U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Voyageurs National Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Voyageurs National Park

voya_geology.pdf

Version: 7/11/2022

Geologic Resources Inventory Ancillary Map Information Document for Voyageurs National Park

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Geologic Resources Inventory Map Document

Voyageurs National Park, Minnesota

Document to Accompany Digital Geologic-GIS Data

voya_geology.pdf

Version: 7/11/2022

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Voyageurs National Park, Minnesota (VOYA).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.

2) **GRI Digital Map and Source Citations** – The citations of the GRI digital geologic-GIS map produced for this project along with the source maps used in its completion. In addition, an index map and a brief explanation of how each source map was used is provided.

3) **Map Unit Listing** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.

4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.

5) **Geologic Cross Sections** – Geologic cross section graphics with source geologic cross section abbreviation.

6) **Ancillary Source Map Information** – Additional source map information presented by source map. For each source map this may include a stratigraphic column, index map, map legend and/or map notes.

7) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

Stephanie O'Meara
Geologist/GIS Specialist/Data Manager
Colorado State University Research Associate, Cooperator to the National Park Service
Fort Collins, CO 80523
phone: (970) 491-6655
email: stephanie_o'meara@partner.nps.gov

About the NPS Geologic Resources Inventory Program

Background

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI. The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. Many additional partners participate in the GRI process by contributing source maps or reviewing products.

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report. These products are designed and written for nongeoscientists.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: https://www.nps.gov/articles/gri-geodatabase-model.htm

Geologic Reports: GRI reports synthesize discussions from the original scoping meeting, follow up conference call(s), and subsequent research. Chapters of each report discuss the geologic setting of the park, distinctive geologic features and processes within the park, highlight geologic issues facing resource managers, and describe the geologic history leading to the present-day landscape. Each report also includes a poster illustrating these GRI digital geologic-GIS data.

For a complete listing of GRI products visit the GRI publications webpage: https://go.nps.gov/gripubs. GRI digital geologic-GIS data is also available online at the NPS Data Store: https://irma.nps.gov/DataStore/Search/Quick. To find GRI data for a specific park or parks select the appropriate park(s), enter “GRI” as a Search Text term, and then select the Search button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: https://www.nps.gov/subjects/geology/gri.htm. At the bottom of that webpage is a “Contact Us” link if you need additional information. You may also directly contact the program coordinator:

Jason Kenworthy
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 987-6923
fax: (303) 987-6792
email: Jason_Kenworthy@nps.gov

The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division. Learn more about I&M and the 12 baseline inventories at the I&M webpage: https://www.nps.gov/im/inventories.htm.

GRI Digital Map and Source Map Citations

The GRI digital geologic-GIS map for Voyageurs National Park, Minnesota (VOYA):

GRI Digital Bedrock Geologic-GIS Map of Voyageurs National Park and Vicinity, Minnesota (*GRI MapCode VOYA)*

The map was produced using the following source maps and digital data.

Jirsa, M.A., 2011, Bedrock Geology of the Crane Lake and Brule Narrows 30' X 60' Quadrangles, Minnesota: Minnesota Geological Survey, M-192, scale 1:100,000. (Bedrock Geologic Map of Crane Lake and Brule Narrows). (*GRI Source Map ID 75668*).

The GRI used only a portion of the source map extent, but all geologic features within this extent were captured, and all relevant ancillary map information (e.g., unit colors and unit descriptions, and report information) from this source was incorporated into the GRI digital geologic-GIS dataset and product.

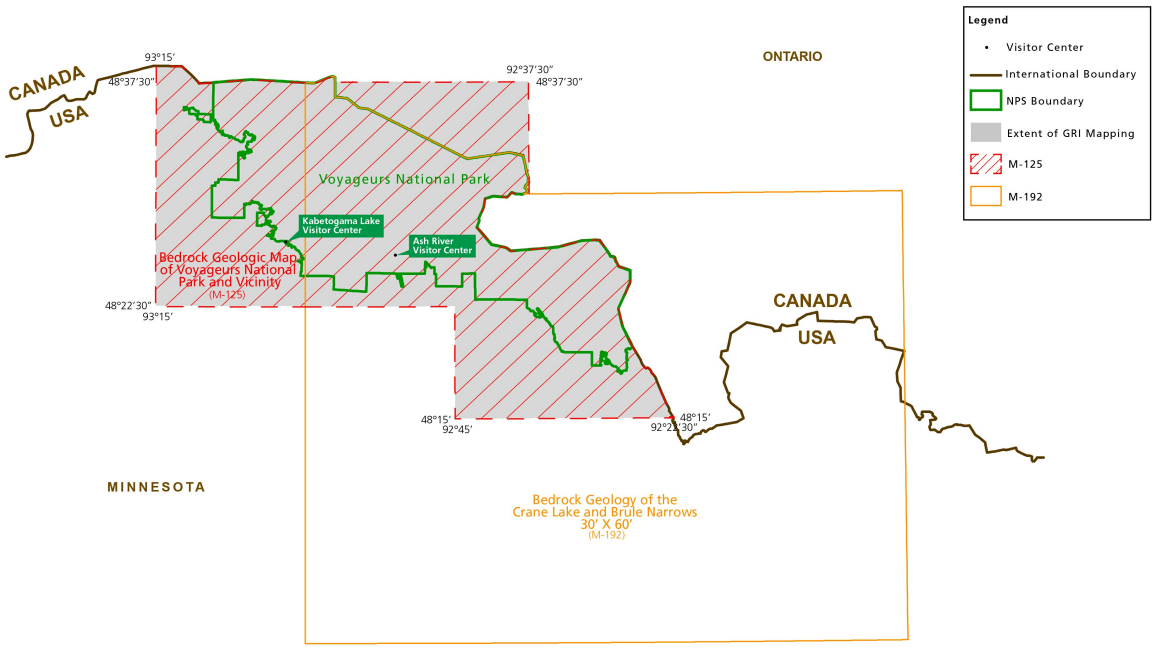
Hemstad, C.B., Southwick, D.L., and Ojakangas, R.W., 2002, Bedrock Geologic Map of Voyageurs National Park and Vicinity, Minnesota: Minnesota Geological Survey, Miscellaneous Map Series M-125, scale 1:50,000. (Bedrock Geologic Map of Voyageurs National Park). (*GRI Source Map ID 52443*).

The GRI used only a portion of the source digital GIS data and incorporated some components of the provided source maps and reports (e.g., unit descriptions and faults) into the GRI digital geologic-GIS dataset and product.

Additional information pertaining to each source map is also presented in the GRI Source Map Information (VOYAMAP) table included with the GRI digital geologic-GIS data.

Index Map

The following index map displays the extent of GRI digital geologic-GIS map, as well as the park boundary (in dark green, as of July, 2022) for Voyageurs National Park, Minnesota (VOYA). The source maps used are also presented, as is the USA-Canada border.



Map Unit List

The bedrock geologic units present in the digital geologic-GIS data produced for Voyageurs National Park, Minnesota (VOYA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., PRd - Diabase). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the GRI Geologic Unit Information (VOYAUNIT) table included with the GRI geologic-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered to be the same unit as one or more units on other source maps used for this project, and these unit symbols, names and/or ages differed. Unit symbols, names and/or ages in a unit description, or on a correlation of map units or other source map figure were not edited. If a unit symbol, name or age was changed by the GRI the unit's source map symbol, name and/or age appears with the unit's source map description.

