UNIVERSITY OF MINNESOTA

MINNESOTA GEOLOGICAL SURVEY
D.L. Southwick, Director

Mapping funded in part by
THE DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINERALS

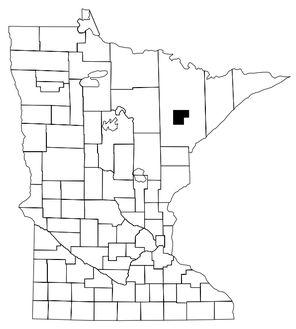
MISCELLANEOUS MAP M-85
Bedrock Geologic Map of the Virginia Horn

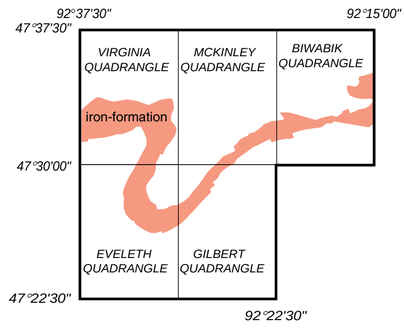
92° 37' 30" 92° 30' 00" 92° 22' 30" 92° 15' 00"
47° 37' 30" 47° 30' 00"

†Early Proterozoic and Cretaceous strata are modified from the following 1:24,000 - scale, Open-file maps of the Minnesota Geological Survey.

Morey, G.B., and Cleland, J.M., Welsh, J.L., and Vlasich, K.T., compilers, 1994, Preliminary bedrock geologic map of the Virginia Quadrangle, St. Louis County, Minnesota, MGS Open-file report 94-4, scale 1:24,000.
Morey, G.B., and Cleland, J.M., compilers, 1996, Preliminary bedrock geologic map of the Biwabik Quadrangle, St. Louis County, Minnesota, MGS Open-file report 96-5, scale 1:24,000.
Morey, G.B., and Cleland, J.M., compilers, 1996, Preliminary bedrock geologic map of the Gilbert Quadrangle, St. Louis County, Minnesota, MGS Open-file report 96-8, scale 1:24,000.
Morey, G.B., and Cleland, J.M., compilers, 1996, Preliminary bedrock geologic map of the McKinley Quadrangle, St. Louis County, Minnesota, MGS Open-file report 96-9, scale 1:24,000.
Morey, G.B., and Cleland, J.M., compilers, 1996, Preliminary bedrock geologic map of the Eveleth Quadrangle, St. Louis County, Minnesota, MGS Open-file report 96-10, scale 1:24,000.

## LOCATION DIAGRAM






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.

Digital base modified from U.S.G.S. 1996 Digital Raster Graphic of the Virginia, McKinley, Biwabik, Eveleth, and Gilbert 1:24 000 Quadrangles (1962; photorevised 1984)

Universal Transverse Mercator Projection, grid zone 15
1927 North American Datum

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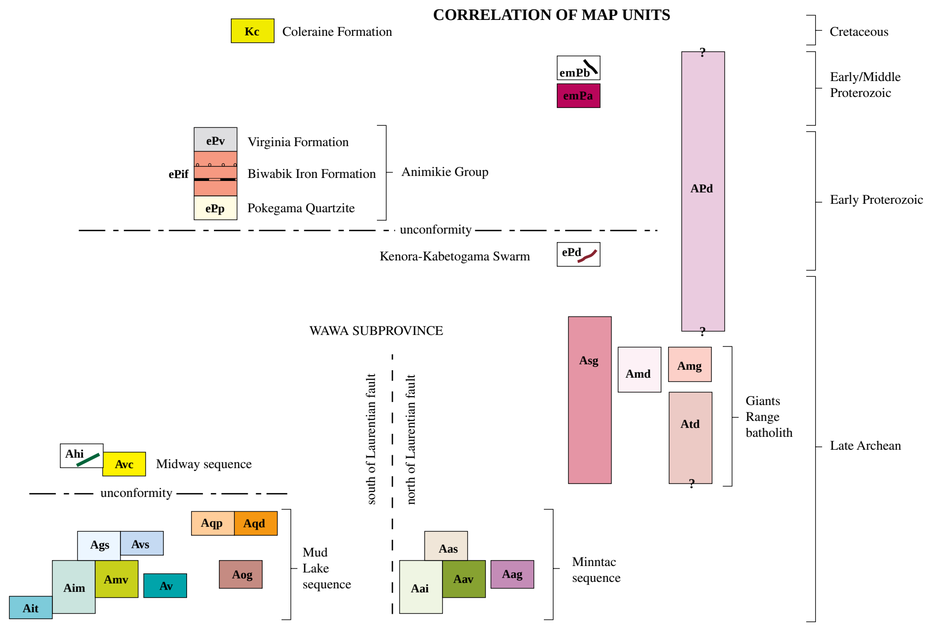
SCALE 1:48 000
1 1/2 0 1 MILE
1 .5 0 1 KILOMETER

