UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
V.W. Chandler, Interim Director

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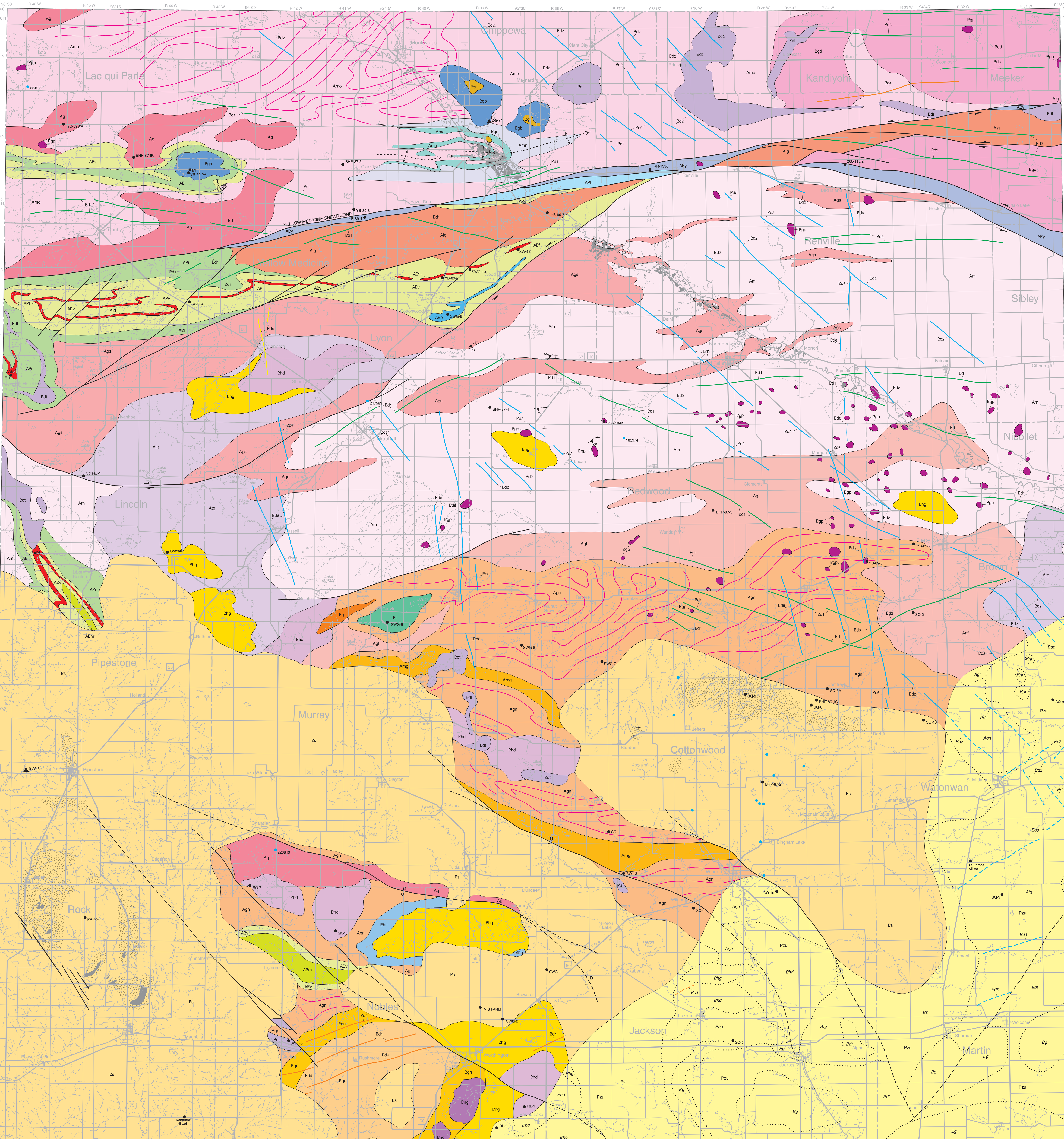
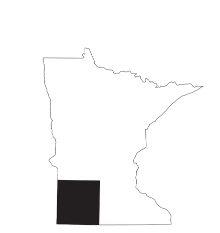


Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum



LOCATION OF MAP AREA

SCALE 1:250 000

5 0 5 10 MILES

5 0 5 10 15 KILOMETERS

GIS compilation and cartography by Joyce Meints and Philip Heywood
Edited by Lori Robinson

GEOLOGIC MAP OF PRE-CRETACEOUS BEDROCK IN SOUTHWEST MINNESOTA

by

David L. Southwick

2002

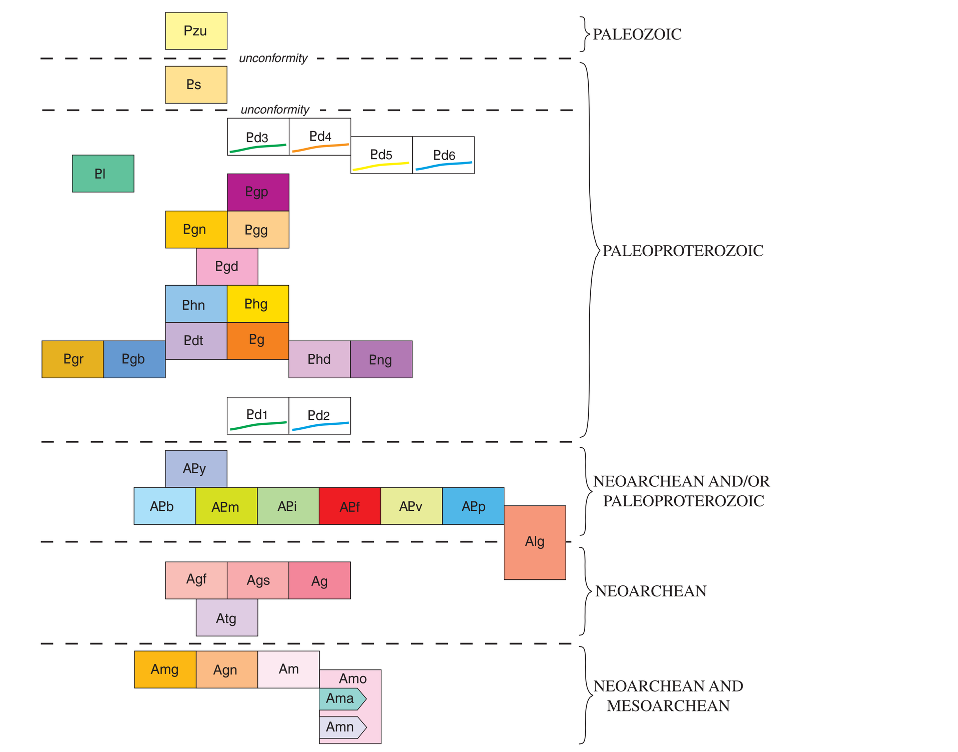
INTRODUCTION

This map shows the configuration of map units of Precambrian (Paleoproterozoic and Archean) and Paleozoic age. The outlines of individual Precambrian units are defined largely on the basis of gravity and high-resolution aeromagnetic data (Chandler, 2002). This map differs from a conventional "first pre-Quaternary" bedrock geologic map in that it does not show the distribution of the comparatively thin, horizontally bedded, Cretaceous shale and siltstone that are widely but discontinuously present above the Precambrian and Paleozoic rocks (Fig. 1).

Many Precambrian rock units depicted on this map on the basis of geophysical expression are assigned Archean or Paleoproterozoic age designations even though they have not been dated radiometrically, or in some cases even sampled. These speculative age assignments are based on either the geophysical continuity of the map unit with a dated rock unit outside the map area, or the similarity of geophysical expression of the map unit to that of a dated rock unit elsewhere. Such age assignments should be viewed as hypothetical, subject to geochronologic verification.