Proterozoic Eon
PRd - Diabase

Proterozoic and Archean Eons
PRAst - Schistose tectonite (fault rock) within and adjacent to major fault zones

Archean Eon
Ag - Granodiorite
Al - Lamprophyre
Ap - Pegmatite and pegmatitic granite
Avl - Lac La Croix Granite, undivided
Alm - Lac La Croix Granite, variably magnetic phase
Alg - Lac La Croix Granite, leucogranite
Ar - Schistose rhyolite
Ac2 - Schistose conglomerate 2
Asq - Schistose feldspathic quartzite
Ac1 - Schistose conglomerate 1
Agr - Schistose quartz-eye rhyolite
Ams - Schistose mafic volcanic wacke and tuff
Aat - Schistose accretionary tuff and tuff breccia
Adp - Metadiorite metapyroxenite metalamprophyre amphibolite and migmatite and gneiss composed primarily of them
Agm - Granite-rich migmatite
Avq - Biotite-hornblende quartz diorite
Avt - Leucogranite-rich migmatite
Ava - Migmatite in which the paleosome is dominantly amphibolite hornblende gneiss and biotite-hornblende gneiss
Asm - Schist-rich migmatite
Abs - Quetico subprovince of the Superior Province, biotite schist (late Archean)
At - Tonalite
Ad - Diorite
Aum - Ultramafic rock
Aws - Wabigoon subprovince of the Superior Province, biotite schist
Asf - Schistose felsic rocks
Am - Mafic schist
Asr - Schistose rhyolite and dacite
Avc - Volcanic conglomerate
As - Amphibolite schist

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

PRd - Diabase (Paleoproterozoic)

PRd - Diabase (Paleoproterozoic)
Fine- to coarse-grained diabasic to gabbroic dikes; the most prominent, which lie along the western edge of the map, have widths as great as 125 feet (40 meters); trajectories of these and other dikes are extended beyond and between outcrop exposures by using aeromagnetic maps. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

PRd - Diabase (Paleoproterozoic)
Fine- to coarse-grained, dark-brown to black. Forms northwest-trending dikes of the Kenora–Kabetogama dike swarm (Southwick and Day, 1983) that are sharply discordant to the structural grain of the enclosing Archean rocks. Larger dikes are compositionally zoned, consisting of hornblende diorite in the center and hornblende gabbro toward the margins. Some large dikes are composite. The larger dikes are readily traced as prominent aeromagnetic highs. One dike in the swarm (outside the map area) yields a baddeleyite U-Pb age of 2,067 ± 5 Ma (Wirth and others, 1995; Buchan and others, 1996). Description from source map: Bedrock Geologic Map of Voyageurs National Park.

PRAst - Schistose tectonite (fault rock) within and adjacent to major fault zones (Paleoproterozoic and late Archean)

Ast - Schistose tectonite (fault rock) within and adjacent to major fault zone (Paleoproterozoic and late Archean Rocks)
Phyllitic and schistose, scaly to platy; composed principally of phyllosilicates, quartz, and carbonate minerals; color ranges from tan to dark-greenish gray. Variants include sericite-carbonate phyllite, biotite-rich phyllonite, and chlorite-rich phyllonite. Shear-related features include dextral S-C fabrics, boudinaged quartz veins, and thin shear bands that locally exhibit small-scale dextral fold patterns. Mineral lineations defined by chlorite and/or biotite plunge steeply to moderately to the northeast. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ag - Granodiorite (late Archean)

Medium- to coarse-grained, light-gray to white; contains both biotite and hornblende. Exposed in the northern portion of the map area and on Fransen and Susans Islands. The granodiorite is moderately foliated and contains elongate mafic xenoliths oriented parallel to the east–northeast regional trend. Lineations defined by alignment of mafic minerals and xenoliths plunge moderately to the east–northeast. Rock resembles and may be correlative with the nearby granodiorite of the Ottertail Lake stock of northwestern Ontario, dated at 2,686.1 +1.5/-1.4 Ma by Davis and others (1989). Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Al - Lamprophyre (late Archean)

Medium- to coarse-grained, dark-green schistose. Composed principally of chlorite, biotite, and pyroxene. West of Dryweed Island, lamprophyre dikes trend northwest and east–northeast. Northwest-trending dikes are composed of biotite-hornblende-plagioclase (on Eightmile Island and near Dryweed Island) and cut regional foliation; thicknesses range from 10 centimeters to greater than 50 meters. East–northeast-trending dikes are composed of hornblende-pyroxene-biotite (Review

Islands), and contain large phenocrysts (one centimeter) of pyroxene. These dikes are subparallel to the regional foliation and are as thick as 10 meters. One east-oriented dike cuts bedding on the south side of Dryweed Island. This dike contains conspicuous rounded fragments of quartz diorite that range in size from 5 millimeters to 25 centimeters in diameter. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ap - Pegmatite and pegmatitic granite (late Archean)

Ap - Pegmatite and pegmatitic granite (Neoarchean)
Coarse- to very coarse-grained; pale pink to pinkish-gray. Locally contains northeast-trending, largely magmatic-flow foliation. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Ap - Pegmatite (late Archean)
Coarse- to very coarse-grained, light-pinkish gray; texture varies abruptly. Consists predominantly of potassium-feldspar, quartz, muscovite, and plagioclase. Mafic minerals are rare to absent. Potassium-feldspar crystals are euhedral and as long as 25 centimeters. Northeast-oriented foliation, consistent with the regional trend, is defined by muscovite in the finer-grained portions of the rock. Intrudes biotite schist south of the Rainy Lake–Seine River fault zone. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Avl - Lac La Croix Granite, undivided (late Archean)

Biotite granite, massive to weakly foliated, medium-grained, somewhat porphyritic, light-gray to light-pink. Contains scattered inclusions of variably digested biotite schist, amphibolite, tonalite, trondhjemite, and leucogranite migmatite; these typically amount to less than about 5 percent of the rock. Grades into granite-rich migmatite (unit Avg) as the proportion of inclusions increases. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Alm - Lac La Croix Granite, variably magnetic phase (late Archean)

Alm - Variably magnetic phase (Neoarchean)
Typically pink to pale pinkish-gray to nearly white; contains veins, dikes, and irregular masses of quartzofeldspathic pegmatite, locally having abundant macroscopic magnetite. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.
Avm - Lineated, locally mylonitized granite (late Archean)
Granoblastic to polymylonitic, strongly lineated granite interpreted to have been granite of unit Avl or granite-rich migmatite of unit Avg prior to intense deformation. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Alg - Lac La Croix Granite, leucogranite (late Archean)

Alg - Leucogranite (Neoarchean)
White to light gray; medium- to coarse-grained; locally taxitic; uniformly non-magnetic. Unit is similar to unit Aln, but differs because it contains a small percentage of muscovite in addition to biotite, and is typically more foliated. In outcrops where both units Alg and Alm or Aln occur, unit Alg predates Alm and Aln. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Alg - Leucogranite (late Archean)
Muscovite- and biotite-bearing, medium- to coarse-grained, strongly to moderately foliated. Weathers

very light-gray to almost white. Forms mappable, predominantly lenticular intrusions, most of which are quasi-conformable to bedding and foliation in the wall rock, and numerous thin sills, dikes, and veinlets that are too small to show at map scale. The leucogranite is related petrogenetically to the pegmatite (map unit Ap), and is generally intruded by it. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ar - Schistose rhyolite (late Archean)

Reddish-gray, well-foliated; contains abundant rounded to angular rock fragments and is interpreted as a clast-rich felsic flow. Rock fragments decrease in abundance up-section from the contact with map units Ac1 and Ac2, sedimentary conglomerates. The suite of rock types represented in the rock fragments is identical to that represented in the sedimentary clasts of the underlying conglomerate. Specular hematite locally occurs along joints. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ac2 - Schistose conglomerate 2 (late Archean)

Polymictic, clast-supported, green to gray. Differs from unit Ac1 in both stratigraphic position and clast composition. Contains rounded pebbles, cobbles, and boulders of felsic plutonic rocks, mafic to felsic volcanic rocks, chert, biotite schist, and iron-formation. Plutonic clasts are subspherical to elliptical, whereas volcanic clasts tend to be moderately elongated in the regional lineation. The schistose matrix is composed of fine- to medium-grained biotite- or chlorite-rich lithic arenite that contains angular to subrounded granules of volcanic rock fragments, intrusive rock fragments, plagioclase, quartz, and chert. Bedding is crude to massive. Subtle, fining-upward to coarsening-upward sequences are common in the conglomerate; thin interbeds of pebbly sandstone are rare. Unit dated at 2,686 to 2,695 Ma (Davis and others, 1989). Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Asq - Schistose feldspathic quartzite (late Archean)