Digital cartography by Joyce Meints, and T.E. Wahl;
Graphic design by R.S. Lively
(January 1998)

## CORRELATION OF MAP UNITS




## DESCRIPTION OF MAP UNITS

CRETACEOUS ROCKS†

**Kc** Coleraine Formation—includes basal iron-formation conglomerate overlain by hematite-cemented quartz arenite.

EARLY OR MIDDLE PROTEROZOIC ROCKS

**emPb** Diabasic gabbro—fine-grained dikes having pronounced chilled margins.

**emPa** Aurora sill—syenite, coarse-grained, vaguely porphyritic, 75-80 modal percent of albitic plagioclase, 1-7 modal percent orthoclase, and lesser amounts anorthoclase and biotite, altered to calcite and chlorite.

EARLY PROTEROZOIC ROCKS

**Animikie Group**

**ePv** Virginia Formation—interbedded carbonaceous shale, mudstone, siltstone, and feldspathic graywacke.

**ePif** Biwabik Iron Formation undivided—contains thick-bedded granular chert, iron silicates, magnetite, and hematite, interbedded with thin-bedded iron silicates, carbonates, magnetite, and hematite. Also mapped where possible is a unit of black tuffaceous shale—locally known as Intermediate Slate—that occurs in the lower one- fourth of the iron-formation (shown by bar-on-line pattern), and a unit of hematitic algal chert and associated conglomerate in the upper one-third of the iron-formation (shown by hemisphere-on-line pattern).

**ePp** Pokegama Quartzite—includes quartzite, quartz-rich siltstone, and shale.

Stratigraphic note: Fractures and irregular depressions on Archean bedrock outcrops locally are filled with well-indurated sedimentary rocks considered to be Early Proterozoic age. Conglomerate is most abundant, containing a poorly sorted array of clasts derived from the underlying bedrock, in a fine-grained sandstone to siltstone matrix that is petrographically similar to Pokegama Quartzite. Red hematitic chert (jasper) having rare stromatolitic laminae, similar to parts of the Biwabik Iron Formation, occurs locally in fractures. Both occurrences are presumed to be erosional remnants of Animikie deposits. Though a common attribute of outcrops in the area, none are large enough to show at the map scale.

**Kenora-Kabetogama Swarm**

**ePd** Diabase and gabbro—aphanitic to medium-grained dikes, mildly deuterically altered, chilled margins.

LATE ARCHEAN OR PROTEROZOIC ROCKS

**APd** Diorite—medium to dark greenish gray, medium-grained. Most is quartz-bearing ferrodiorite containing pseudomorphs of prismatic ferroaugite, now actinolite, calcite, and chlorite; and pumpellyite after ophitic pyroxene. Magnetic due to abundant pyrrhotite. Crossed by a network of brittle, chlorite-lined faults. Temporal relationship to surrounding rocks is unknown; however, textural attributes, including lack of internal fabric and presence of unstrained myrmekitic quartz imply that the intrusion may be as young as Middle Proterozoic (Keweenawan); may alternatively be a Late Archean intrusion related to the Giants Range batholith.

LATE ARCHEAN ROCKS

**Giants Range batholith**

**Asg** Silicified granitoid rock—very light pink, tan, and white. Variably silicified rock having relict textures of units Atd and Amd, cut by abundant quartz veins.

**Amd** Monzodiorite to diorite—pinkish gray to dark greenish gray, quartz-bearing, coarse- to very coarse-grained, variably porphyritic, locally trachytoid. Phenocrysts include microcline and hornblende. Contains cognate mafic enclaves and layers of dark green hornblende diorite to hornblendite. Informally referred to as the "Pike Mountain monzodiorite" for rocks exposed at that locality.

**Amg** Monzonite to granite—salmon-pink, medium-grained, hornblende-, biotite-, and muscovite-bearing. Inferred to be the source of muscovite-bearing pegmatite dikes that intrude adjacent schist, but are too small to be shown. Informally referred to as the "Mesabi granite" for exposures at an abandoned quarry west of the Minntac taconite processing plant and shown on mining company maps.

