sized rounded inclusions of aphanitic basalt.
- *nmu* — *Undifferentiated volcanic rocks*—Magnetic polarity unknown.

MIDCONTINENT RIFT INTRUSIVE SUPERSUITE—Intrusive rocks formed during the development of the Midcontinent rift.

BEAVER BAY COMPLEX—Multiphase intrusive complex of mostly hypabyssal intrusions emplaced in central part of North Shore Volcanic Group. Consistent normal magnetic polarity and two U-Pb ages (about 1096 Ma; Paces and Miller, 1993) suggest emplacement generally after Duluth Complex intrusions.

- *nbg* — *Silver Bay intrusions*—Suite of massive to zoned ferrogabbroic intrusions locally emplaced in Beaver River diabase; U-Pb age 1095.8 ± 1.2 Ma (Paces and Miller, 1993).
- *nbg* — *Variextured gabbro*—Medium- to coarse-grained, subophitic to intergranular, granophyric; marginal phase of zoned intrusions.
- *nbfc* — *Foliated olivine ferrogabbro cumulate (PCFO)*—Medium-grained, foliated, texturally layered; interior phase of some zoned intrusions gradational into unit *nbg*.
- *nbgp* — *Poikilitic olivine ferrogabbro cumulate (PCFo)*—Medium-grained, foliated, texturally layered; interior phase of some zoned intrusions gradational into unit *nbg*.
- *nbgp* — *Melanogranophyre*—Massive; contains prismatic mafic minerals; commonly associated with variextured gabbro (unit *nbg*).

Beaver River diabase—Extensive mafic dike and sill complex extending from Split Rock River to Lutsen on the shore of Lake Superior; multiple composite phases present locally.

- *nbd* — Diabase—Undifferentiated; poorly exposed or inferred in incompletely mapped areas.
- *nbdc* — *Ophitic olivine diabase*—Fine- to medium-grained; granular olivine; constitutes main phase of Beaver River diabase.
- *nbg* — *Intergranular olivine gabbro*—Medium- to coarse-grained, nonfoliated, variably granophyric; in narrow gradational contact with ophitic olivine diabase (unit *nbdc*).
- *nbfd* — *Ferrodiorite*—Medium-grained, intergranular, nonfoliated to poorly foliated, granophyric; commonly leucocratic; locally olivine-bearing; in narrow gradational contact with intergranular olivine gabbro (map unit *nbg*) and ferrodiorite cumulate (unit *nbfc*).
- *nbfc* — *Ferrodiorite cumulate (PCFo)*—Medium- to coarse-grained; foliated; locally layered; commonly forms innermost phase of composite intrusions.
- *nbdc* — *Anorthosite inclusion*—Gray to pale-green, coarse- to medium-grained anorthosite to gabbroic anorthosite (more than 90 percent plagioclase); forms rafts (rarely over 500 m) blocks in unchilled ophitic olivine diabase (unit *nbdc*).
- *nbg* — *Granitoid inclusion*—Pinkish to orange, microgranitic to intergranular leucogranitic; enclosing diabase commonly chilled.
- *nbdc* — *Victor Head diabase*—Ophitic olivine diabase, fine-grained; strongly oxidized to light red; forms 50–65-m-thick sheet intruded by unit *bvvd* of Beaver River diabase.
- *nbdc* — *Milepost 7 sill*—Intergranular to porphyritic, aphanitic to medium-grained, massive, ferrodiabase (15–18 percent); forms 10–20-m-thick sill in Gooseberry River basalts (unit *ngrb*).
- *nbdc* — *Sonju Lake intrusion*—Strongly differentiated, 1–1.5-km-thick, sheet-like intrusion emplaced beneath Finland granophyre; U-Pb age 1096.1 ± 0.8 Ma (Paces and Miller, 1993).
- *nbu* — *Undivided upper cumulates*—Poorly exposed; inferred from aeromagnetic data to include olivine gabbro cumulate, oxide gabbro cumulate, apatite olivine ferrodiorite cumulate, and olivine ferromonzodiorite units.
- *nbmz* — *Olivine ferromonzodiorite*—Coarse-grained, nonfoliated to poorly foliated, variably granophyric, apatitic; forms most differentiated unit.
- *nbad* — *Apatite olivine ferrodiorite cumulate (PCFOA)*—Medium-grained, foliated; locally layered.
- *nbg* — *Oxide gabbro cumulate (PCF, PCFO)*—Coarse-grained, foliated; rarely layered.
- *nb* — *Olivine gabbro cumulate (PCF, PCf)*—Coarse-grained, foliated.
- *nbd* — *Undivided lower cumulates*—Poorly exposed; inferred from subdued aeromagnetic data to include metatroctolite, dunite, and troctolite cumulates.
- *nbd* — *Troctolite cumulate (PCF, PCO, PCf)*—Medium- to coarse-grained, ophitic, foliated; locally layered in places, particularly at base.
- *nbd* — *Dunite cumulate (O, Op)*—Strongly serpentinized, fine-grained.
- *nbmz* — *Melatroctolite cumulate (PO, OP)*—Medium-fine-grained to fine-grained, foliated, subtly layered; grades in olivine concentration from top (60%) to base (40%).
- *nbmg* — *Ophitic olivine gabbro to augite troctolite*—Generally nonfoliated; inferred to be noncumulate extension of Sonju Lake intrusion.
- *nbmz* — *Hybrid dikes*—Heterogeneous mix of fine-grained mafic and felsic rocks in orthogonal dike set; may be related to emplacement of Beaver River diabase.