Medium-grained, light-gray to tan. Framework grains are quartz and feldspar; they are angular to subrounded and slightly flattened in the regional foliation. The matrix most commonly consists of fine-grained sericite, quartz, and chlorite, although biotite- and chlorite-rich beds are locally present. Beds range in thickness from 5 centimeters to one meter; subtle planar lamination and trough cross stratification are typical. In outcrops, cross stratification consistently indicates tops to the south and westerly transport directions. Unit locally includes discontinuous lenses (10-centimeters- to one-meter-thick) of schistose conglomerate that contains pebble- to cobble-sized clasts. Green rip-up clasts composed of sericite-chlorite schist are locally present. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ac1 - Schistose conglomerate 1 (late Archean)

Polymictic, clast- to matrix-supported, green to gray. Contains rounded to angular pebbles, cobbles, and boulders of mafic to felsic volcanic rocks, pebbles of chert, and rare clasts of felsic plutonic rocks and ironformation. Numerous angular to rounded quartz pebbles are common near the top of the unit on the southwest end of Drywood Island. Plutonic clasts are subspherical to elliptical, whereas volcanic clasts tend to be moderately to strongly elongated in the regional foliation. Pebbles, cobbles, and boulders of rhyolite (unit Asr) containing blue quartz-eyes are the dominant clast type. The schistose matrix is composed of fine- to medium-grained biotite- or chlorite-rich lithic arenite that contains angular to subrounded granules of volcanic rock fragments, rare intrusive rock fragments,

plagioclase, quartz, and chert. Bedding is crude to massive. A subtle, overall fining upward sequence is prevalent. Lenses of conglomerate interfinger with accretionary tuff beds of unit Aat. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Aqr - Schistose quartz-eye rhyolite (late Archean)

Medium-gray to light-green, well foliated. Contains euhedral phenocrysts of plagioclase and distinctive, doubly terminated crystals of blue quartz. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ams - Schistose mafic volcanic wacke and tuff (late Archean)

Dark green, strongly foliated chlorite schist. The rock is schistose, fine- to medium-grained, and contains angular to subrounded sand grains of dominantly mafic volcanic rocks, plagioclase, quartz, and chert. Occurs near the northwest corner of the map area. (Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Aat - Schistose accretionary tuff and tuff breccia (late Archean)

Gray to pink rock consisting of abundant accretionary clasts in a schistose to phyllitic matrix composed dominantly of chlorite. The clasts are flattened within the metamorphic cleavage and rotated by dextral shear, and range from one to 10 centimeters in the longest dimension. Internally, they are fine-grained and consist of a sugary pink rind that grades inward to a lightgreen inner rind and pink core. Individual beds range in thickness from 10 centimeters to 2 meters, are well graded, and consist dominantly of fining southward sequences. Scour-valleys are locally present and imply southward stratigraphic younging. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Adp - Metadiorite metapyroxenite metalamprophyre amphibolite and migmatite and gneiss composed primarily of them (late Archean)

Typically moderately discrete plutons that were intruded by granite of units Alm, Aln, and Alg, and variably modified by metamorphism and deformation. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Agm - Granite-rich migmatite (late Archean)

Agm - Granite-rich migmatite (Neoarchean)
Contains 50 to 75 percent neosome of Lac La Croix Granite. Structural continuity is established by the neosome, which results in foliation trends that locally are oblique to those established by more schistose rocks in units Abs and Asm. Schist inclusions occur as blocks, lenses, and septa; rarely as irregular layers; paleosomes include biotite schist (units Abs), tonalitic to granodioritic gneiss (unit Atm), and amphibolite (similar to units Adp and Aas). Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Avg - Granite-rich migmatite (late Archean)
Granite of the Lac LaCroix type that contains abundant inclusions. The paleosome consists of blocks and slabs as large as several meters, the longest of which are biotite schist, amphibolite, tonalite,

trondhjemite, and leucogranite migmatite, as well as pale gray, ovoid to wispy inclusions of granitoid rock that are interpreted as the magmatically digested remnants of original schistose blocks. Where the inclusions are predominantly the digested or transformed type, the bulk rock meets the definition of nebulitic migmatite (Mehnert, 1967). In general, paleosomatic inclusions constitute between 5 and 25 percent of the unit. Contacts with Lac LaCroix Granite (unit Avl) are gradational and their placement is somewhat subjective. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Of note, units Agm and Avg are considered by the GRI to be equivalent units based on dominant lithology and adjacency on source maps.

Avq - Biotite-hornblende quartz diorite (late Archean)

Massive, medium-grained, medium- to dark-gray. Extensively brecciated and invaded by pink granite of Lac LaCroix type (unit Avl). Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Avt - Leucogranite-rich migmatite (late Archean)

Layered or stromatoform migmatite in which the paleosome is predominantly biotite schist comparable to unit Aqs, and the neosome is leucogranite comparable to unit Alg, together with leucotrondhjemite. Granitic layers range in thickness from one meter to several tens of meters, and typically constitute about 50 to 90 percent of the bulk rock. Boudinage and superimposed mesoscale folds of at least two generations are present, but are less well developed than in unit Avs. Contacts with units Alg and Avs are gradational and their placement is somewhat subjective. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Ava - Migmatite in which the paleosome is dominantly amphibolite hornblende gneiss and biotite-hornblende gneiss (late Archean)

Includes granite-rich and amphibolite-rich variants; gross structural aspect ranges from stromatoform to blocky. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Asm - Schist-rich migmatite (late Archean)

Asm - Schist-rich migmatite (late Archean)
Contains 50 to 75 percent of biotite schist paleosome and Lac La Croix Granite (all phases) neosome. Structural continuity is established by schist component (the unit is schist with multiple intrusions—in contrast to unit Agm that is granite with schist inclusions). Neosomatic intrusions occur as irregular sills and comparatively straight-walled dikes. Paleosome is primarily schist of metasedimentary protolith (similar to unit Abs), but includes foliated, white tonalitic to granodioritic lenses, sills, and dikes (similar to unit Atm) that were strongly deformed in D2. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Avs - Schist-rich leucogranite migmatite (late Archean)
Layered or stromataform migmatite in which the paleosome is predominantly biotite schist comparable to unit Aqs and the neosome is leucogranite comparable to unit Alg, together with leucotrondhjemite. Granitic layers range in thickness from a centimeter to several meters, and typically consititute about 10 to 15 percent of the bulk rock. Boudinage and superimposed mesoscale folds of at least two generations are well developed. Contacts with units Aqs, Alg, and Avlm are highly gradational and

their placement is somewhat subjective. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Of note, units Asm and Avs are considered by the GRI to be equivalent units based on dominant lithology and adjacency on source maps.

Abs - Quetico subprovince of the Superior Province, biotite schist (late Archean)

Abs - Biotite schist of graywacke-mudstone protolith (Neoarchean)
Contains as much as 25 percent granitoid neosome. Bedding and particle-size grading that reveals stratigraphic facing are preserved locally. Bedding typically is subparallel to D2-related schistosity. Cut locally by tonalite, leucogranite, and granodioritic sills, lenses, and dikes that also contain D2 fabric. Description from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Aqs - Biotite Schist (late Archean)
Psammitic to pelitic, fine- to medium grained, light- to dark-gray; derived from rhythmically bedded, texturally graded graywacke and shale. Composed dominantly of plagioclase, quartz, biotite, and muscovite; contains minor garnet, sillimanite, kyanite, and hornblende in beds of appropriate bulk composition and metamorphic grade. Individual beds are typically 5- to 20-centimeters-thick; some sandy beds are as thick as 2 meters. Isoclinal folding is indicated by reversals in the direction of stratigraphic younging, although outcrop-scale folds are rarely observed. This unit is the characteristic and dominant rock type in the northern part of the Quetico subprovince, south of the Rainy Lake–Seine River fault zone. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Of note, units Abs and Aqs are considered by the GRI to be equivalent units based on dominant lithology and adjacency on source maps.