**Atd** Tonalite to quartz diorite—gray, black, and white, biotite- and hornblende-bearing, modally banded. Contains a complex suite of mafic to felsic subunits that are inferred from field relationships to be approximately comagmatic. Variably deformed and metamorphosed, implying emplacement more or less synchronous with $D_2$ deformation. Informally referred to as the "Lookout Mountain tonalite" for exposures near that locality at the Lookout Mountain wayside along U.S. Highway 53 north of Virginia.

Supracrustal and hypabyssal intrusive rocks **south** of the Laurentian fault—metamorphosed to prehnite-pumpellyite and low greenschist grade during $D_2$ deformation.

**Midway Sequence**

**Ahi** Hornblende-bearing intrusions—dark greenish gray to maroon, porphyritic. Occur as dikes that typically are a few cm to meters thick, and trend variably. Intrudes nearly all units.

**Avc** Volcanic and conglomeratic rocks—south-facing homoclinal sequence, approximately 300-400 m thick, unconformably overlying units Aqp, Ags, Aim, and Amv of the Mud Lake sequence, described below. Contains a basal lithic sandstone having clasts of volcanic rocks and graywacke; a discontinuous medial package of hornblende- and plagioclase-bearing trachyandesite lava flows, breccia, and tuff; and a thick, upper package of fluvial and alluvial conglomerate derived from underlying trachyandesite, quartz-feldspar porphyry, and older volcanic and clastic rocks. Unit has many attributes of "Timiskaming-type" sequences in the Kirkland Lake and Thunder Bay areas of Ontario. Like the Timiskaming sequences of Ontario, this unit was deposited after $D_1$ folding, but before metamorphism and cleavage development associated with $D_2$ deformation.

**Mud Lake sequence**

**Aqp** Quartz-feldspar porphyry—Color varies with degree of alteration from gray (unaltered) to light apple green (sericite-carbonate altered). Altered rocks weather to a light rusty orange color. Contains ornately embayed quartz phenocrysts as large as 1 cm, and variable percentage of plagioclase phenocrysts and minor muscovite and biotite in a quartzofeldspathic groundmass. Least-altered analyzed samples are rhyodacitic to dacitic in composition.

**Aqd** Quartzofeldspathic dikes—gray and white where unaltered. Equigranular to microporphyritic, having phenocrysts of plagioclase. Occurs as tabular bodies that are grossly parallel to bedding in host rocks, though discordant at centimeter scale.

**Avs** Volcaniclastic sedimentary rocks—white to light gray, siliceous, and thinly bedded. Includes tuff, lapilli tuff, and tuffaceous graywacke.

**Ags** Graywacke and slate—shades of gray (unaltered) and brown(altered). Graywacke is fine-to-medium grained, plagioclase and rock fragment-rich; having variable percentage of chloritic matrix. Bedding thickness varies from a few cm to 1 m, and bed contacts are remarkably straight—rarely bulbous. Slate is dark gray, thinly bedded to laminated, and locally graphitic. Conglomeratic strata are rare.

**Aog** Ophitic gabbro—dark greenish gray. Consists principally of plagioclase that varies from phenocrysts to interstitial grains, ophitic to subophitic pyroxene variably altered to chlorite, and Fe-Ti-oxides altered to leucoxene. Occurs as sills and dikes of tholeiitic composition that intrude units Aim and Amv. Inferred to be hypabyssal intrusions magmatically related to the chemically similar flows of unit Amv.

**Amv** Mafic volcanic rocks—dark green, tholeiitic. Occur as massive, pillowed, and locally autobrecciated flows composed of fine-grained plagioclase, pyroxene partially altered to chlorite, and leucoxene after sphene.

**Av** Volcanic rocks—dark greenish gray, pillowed and massive, to strongly schistose flows. The unit is inferred to be magmatically transitional between units Aim and Amv, as it contains plagioclase and pyroxene phenocrysts like unit Aim, together with leucoxene like unit Amv. Samples have tholeiitic whole-rock geochemical signatures like those of unit Amv, but REE patterns like those of the calc-alkalic rocks (Aim, Ait).

**Aim** Calc-alkalic volcanic rocks of mafic to intermediate composition—massive parts are medium greenish gray, fine-grained, and locally contain phenocrysts of plagioclase and altered pyroxene. Upper parts of flows weather white; are variably autobrecciated; and contain abundant, small, quartz-filled amygdules. Contains some thick, poorly sorted breccia packages inferred to be pyroclastic and hydroclastic flows. Flow top and other breccia deposits commonly grade to moderately well-sorted volcanic conglomerate.