Finland granophyre—Large lens-shaped, zoned, intermediate to felsic intrusion; cuts Lax Lake gabbro, is underplated by Sonju Lake intrusion and cut by Beaver River diabase; U-Pb age 1097.8 ± 4.4 Ma (J. Vervoort, Univ. of Arizona, Tucson, written commun., 2001).

- *nbgr* — *Leucogranite*—Deep red-orange; predominantly microgranic, locally aphanitic; miarolitic cavities common; forms upper part of intrusion.
- *nbmz* — *Quartz ferromonzodiorite*—Mottled pink to gray; contains 5–25 percent prismatic iron silicates; forms lower part of intrusion.

Cloquet Lake layered series—Very poorly exposed mafic to felsic intrusive rocks forming nested, saucer-shaped intrusions; divided into upper and lower series that define crude differentiation cycles; interpreted from aeromagnetic data, rare outcrop, and scattered drill cores.

- *nbgp* — *Granophyre*—Upper series; based on one drill core of microgranitic leucogranite and a subdued aeromagnetic signature.
- *nbmz* — *Monzodiorite and other intermediate-to-felsic rock types*—Upper series, based on one drill core and a strong aeromagnetic signature.
- *nbgp* — *Granophyre*—Pink microgranitic leucogranite; transgressive relationship to other Beaver River diabase Lax Lake units suggests correlation with Finland granophyre (unit *bgr*).

Upper Manitou River gabbro—Composite mixture of mafic to felsic noncumulate rocks; forms irregular to dike-like intrusions; may correlate with similar rock types in Beaver Lake dioritic.

- *nbmg* — Gabbro—Ophitic olivine gabbro to intergranular granophyric gabbro, fine- to medium-coarse-grained, moderately altered; interstitial granophyre is less than 15 percent.
- *nbmd* — *Diorite*—Intergranular olivine ferrodiorite to quartz ferromonzodiorite, fine- to medium-grained, nonfoliated, variably granophyric (5–35 percent).
- *nbmgp* — *Melanogranophyre*—Micrographic quartz ferromonzonite; pinkish, fine- to medium-grained; contains 5–15 percent prismatic iron silicates and oxides.
- *bgt* — *Houghtaling Creek troctolite*—Augite troctolite to olivine gabbro cumulates (PCf, PCO); medium-grained, ophitic, typically foliated, rarely layered; forms keel-shaped macrodike.
- *nbgn* — *Dam Five gabbronorite*—Gabbronorite cumulates (PCi); olivine gabbro at basal margin; medium-grained, foliated; forms monoclinally dipping sequence along northern part of Houghtaling Creek troctolite.

Wilson Lake ferrogabbro—Plug-like zoned intrusion with dike-like extensions into surrounding gabbronorite and gabbroic anorthosite; southeast margin cut by Dam Five gabbronorite (unit *nbgn*).

- *nbmd* — *Olivine diabase to monzogabbro*—Medium- to coarse-grained, ophitic to subophitic, locally granophyric (less than 15 percent); forms marginal phase of main intrusion and occurs in dike-like extensions.
- *nrfg* — *Ferrogabbro cumulate (PCFO) to nonfoliated monzogabbro*—Medium- to coarse-grained; ferrogabbroic rocks are foliated.

Fourmile Lake ferrogabbro—Differentiated suite of intermediate to felsic rocks within the Houghtaling Creek troctolite; probably large xenolith related to Wilson Lake ferrogabbro or Dam Five gabbronorite.