At - Tonalite (late Archean)

Fine- to medium-grained, light-gray to white, moderately to well foliated, biotite-rich. Unit crosscuts diorite (unit Ad) and probably represents the latest phase of a subvolcanic intrusion. Similar rocks to the northeast have been dated at about 2,729 to 2,736 Ma (Davis and others, 1982, 1989; Goldich and Fischer, 1986). Description from source map: Bedrock Geologic Map of Voyageurs National Park ..

Ad - Diorite (late Archean)

Fine- to medium-grained, medium- to dark-gray, moderately to well foliated, biotite- and hornblende-bearing. Cut by tonalite (unit At) and locally forms angular brecciated fragments surrounded by the tonalite. Unit occurs north of tonalite on Grassy Island and as thin sills within felsic and mafic metavolcanic rocks. Description from source map: Bedrock Geologic Map of Voyageurs National Park .

Aum - Ultramafic rock (late Archean)

Massive to schistose, dark-green to gray. Serpentinized peridotite that retains relict olivine, orthopyroxene, and clinopyroxene in its more massive parts, along with traces of chromite. Minor chalcopyrite noted locally. Occurs only on a small island northeast of Grindstone Island. Contacts with

other units are not exposed. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Aws - Wabigoon subprovince of the Superior Province, biotite schist (late Archean)

Aws - Biotite schist (late Archean)
Fine- to medium-grained, light- to dark-gray, locally tan; derived from rhythmically bedded, texturally graded graywacke and shale. The predominant mineral assemblage is plagioclase, quartz, and muscovite, plus chlorite or biotite. Individual beds are typically 5- to 20-centimeters-thick; some sandy beds are as thick as 2 meters. Isoclinal folding is indicated by reversals in the direction of stratigraphic younging, although outcrop-scale folds are rarely observed. This unit is very similar to unit Aqs; however, their equivalence is unknown. The two units are separated by the Rainy Lake–Seine River fault zone and Jackfish Bay fault, major bounding structures of the Wabigoon subprovince. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Asf - Schistose felsic rocks (late Archean)

Very strongly foliated, light-green to gray. Interpreted as metamorphosed dacitic tuff that interfingers with flows of map unit Asr. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Am - Mafic schist (late Archean)

Scaly to fairly massive, dark-green-gray; derived from mafic volcanic flows and interstratified tuff. Chlorite schist is the predominant rock type and was probably derived from mafic tuffaceous protoliths. Less common sericite schist is interpreted to be derived from felsic tuff. Schistose fabric is intense between the Tilson Bay fault and the Rainy Lake–Seine River fault zone; rock grades tectonically into the sheared rock of the schistose tectonite unit (Ast) with local thin interbeds of low-grade, sulfide-rich iron-formation and highly altered fragmental rocks along the fault (on the small island northeast of Drywood Island). The metabasalt flows and interbedded tuffaceous sequences are generally thin. Flows are fine-grained metabasalt composed of chlorite, green hornblende and plagioclase, plus varying small amounts of biotite, magnetite, and ilmenite. They contain relict vestiges of vesicular pillow rinds and, rarely, complete pillows. Intact pillows on the south side of Grassy Island and on a small island north of Grindstone Island exhibit yellowish epidote alteration. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Asr - Schistose rhyolite and dacite (late Archean)

Light- to medium-gray, well foliated. Flows contain euhedral phenocrysts of plagioclase and distinctive, doubly terminated blue quartz. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Avc - Volcanic conglomerate (late Archean)

Bimodal, matrix-supported, gray to dark-green-gray. Contains moderately to highly stretched felsic to mafic volcanic clasts that appear to have been originally rounded to subrounded. Occurs as discontinuous beds as thick as one to 10 meters that are interstratified with felsic and mafic

metavolcanic rocks. Matrix is biotite- or chlorite-rich, fine-grained tuffaceous meta-arenite. Stretched rhyolite clasts that contain doubly terminated blue quartz phenocrysts probably were derived from the schistose rhyolite and dacite unit (Asr). This conglomerate may represent subaerial debris flows. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

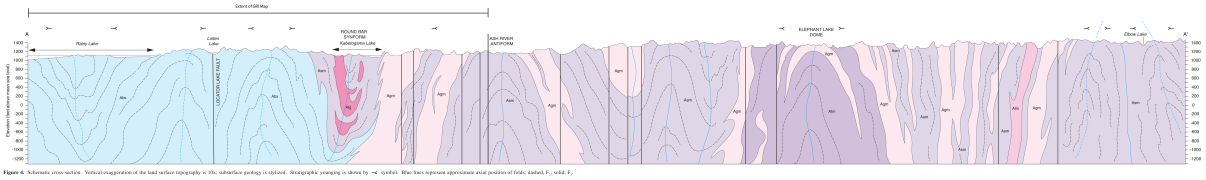
As - Amphibolite schist (late Archean)

As - Amphibolite schist (late Archean)
Very strongly foliated, dark-green in color. Composed of hornblende, biotite, and chlorite. Contains thin, discontinuous lenses of brown iron-carbonate alteration, thin beds of magnetite-rich schist, and dark-gray cherty layers (Day, 1990). Occurs along the north side of the Rainy Lake–Seine River fault zone. Description from source map: Bedrock Geologic Map of Voyageurs National Park.

Geologic Cross Section

The geologic cross section present in the GRI digital geologic-GIS data produced for Voyageurs National Park, Minnesota (VOYA) is presented below. The cross section graphic was scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

Cross Section A-A'



Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Of note, only a limited extent of the cross section is within the extent of the GRI digital geologic-GIS data. This is indicated on the cross section graphic by the extent bar with text along the top of the graphic (beginning in the top left).

GRI Ancillary Source Map Information

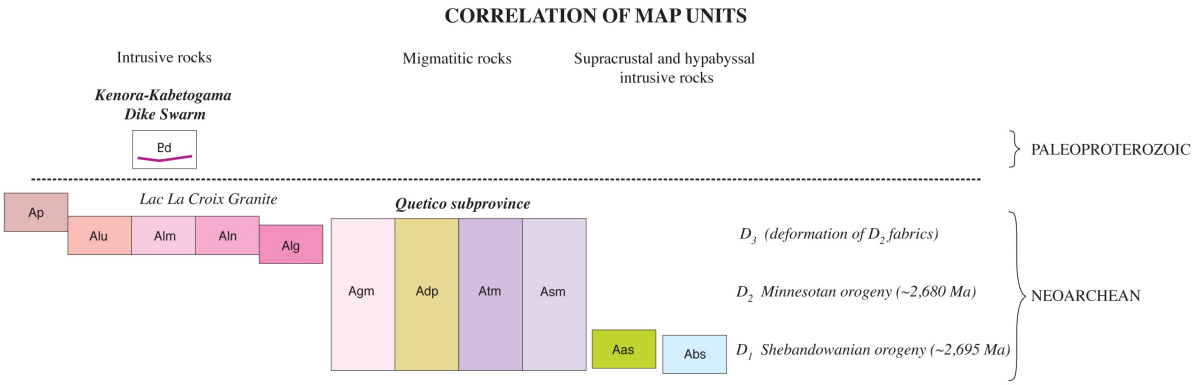
Bedrock Geologic Map of Crane Lake and Brule Narrows (M-192)

The formal citation for this source.

> Jirsa, M.A., 2011, Bedrock Geology of the Crane Lake and Brule Narrows 30' X 60' Quadrangles, Minnesota: Minnesota Geological Survey, M-192, scale 1:100,000. (*GRI Source Map ID 75668*).