**Ait** Tuff—fine- to medium-grained, siliceous, white-weathered, thinly bedded. Probably reworked locally.

Supracrustal and hypabyssal intrusive rocks **north** of the Laurentian fault—metamorphosed to amphibolite grade during $D_2$ deformation

Schists that occur north of the Laurentian fault, though strongly recrystallized, locally contain relict volcanic and clastic textures that collectively provide a sense of southward stratigraphic younging. The strata grade irregularly from calc-alkalic volcanic and volcaniclastic rocks at the base (unit Aai), to medial strata composed of interlayered calc-alkalic and tholeiitic rocks (unit Aav), to an upper unit of schistose graywacke (unit Aas). Gabbroic sills and dikes (unit Aag) are intercalated with the volcanic strata of units Aai and Aav. Lithologic and stratigraphic similarity of this package to the Mud Lake sequence, and the absence of metamorphic retrogression in the amphibolite grade rocks, implies that they may represent deeper crustal level equivalents of the greenschist grade rocks to the south.

**Minntac sequence**

**Aas** Schist of sedimentary (graywacke and slate) protolith—dark gray, plagioclase-, biotite-, and hornblende-bearing, nearly completely recrystallized metamorphic texture. Some relict detrital textures and graded bedding are preserved locally.

**Aag** Schist of gabbroic protolith—dark greenish gray to black, composed largely of amphibole that locally pseudomorphs pyroxene phenocrysts. Analyzed samples are tholeiitic in composition. Occurs as irregular and discontinuous bodies inferred to be hypabyssal sills magmatically related to flows of unit Aav, and similar in composition to dikes and sills of unit Alg that intrude greenschist grade volcanic rocks (units Aim and Amv) of the Mud Lake sequence.

**Aav** Schist of mafic volcanic protolith—dark greenish gray; consists of amphibole, plagioclase, opaque oxides, and garnet. Locally displays well preserved, though strongly deformed, pillow structures and autobrecciated interflow units. Pillows show intense lineation plunging variably eastward and displaying aspect ratios of 10:4:1. Composition is tholeiitic—very similar to unit Amv in the greenschist grade rocks of the Mud Lake sequence to the south.

**Aai** Schist of intermediate volcanic and volcaniclastic protolith—variably light-weathered; garnet, hornblende-, plagioclase-, and quartz-bearing schist that shows relict bedding and clastic textures in some exposures. Lineated relict clasts in fragmental rocks have aspect ratios as great as 20:5:1. Analyzed samples are calc-alkalic—similar to unit Aim. Contains hypersthene- and magnetite-rich laminae (low grade iron-formation) locally within strata inferred to represent interflow sedimentary packages.

## MAP SYMBOLS

GEOLOGIC CONTACTS

Approximately located; inferred from geophysical data and topographic lineaments away from outcrops and drill holes

FAULTS

Inferred, offset sense imprecisely known, located in part by geophysical data and lineaments

Approximately located strike-slip fault, relative offset as shown; right-lateral, left-lateral

Approximately located dip-slip fault, relative offset as shown; upthrown: U, downthrown: D

Approximately located, intruded by dike

Approximately located, filled by vein quartz

AXIAL SURFACE TRACES OF FOLDS

First generation ($F_1$) folds in Archean rocks; anticline, syncline

Inferred axial trace of the principal $F_1$ fold of Archean strata; Mud Lake syncline (MLS)

Second generation ($F_2$) fold; upright anticline, syncline; inverted or inclined axial trace of anticline, syncline

Folds in Proterozoic strata; dashed where approximately located; anticline, syncline, monocline

STRIKE AND DIP OF BEDS

80 Inclined, vertical; stratigraphic top direction not determined

72 Inclined, vertical; stratigraphic top indicated by ball

63 Overturned

FOLIATION, CLEAVAGE, AND SCHISTOSITY

Foliation defined by modal banding and alignment of mineral grains in intrusive rocks; inclined, vertical

85 Cleavage and schistosity of metamorphic origin associated with $D_2$ deformation; inclined, vertical

BEARING AND PLUNGE OF LINEATION

Bearing and plunge of elongate mineral grains, pillows, and clasts, and the axial traces of small-scale folds, all developed during $D_2$ deformation; may be combined with other symbols

OUTCROP or group of closely spaced, small outcrops

DRILL HOLES

Exploration hole drilled to test gold potential—all angle-drilled. (data on file with the Minnesota Department of Natural Resources, Minerals Division, Hibbing, Minnesota)

MINES

Abandoned

Active as of approximately 1986

# BEDROCK GEOLOGIC MAP OF THE VIRGINIA HORN, MESABI IRON RANGE, ST. LOUIS COUNTY, MINNESOTA

by
Mark A. Jirsa, Terrence J. Boerboom, and G.B. Morey

1998