- *nbfg* — *Ferrogabbronorite cumulate (PCIF ± O)*—Medium-grained, foliated.
- *nbmd* — *Ferromonzodiorite*—Variously granophyric; forms marginal to coarse grained, poorly foliated to nonfoliated, granophyric with prismatic mafic minerals.
- *nbgp* — *Melanogranophyre*—Fine-grained, micrographic, weakly porphyritic, locally granoblastic; subprismatic mafic minerals.

Cabin Creek porphyritic diorite—Porphyritic to quartz ferromonzodiorite, fine-grained, commonly altered, felty-textured; contains as much as 60 percent centimeter-sized plagioclase phenocrysts; forms two sheets of intrusion; relationships with other Fourmile Lake units unknown.

- *nbgd* — *Leveaux porphyritic diorite*—Thick (50 to more than 100 m), sheet-like intrusion of fine-grained felsic porphyritic diorite; contains abundant (about 40 percent) plagioclase phenocrysts in upper half; intruded by Beaver River diabase.
- *nbsa* — *Shoapack Lake diorite*—Heterogeneous rock characterized by inclusions of felsite, basalt, gabbro, and Archean rocks in a very fine grained dioritic matrix.

DULUTH COMPLEX—Multiphase igneous complex of mostly plutonic intrusions emplaced along base of North Shore Volcanic Group; subdivided into four major rock series on basis of lithology, internal structure, and age.

- *nbmc* — *Inclusion of magnetic rock of uncertain type*—Mapped where bedrock not exposed on the basis of localized, strong aeromagnetic high within area of subdued aeromagnetic signature; possibly underlain by troctolite and gravel; probably mafic volcanic hornfels or gabbroic phases of Duluth Complex series.
- *bxt* — *Undifferentiated troctolitic cumulates*—Areas underlain by troctolite exposure insufficiently mapped to assign to specific intrusive units.
- *nbmc* — *Oxide ultramafic intrusion*—Fe-Ti oxide-bearing dunite, clinopyroxenite, and peridotite; forms irregular bodies cutting troctolitic cumulates; mapped from drill core and localized aeromagnetic highs.

Layered series—Subsuite of the Duluth Complex composed of multiple, discrete, layered mafic intrusions that display variable degrees of internal differentiation.

Layered series at Duluth—Well-differentiated, 3.5–5-km-thick sheet-like intrusion. Known from detailed mapping (Taylor, 1964; Miller and others, 1993); subdivided into zones based on dominant cumulate mineralogy; U-Pb ages 1099.3 ± 0.3 Ma (Paces and Miller, 1993) and 1098.8 ± 1.4 Ma (Green and others, 2001).

- *nbdt* — *Basal contact zone*—Variextured olivine gabbro to augite troctolite, coarse-grained.
- *nbat* — *Troctolite zone*—Troctolitic cumulates (PCf, PO, OP); medium- to coarse-grained, foliated; locally melanocratic in lower section; modally layered; forms basal sill.
- *nbac* — *Cyclic zone*—Macrocyclically layered troctolite to augite troctolite (PCof), olivine gabbro (PCf), and olivine oxide gabbro (PCFO) cumulates; boundaries between macrocycles marked by sharp or cumulus regression (PCFO to PO) and local presence of microgabbro.
- *nbdg* — *Gabbro zone*—Cumulates of oxide gabbro (PCF), olivine oxide gabbro (PCFO), and oxide gabbronorite (PCFg); medium-grained, foliated; locally apatitic (3–5 percent) and granophyric (less than 10 percent); contains abundant inclusions of anorthositic-series rocks.
- *nbuc* — *Upper contact zone*—Irregular mixture of fine-grained ilmenite ferrodiorite and medium-grained apatitic feromonzodiorite to quartz ferromonzodiorite; nonfoliated; ferrodiorite typically forms border phase with anorthositic-series rocks.
- *nbum* — *Melanogranophyre*—Irregular composite intrusion of ferromonzodiorite to leucogranite emplaced within anorthositic series; probably represents late-stage differentiates of the Layered series at Duluth.
- *nbmc* — *Anorthositic inclusions*—Large singular inclusion or clusters of anorthositic-series rocks; confined to cyclic zone (unit *nbac*) and gabbro zone (unit *nbdg*).
- *nbmc* — *Poikilitic olivine gabbroic anorthosite cumulate (PPoct)*—Medium- to coarse-grained, foliated, plagioclase cumulate contains 1–10-cm-diameter olivine oikocrysts; includes unit *agp* of Green and others (1966) and units *spoa* and *poa* of Miller (1986).
- *nbmc* — *Poikilitic noritic anorthosite cumulate (PPn)*—Medium-grained; unit *agh* of Green and others (1966).
- *nbmc* — *Porphyritic olivine gabbro*—Medium-grained, ophitic olivine gabbro; contains 5–15-percent plagioclase phenocrysts; may represent flow-differentiated contact zone of anorthositic series at Duluth (Miller and others, 1993).
- *nbmg* — *Katydid Lake gabbroic anorthosite*—Medium- to coarse-grained, poorly foliated, intergranular, plagioclase-porphyritic gabbroic anorthosite; commonly altered.
- *nbmg* — *Scott Creek leucogabbro*—Fine- to coarse-grained, plagioclase-porphyritic leucogabbro to ferrodiorite; cuts Katydid Lake gabbroic anorthosite (unit *mgp*) in roof zone of Duluth Complex.