Prominent graphics and text associated with this source are presented below.

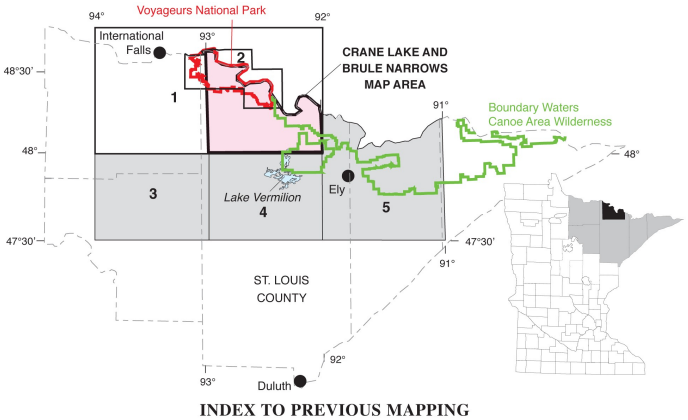
Correlation of Map Units



Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

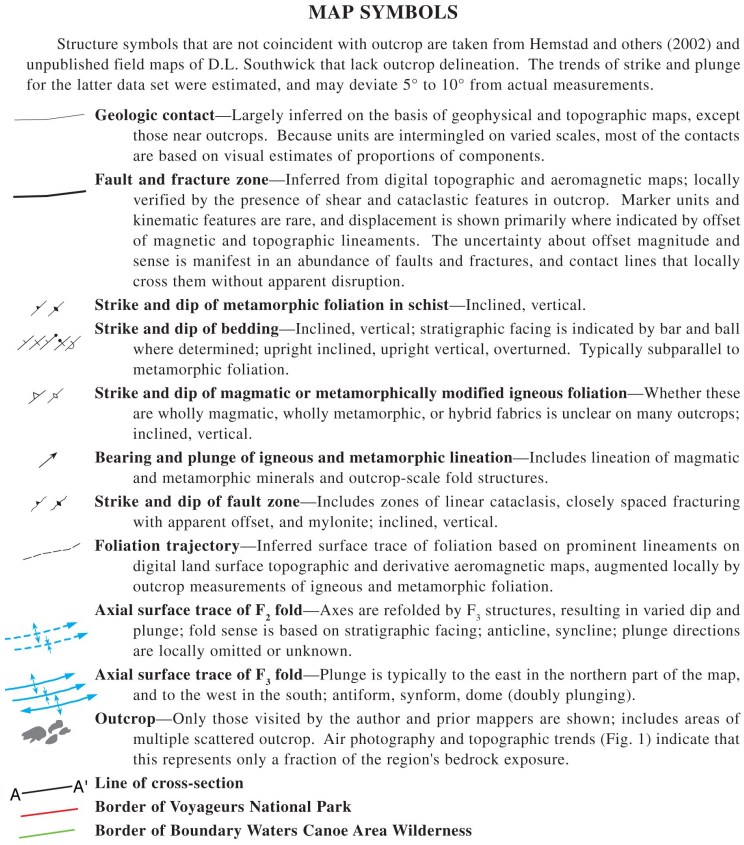
Of note, only a partial extent of the source map was used for the GRI digital geologic-GIS data for Voyageurs National Park, and thus not all units presented on the unit correlation figure exist in the GRI digital geologic-GIS data. In addition, some units present in the extent of the data used by the GRI may have had their unit symbol and/or name changed as the unit is considered by the GRI to be the be equivalent to another unit on the other source map.

Index Map



Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Map Symbols



MAP SYMBOLS

Structure symbols that are not coincident with outcrop are taken from Hemstad and others (2002) and unpublished field maps of D.L. Southwick that lack outcrop delineation. The trends of strike and plunge for the latter data set were estimated, and may deviate 5° to 10° from actual measurements.

Geologic contact—Largely inferred on the basis of geophysical and topographic maps, except those near outcrops. Because units are intermingled on varied scales, most of the contacts are based on visual estimates of proportions of components.

Fault and fracture zone—Inferred from digital topographic and aeromagnetic maps; locally verified by the presence of shear and cataclastic features in outcrop. Marker units and kinematic features are rare, and displacement is shown primarily where indicated by offset of magnetic and topographic lineaments. The uncertainty about offset magnitude and sense is manifest in an abundance of faults and fractures, and contact lines that locally cross them without apparent disruption.

Strike and dip of metamorphic foliation in schist—Inclined, vertical.

Strike and dip of bedding—Inclined, vertical; stratigraphic facing is indicated by bar and ball where determined; upright inclined, upright vertical, overturned. Typically subparallel to metamorphic foliation.

Strike and dip of magmatic or metamorphically modified igneous foliation—Whether these are wholly magmatic, wholly metamorphic, or hybrid fabrics is unclear on many outcrops; inclined, vertical.

Bearing and plunge of igneous and metamorphic lineation—Includes lineation of magmatic and metamorphic minerals and outcrop-scale fold structures.

Strike and dip of fault zone—Includes zones of linear cataclasis, closely spaced fracturing with apparent offset, and mylonite; inclined, vertical.

Foliation trajectory—Inferred surface trace of foliation based on prominent lineaments on digital land surface topographic and derivative aeromagnetic maps, augmented locally by outcrop measurements of igneous and metamorphic foliation.

Axial surface trace of F_2 fold—Axes are refolded by F_3 structures, resulting in varied dip and plunge; fold sense is based on stratigraphic facing; anticline, syncline; plunge directions are locally omitted or unknown.

Axial surface trace of F_3 fold—Plunge is typically to the east in the northern part of the map, and to the west in the south; antiform, synform, dome (doubly plunging).

Outcrop—Only those visited by the author and prior mappers are shown; includes areas of multiple scattered outcrop. Air photography and topographic trends (Fig. 1) indicate that this represents only a fraction of the region's bedrock exposure.

A A' **Line of cross-section**

Border of Voyageurs National Park

Border of Boundary Waters Canoe Area Wilderness

Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Figure 1: Digital Topographic Image

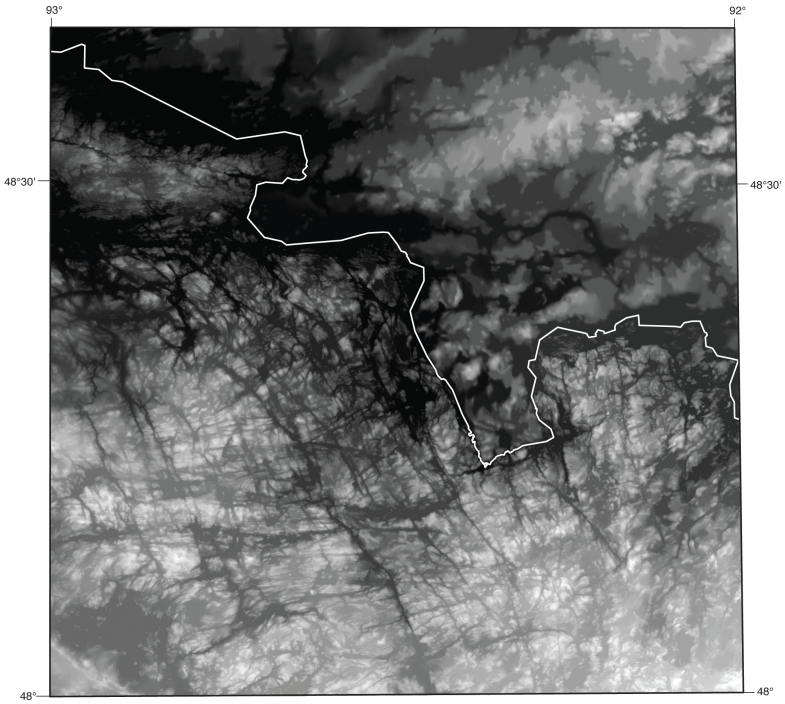


Figure 1. Digital topographic image of the Crane Lake and Brule Narrows 30' x 60' quadrangles showing strong influence of bedrock structure and composition on the land surface. Lighter shades represent higher elevations. International border is white.

Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Figure 2: Generalized Map of Northeastern Minnesota

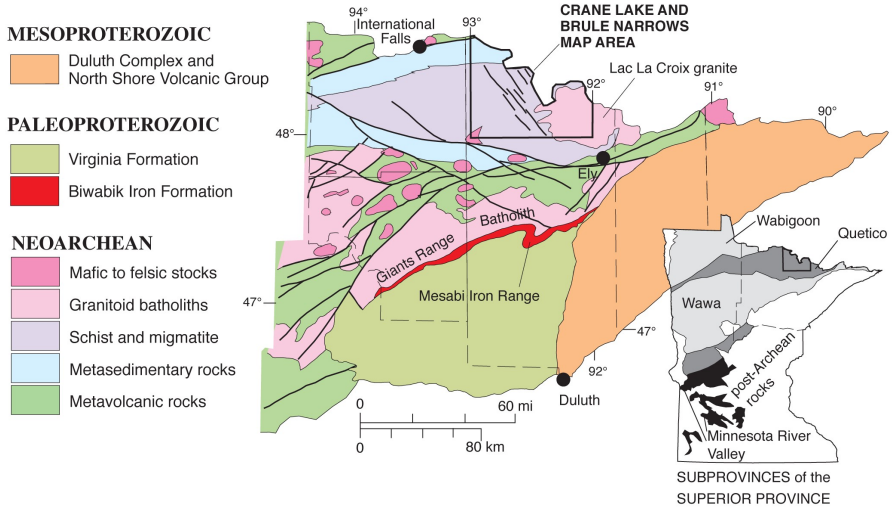


Figure 2. Generalized map of northeastern Minnesota showing the geologic setting of the Crane Lake and Brule Narrows 30' x 60' quadrangles. Inset shows location within subprovinces of the Archean Superior Province (Wabigoon, Quetico, Wawa, and Minnesota River Valley).

Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Figure 3: Aeromagnetic Image

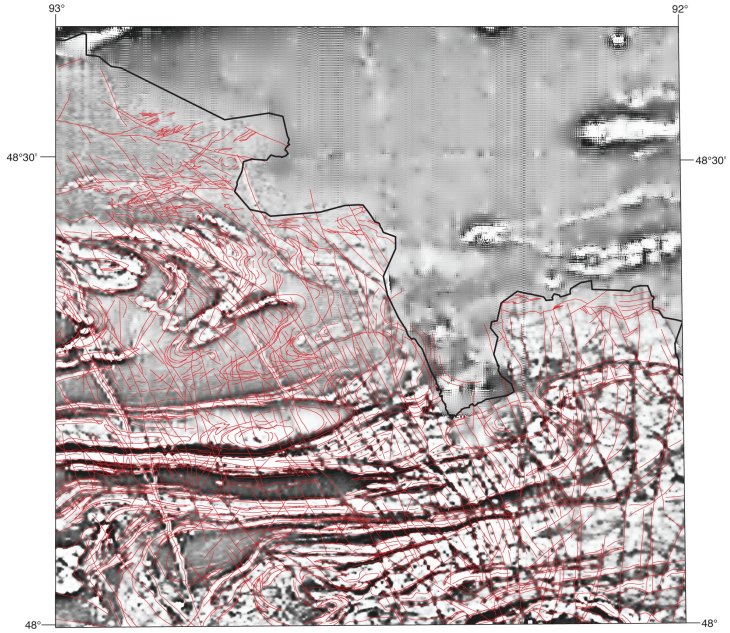


Figure 3. First vertical derivative aeromagnetic image. Lighter shades indicate larger relative magnetite content. Geologic contacts, faults, foliation trajectories, and dikes are shown in red.

Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Table 1: Summary of Magnetic Susceptability Measurements

Table 1. Summary of magnetic susceptibility measurements (cgs units x 10^3). On the upper table, "Average" represents the average of the largest values in a range of 10 measurements taken of each rock type in outcrop; "Number" is how many of the largest values were averaged. The lower table shows the representative high values for minor rock types.

Rock type	Unit	Average	Largest	Number
Lac La Croix-type granite (LLC)	Alm, Aln	0.63	8.2	513
Pegmatite in LLC	Alm	0.83	5.4	50
Biotite schist	Abs	0.23	3.9	250
Foliated-gneissic tonalite-granodiorite	Atm	0.56	9.2	190

Minor units		Representative values
Diabase dikes	Pd	1.5, 2.0, 2.4
Leucogranite (LLC)	Alg	0
Diorite, leucogabbro	Adp	0.42. 0.03, 0.21
Metadiorite	Adp	1.0, 1.4, 1.6, 3.4
Metalamproid, metapyroxenite	Adp	1.0, 1.2
Amphibolitic schist and gneiss	Adp	0.03, 0.07
Biotite selvages, schlieren in LLC	Alm	1.5, 14.0

Graphic from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Map Notes

Ancillary text from the the Bedrock Geologic Map of Crane Lake and Brule Narrows map.

Introduction

This interpretation incorporates maps and notes from 20 years of field mapping by David L. Southwick (summarized in Southwick and Ojakangas, 1979) augmented by digital topography, reprocessed aeromagnetic data, in-fill gravity data, and the author's field work. The northern part of the map is modified only slightly from relatively detailed mapping in Voyageurs National Park (Hemstad and others, 2002; scale 1:50,000). The interpretation of the eastern and southern sections of the map is consistent, though not directly continuous, with units depicted on adjacent published maps at this scale (see the Index to Previous Mapping; Jirsa and Boerboom, 2003; Jirsa and Miller, 2004). Nowhere else in Minnesota is bedrock so well exposed; however, because of time and access constraints, the outcrop shown on this map is only a fraction of the total exposure. The digital land surface topographic image (Fig. 1) portrays the strong control of this surface by the structure and composition of bedrock. For example, large areas of granitic bedrock are topographically higher than areas of migmatitic and schist-rich rocks. Differential weathering produced curvilinear topographic relief that crudely depicts foliation trends and reveals complex folding. Prominent fractures and faults in all rock types are manifest in linear topographic lows—many of which are waterways. Taken together with outcrop data and geophysical maps, the new image mimics at the map scale the complex migmatitic, magmatic, deformation, and alteration features observed at the outcrop scale.

Text from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Geologic Setting

The map portrays a complex history of sediment deposition, multiple intrusive events, and several periods of deformation and metamorphism. It lies within the southern exposed extent of the Archean Superior Province. In Minnesota, the province is divided into 4 major tectonomagmatic terranes known as the Wabigoon, Quetico, Wawa, and Minnesota River Valley subprovinces (Fig. 2). Each terrane represents a discrete fragment of oceanic and continental crust that was assembled by accretion into the Superior craton, largely completed by approximately 2.6 Ga. The map lies wholly within the Neoarchean Quetico subprovince. The bedrock consists of biotite-plagioclase-quartz schist, granitoid and minor mafic intrusions, and complex migmatite containing multiple paleosomatic and neosomatic components. The schist was derived from graywacke and pelitic sediments deposited ~2,698 to 2,692 Ma (Davis and others, 1989; Fralick and others, 2006) in an accretionary prism during early stages of collision between the Wawa subprovince island arc to the south, and the Superior craton (superterrane) to the north. Later stages of this D1 collisional event, known as the Shebandowanian orogeny (Percival and others, 2006), produced tilting, broad nappe structures, and thrust imbrication of volcanoplutonic rocks in subprovinces north and south of the Quetico subprovince (Poulsen and others, 1980; Jirsa and others, 1992); and recumbent folding within the Quetico subprovince (Bauer, 1985). An early suite of leucogranite, granodiorite, trondhjemite, and tonalite is interlayered on all scales with biotite schist (Southwick, 1991). A second deformation event (D2) occurred at about 2,680 Ma (Boerboom and Zartman, 1993) during the Minnesotan orogeny (Percival and others, 2006), and produced regional penetrative fabrics, folds, and prograde metamorphism. A third deformation event (D3) is manifest in the Quetico subprovince as broad, east- and west-plunging folds (synforms, antiforms) of D2 fabrics, and by faulting. At least part of this deformation was synchronous with migmatization and emplacement of 2-mica leucogranite and a slightly younger, typically red, variably magnetic biotite granite known as the Lac La Croix (Southwick, 1991; Bauer and others, 1992). The Lac La Croix Granite has a U-Pb zircon age of 2,666 ± 4 Ma (Percival and Sullivan, 1988), which is consistent with a U-Th-Pb monazite age for the end of what is inferred here to be the D3 event at 2,667 ± 20 Ma (Valli and others, 2004). The metamorphic grade is more or less symmetrical along the axis of the Quetico subprovince, with greenschist grade at the margins and middle to upper amphibolite facies near the axis. Metamorphism was generally