Early gabbro series—Early mafic phase of Duluth Complex as indicated by U-Pb zircon ages and reverse magnetic polarity; dominantly composed of gabbroic cumulates in multiply intruded sheet-like intrusions.

- *nbgb* — *Crocodile Lake gabbro*—Generally gabbroic cumulates; identified from reconnaissance mapping of Grout and others (1959); U-Pb ages 1107.0 ± 1.1 Ma (Davis and Green, 1997) and 1107.9 ± 0.3 Ma (Paces and Miller, 1993).
- *nbpl* — *Poplar Lake intrusion*—Interlayered suite of dominantly gabbroic cumulates and minor troctolite and anorthositic cumulates; known from mapping by Nathan Mooney and Nathan, 1977, 1978; Mathez and others, 1977); U-Pb age 1107.9 ± 0.3 (Paces and Miller, 1993);
  - *Contact zone*—Variextured, nonfoliated, biotite olivine gabbro, augite troctolite, and gabbronorite; locally granophyric and sulfide-bearing; unit *ol* of Mooney and Nathan (1977, 1978).
  - *Ferrogabbroic cumulates (PDF, PCFO, PDCF)*—Coarse-grained, foliated, layered, biotitic, locally altered, and sulfide-bearing; unit *dg* of Mooney and Nathan (1977, 1978).
  - *Oxide-rich ferrogabbroic rocks*—Fine- to medium-grained, granular to weakly foliated; subunit of ferrogabbroic cumulates (unit *nbg*); includes units *dc*, *dd*, *dh*, *dl*, and *dv* of Mooney and Nathan (1977, 1978).
  - *Gabbroic cumulates (PC, PCf, PCfnO)*—Fine- to medium-grained, foliated, locally plagioclase porphyritic; units *db* and *dp* of Mooney and Nathan (1977).
  - *Troctolite cumulates (PO, POo)*—Fine- to medium-grained, foliated, locally leucocratic; units *da* and *dq* of Mooney and Nathan (1977, 1978).
  - *Anorthositic cumulates (PPofl)*—Medium- to coarse-grained, foliated, ophitic, locally altered, and sulfide-bearing; units *dj* and *ds* of Mooney and Nathan (1977, 1978). Some rocks may be related to the Anorthositic series.

Felsic series—Massive, intermediate to felsic intrusive rocks; forms isolated to segmented bodies in roof zone of the Duluth Complex; preliminary U-Pb ages indicate emplacement 1109–1106 Ma (J. Vervoort, Univ. of Arizona, Tucson, written commun., 2001).

- *fgpx* — *Undivided granophyric rocks*—Small, isolated areas of felsic rocks not associated with major granophyre bodies.
- *fimu* — *Undifferentiated intermediate rocks*—Small areas of intermediate rock related to small granophyre bodies or forming isolated masses.
- *fthg* — *Fairbanks–Brimson granophyre*—Granophyre inferred from subdued aeromagnetic anomaly patterns.
- *fmwg* — *Mt. Weber granophyre*—Micrographic to intergranular pink leucogranite; known from sparse outcrop and subdued aeromagnetic anomaly signature; U-Pb age 1106.3 ± 3.6 Ma (J. Vervoort, Univ. of Arizona, Tucson, written commun., 2001).
- *fbg* — *Beth Lake granophyre*—Micrographic to intergranular pink leucogranite; may correlate with Whitefish Lake granophyre (unit *fwfg*); unit *gpy* of Davidson (1977a).
- *fwlw* — *Wine Lake monzodiorite*—Medium- to coarse-grained, intergranular granodiorite to quartz ferromonzodiorite; underlies Beth Lake granophyre (unit *fbg*); units *hgd*, *hgd*, and *gnd* of Davidson (1977b).
- *fwfg* — *Whitefish Lake granophyre*—Micrographic to intergranular pink leucogranite; locally aphyric; U-Pb age 1109.6 ± 4.0 Ma (J. Vervoort, Univ. of Arizona, Tucson, written commun., 2001).
- *fbtg* — *Isabella granophyre*—Micrographic to intergranular pink leucogranite; known from two drill cores and subdued aeromagnetic signature.
- *fsog* — *Saganaga Tonalite*—Mostly quartz tonalite; diorite border phase; U-Pb age 2689 ± 1 Ma (Corfu and Stott, 1998).
- *fsrg* — *Snowbank Lake Granite*—Composite stock of mostly syenodiorite.