syntectonic with D2 and D3 deformations, and a contact metamorphic overprint occurs locally adjacent to the Lac La Croix Granite. Although deformation along the north and south boundaries of the Quetico subprovince had begun much earlier, at least some of the boundary faulting was assigned to a D4 event by Tabor and Hudleston (1991). Bedrock in the western part of the map area is cut by Paleoproterozoic diabasic dikes that constitute the easternmost extent of the Kenora–Kabetogama dike swarm (Southwick and Day, 1983).

Knowledge of economic mineral deposits in this region is limited. Historic records of a gold prospect in the 1920s showed significant assays—though apparently not mineable quantities—of gold associated with quartz veining along the Vermilion River at what is now Gold Mine Camp Resort southwest of Crane Lake. A dimension stone quarry has begun operations in Lac La Croix Granite near Gustafson Lake about 10 miles (16 kilometers) southeast of Buyck. Potential for rare-element mineralization has been demonstrated in some pegmatitic components of similar migmatitic rocks in the Quetico subprovince in adjacent Ontario (Breaks and others, 2003); however, no detailed analyses were done to explore the possibility here.

Text from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Geophysical Data

The bedrock consists of migmatitic rocks having interlayered components that vary in proportions over relatively short distances at outcrop scale, which obfuscates depiction at map scale. Geophysical maps, verified locally by outcrop, were used for generalization—derivative aeromagnetic maps (Fig. 3) were most useful. The rocks show significant contrast in magnetic intensity, and the overall magnetic expression varies in irregular ways that generally cannot be predicted from macroscopic inspection of outcrops. For this reason, thousands of measurements of magnetic susceptibility were made in the field. The results, summarized in Table 1, show several significant trends. The largest magnetic susceptibilities are recorded in comparatively rare, variably metamorphosed mafic rocks having apparent dioritic, pyroxenitic, and lamprophyric protoliths (some of the units labeled Adp); however, these rock types are not magnetic in all cases. The rock type that most consistently produces magnetic anomalies is pink to red Lac La Croix Granite (unit Alm). This is especially true where the unit has pegmatitic pods containing coarse-grained magnetite. Historically, some of these magnetite occurrences are large enough to have encouraged exploration for iron ore. Apparent interlayering of magnetic (unit Alm) and less magnetic (unit Aln) granite characterizes the Lac La Croix Granite in the eastern part of the map. Other rock types are also magnetic locally, most typically where the older rocks are invaded by pink, magnetic, Lac La Croix Granite neosome. This implies that either iron-rich fluids were introduced to paleosomes during granite emplacement, or the ferric iron oxide content of some paleosomes was reduced to magnetite by contact metamorphism. The most prominent map-scale magnetic contrasts on first and second vertical derivative maps are northwest-trending, linear, magnetic lows that transect the regional northeast-striking magnetic fabric. The coincidence of these anomalies with topographic lows and local exposures of cataclastic to mylonitic fabrics implies that many are faults. Thus, the magnetic susceptibility at any given locality appears to be the result of magmatic iron-oxide content, "prograde" effects of Lac La Croix Granite emplacement (magmatic intermingling, metamorphism, hydrothermal alteration), and subsequent "retrogressive" oxidation by weathering.

Gravity anomaly data coverage is inconsistent due to access, despite new in-fill data acquired for this map. When compared with the gravity expression of adjacent greenstone-granite subprovinces, the overall signature of rocks in the Quetico subprovince is very subdued. Nevertheless, derivative gravity maps—with intensities scaled to this map area (not scaled to the statewide gravity data set)—show comparatively higher expression in areas consisting largely of Lac La Croix Granite and related granite-rich migmatite. Higher amplitude anomalies also occur in the south-central and southwestern parts of the map. Anomalies in the south-central portion reflect an area of biotite schist containing abundant lamprophyric intrusions generally too small to map as separate entities. Anomalies in the southwest portion appear to reflect a metadioritic intrusion. Several closely spaced Paleoproterozoic

diabase dikes along the west edge of the map collectively produce moderately high gravity signatures.

Text from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Acknowledgement

Advice on geophysical interpretations by V.W. Chandler.

Text from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

Disclaimer

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 cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

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Text from source map: Bedrock Geologic Map of Crane Lake and Brule Narrows.

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Numbers in parentheses correspond with those shown on the Index to Previous Mapping.

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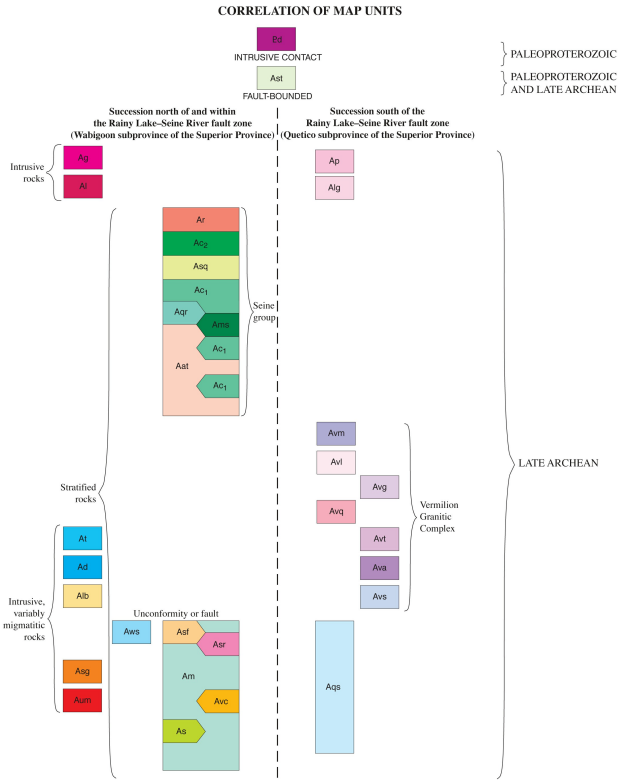
Bedrock Geologic Map of Voyageurs National Park (M-125)

The formal citation for this source.

> Hemstad, C.B., Southwick, D.L., and Ojakangas, R.W., 2002, Bedrock Geologic Map of Voyageurs National Park and Vicinity, Minnesota: Minnesota Geological Survey, Miscellaneous Map Series M-125, scale 1:50,000. (*GRI Source Map ID 52443*).

Prominent graphics and text associated with this source are presented below.