Giants Range batholith—Multiphase granitoid batholith composed of older (2685 ± 4 Ma) gneissic and younger (2674 ± 5 Ma) massive phases; U-Pb ages from Boerboom and Zartman (1993).

- *Agne* — *Heterogeneous tonalitic gneiss.*
- *Agra* — *Equigranular monzonite, quartz monzonite, and granodiorite.*
- *Agrp* — *Porphyritic quartz monzonite and granodiorite.*
- *Apda* — *Porphyritic dacite, andesite, and rhyodacite*—Dikes, sills, and irregular intrusions and extrusive equivalents; U-Pb age 2683 ± 1.4 Ma west of map area (Peterson and others, 2001), but ages probably span a range.
- *Admc* — *Mafic and ultramafic intrusions*—Variably metamorphosed.

SUPRACRUSTAL ROCKS—Variably deformed, moderately metamorphosed sedimentary and volcanic rocks; granitic and metamorphosed supracrustal rocks of the Wawa and Quetico subprovinces of the Superior Province.

- *Admv* — *Undifferentiated volcanic rocks.*
- *Admg* — *Undifferentiated conglomerate.*
- *Amph* — *Amphibolite*—Mafic volcanic strata; contact metamorphosed by the Giants Range batholith.
- *Amcf* — *Knife Lake Group*—Metasedimentary rocks and minor felsic metavolcanic rocks.
- *Admg* — *Conglomerate*—Clast- and matrix-supported; locally includes clasts of Saganaga Tonalite (unit *Asc*).
- *Agwa* — *Graywacke and argillite*—Well-bedded, commonly deformed, and moderately metamorphosed.
- *Afls* — *Felsic tuff*—Tuffaceous sandstones and breccias of dacitic protolith.
- *Admf* — *Phyllitic and phyllonitic rocks*—Metasedimentary and tuffaceous protolths.
- *Acvf* — *Lake Vermilion Formation*—Graywacke and felsic volcaniclastic rock.
- *Amcm* — *Newton Lake Formation*—Komatiitic and tholeiitic mafic volcanic rocks, sedi-mentary clastic rocks, and graywacke-bearing rocks to gabbro sills.
- *Admc* — *Conglomerate, iron-formation, and graywacke*—Commonly sheared; present as thin lenses.
- *Afls* — *Felsic tuff, lapilli tuff, breccia, and tuff*—Graywacke and siliceous marble also present.
- *Admv* — *Tholeiitic basalt and basaltic komatiite*—Pillowed and massive.
- *Aegs* — *Ely Greenstone*—Dominantly pillowed and massive, mafic to intermediate volcanic rock; interbedded iron-formation (unit *Aif*); calc-silicate rocks and rhyolite lava and volcaniclastic rocks common in lower part; also contains clastic rock units; strongly metamorphosed in the vicinity of the Giants Range batholith; U-Pb age 2722 ± 1 Ma from felsic unit (Peterson and others, 2001).
- *Aif* — *Undifferentiated iron-formation.*

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Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. In addition, effort has been made to ensure that the interpretation conforms to sound geologic and stratigraphic principles. No claim is made that the interpretation presented herein is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

MAP SYMBOLS

Geologic contact
- Approximate
- Speculative

Fault
- Inferred
- Speculative

Fold axis
- Anticlinal
- Synclinal

Mafic sill

Mafic dike of unknown polarity

Bedding in sedimentary rocks
- Inclined
- Horizontal
- Vertical
- Overturned

Inclined bedding in volcanic rocks

Modal layering in igneous rocks
- Inclined
- Horizontal
- Vertical

Foliation in igneous rocks
- Inclined
- Horizontal
- Vertical

Joints
- Mineralized
- Open

Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15