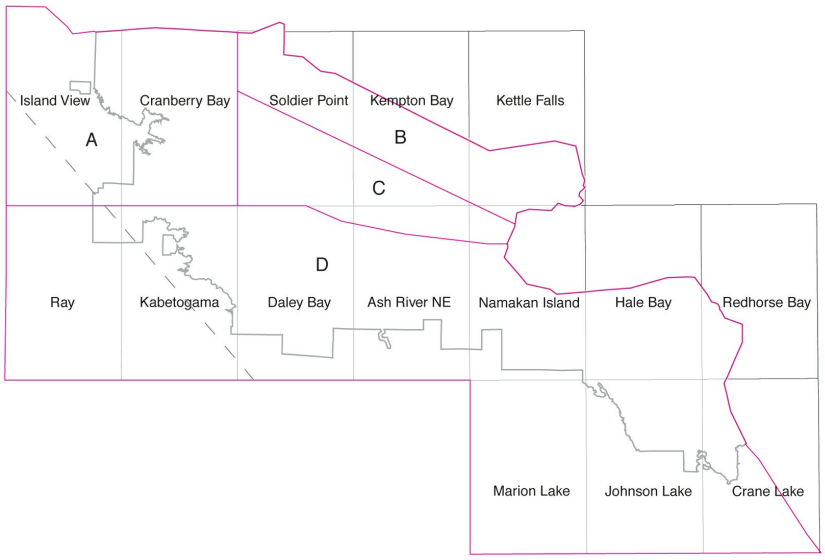
Correlation of Map Units



Graphic from source map: Bedrock Geologic Map of Voyageurs National Park.

Of note, only a partial extent of the source map was used for the GRI digital geologic-GIS data for Voyageurs National Park, and thus not all units presented on the unit correlation figure exist in the GRI digital geologic-GIS data. In addition, some units present in the extent of the data used by the GRI may have had their unit symbol and/or name changed as the unit is considered by the GRI to be the be equivalent to another unit on the other source map.

Index Map

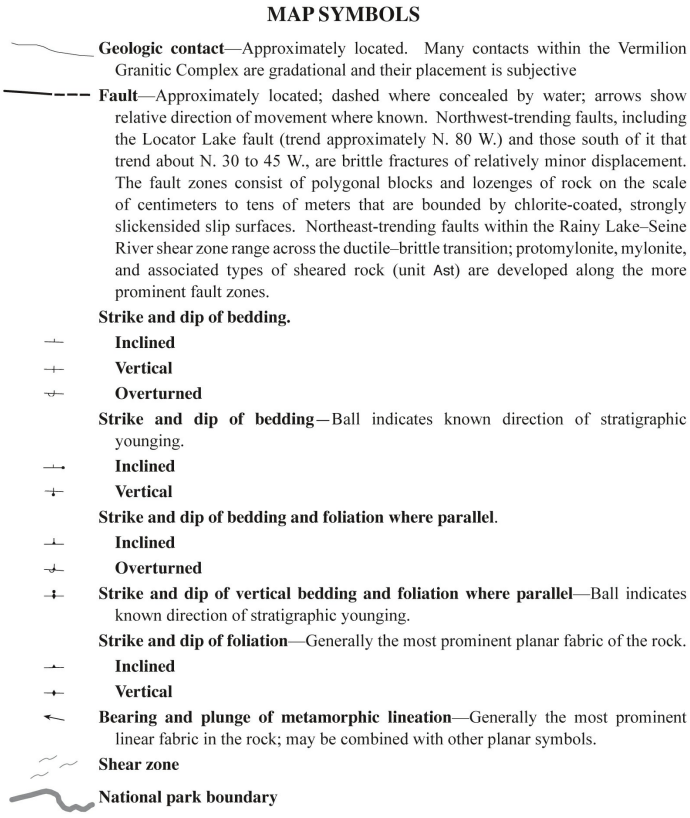


INDEX TO QUADRANGLE MAPS AND SOURCES OF GEOLOGIC MAPPING

A. Detailed mapping by C.B. Hemstad, 1999 to 2001 (Hemstad and others, 2000, 2001)
B. Reconnaisance-scale mapping by R.W. Ojakangas, 1968 to 1969, and by C.B. Hemstad, 2000
C. Reconnaisance-scale mapping by C.B. Hemstad, 2000
D. Reconnaisance-scale mapping by D.L. Southwick, 1968 to 1971

Graphic from source map: Bedrock Geologic Map of Voyageurs National Park.

Map Symbols



MAP SYMBOLS

Geologic contact—Approximately located. Many contacts within the Vermilion Granitic Complex are gradational and their placement is subjective

Fault—Approximately located; dashed where concealed by water; arrows show relative direction of movement where known. Northwest-trending faults, including the Locator Lake fault (trend approximately N. 80 W.) and those south of it that trend about N. 30 to 45 W., are brittle fractures of relatively minor displacement. The fault zones consist of polygonal blocks and lozenges of rock on the scale of centimeters to tens of meters that are bounded by chlorite-coated, strongly slickensided slip surfaces. Northeast-trending faults within the Rainy Lake–Seine River shear zone range across the ductile–brittle transition; protomylonite, mylonite, and associated types of sheared rock (unit Ast) are developed along the more prominent fault zones.

Strike and dip of bedding.

Inclined

Vertical

Overturned

Strike and dip of bedding—Ball indicates known direction of stratigraphic younging.

Inclined

Vertical

Strike and dip of bedding and foliation where parallel.

Inclined

Overturned

Strike and dip of vertical bedding and foliation where parallel—Ball indicates known direction of stratigraphic younging.

Strike and dip of foliation—Generally the most prominent planar fabric of the rock.

Inclined

Vertical

Bearing and plunge of metamorphic lineation—Generally the most prominent linear fabric in the rock; may be combined with other planar symbols.

Shear zone

National park boundary

Graphic from source map: Bedrock Geologic Map of Voyageurs National Park.

Map Notes

Ancillary text from the Bedrock Geologic Map of Voyageurs National Park map

Structural Note

In order to include as much structural data as possible, the dip and plunge angles have been excluded from this regional compilation, but are included in the digital files. Foliation dips are generally steep, ranging from 50º to 90º; steeper dips tend to be associated with northeast-trending shear zones. Bedding dips are more variable, ranging from horizontal to vertical, but mostly range between 30º and 70º. Often they are parallel with foliation, especially near northeast-oriented shear zones. Lineations plunge from 5º to 70º, with most occurring in the range between 10º and 40º.

Rocks in most of the map area experienced a complex tectonic history that involved several generations of folding and the associated development of multiple rock fabrics. Multiple fabrics on this regional compilation are not distinguished; rather, only the principal or most prominent planar and linear fabric elements that impart structural "grain" are shown.

Text from source map: Bedrock Geologic Map of Voyageurs National Park.

Outcrop Viability Note

Note on the availability of outcrop: Outcrops are generally abundant in the area northeast of Kabetogama Lake and the west end of Black Bay in Rainy Lake (above the dashed line on the index). Throughout that region, outcrops occur on most hills and ridges, on most islands in the major lakes, and along the lake shores. Outcrops diminish abruptly in abundance west and southwest of Kabetogama Lake (below the dashed line on the index).

Much of the geologic mapping compiled here was done at reconnaisance-scale and did not involve the detailed plotting of outcrop shapes. Detailed outcrop information is available on the Island View (Hemstad and others, 2000) and Cranberry Bay quadrangles (Hemstad and others, 2001).

Text from source map: Bedrock Geologic Map of Voyageurs National Park.

Disclaimer

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 cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site specific verification.

Text from source map: Bedrock Geologic Map of Voyageurs National Park.

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GRI Digital Data Credits

This document was developed and completed by James Winter, Dalton Meyer and Stephanie O'Meara (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program. Quality control of this document by James Winter and Stephanie O'Meara.

The information in this document was compiled from GRI source maps, and intended to accompany the digital geologic-GIS map(s) and other digital data for Voyageurs National Park, Minnesota (VOYA) developed by James Winter and Stephanie O'Meara (Colorado State University) (see the GRI Digital Map and Source Map Citations section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS map).

GRI finalization by Stephanie O'Meara

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado). Updated source map research by Stephanie O'Meara.