This map was compiled and digitized at 1:250,000-scale. Therefore, no gain in the accuracy, precision, or resolution of the map will result from enlargement.

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact, approximately located. Virtually all contacts are mapped from potential-field geophysical data.

Contact, mapped beneath Paleozoic strata.

Dike, mapped beneath Paleozoic strata.

Inferred fault, displacement sense unknown.

Inferred fault, mapped beneath the Sioux Quartzite or Paleozoic strata.

Inferred dip-slip fault; sense of displacement is indicated by U and D on upthrown and downthrown blocks, respectively.

Inferred strike-slip fault; sense of displacement indicated by arrows.

Structural form lines that approximate the general trend of gneissic layering. Lines are generalized from the digital image of the first vertical derivative of the aeromagnetic field; they are shown only in areas where the geophysical image reveals consistent, interpretable patterns.

45 Strike and dip of principal or most prominent foliation.

41 Bearing and plunge of principal or most prominent lineation.

Axial surface trace of upright antiform in gneissic rocks; arrow indicates general sense of axial plunge.

Bedrock outcrop.

Detailed mapping of bedrock outcrop. See the index to previous mapping for regional data sources.

Large area of bedrock near the land surface.

Exploration borehole, scientific borehole, or water well from which core or cuttings of Precambrian bedrock was recovered.

Location of a water well that reached Precambrian bedrock. The logs of the wells contain interpretable descriptions of the bedrock encountered, but no samples are available for verification.

2-9-94 Centroid of felt reports of a minor earthquake on the indicated date.

DESCRIPTION OF MAP UNITS

PALEOZOIC ROCKS

Pzu **Upper Cambrian sandstone and shale**—Undifferentiated as to formation, situated along the northwestern margin of the Hollandale embayment. Essentially flat-lying marine strata that unconformably overlie Precambrian rocks. Thickness of the section ranges from less than 10 feet (3 meters) along the northwest margin of the unit to more than 300 feet (91 meters) just east of the map area. Contacts of Precambrian rock units mapped geophysically beneath the Paleozoic rocks are indicated by dotted lines and the map-unit symbols for these units are in italics.

PALEOPROTEROZOIC ROCKS

Ᵽs **Sioux Quartzite**—Quartzite, hard, vitreous, red to pink, prominently cross-bedded, derived mainly from medium- to coarse-grained quartz sandstone. Thin layers of well-indurated mudstone, siltstone, and fine-grained sandstone represent less than 5 percent of the formation. The rocks are gently warped and/or tilted; master beds typically dip between 5 and 15 degrees. Faults mapped beneath the Sioux Quartzite are indicated by thick dashed lines.

Diabase dikes—Six groups of dikes are distinguished on the basis of trend, magnetic polarity, relative age, modal and geochemical composition, and petrographic attributes.

Ᵽd1 ***Reversely polarized, east-northeast to west-northwest trend (azimuth 070-110)***—Dikes are deuterically altered Fe-tholeiite in which secondary amphibole has grown extensively at the expense of primary clinopyroxene. The group includes prominent dikes exposed south of Granite Falls and south of Franklin. Two dikes near Granite Falls yield whole-rock K-Ar dates of 2080 and 1980 Ma (Hanson and Himmelberg, 1967). A dike near Franklin is dated at 2067 ± 12 Ma (U-Pb on baddeleyite; M. Schmitz, unpub. data, 1998). Petrographically, geochemically, and geochronologically these dikes closely resemble dikes of the Kenora–Kabetogama swarm (Southwick and Day, 1983) sampled north of this map area. See group Ᵽd2 below.

Ᵽd2 ***Reversely polarized, northwest trend (azimuth 125-140)***—Petrographic and geochemical attributes are unknown within the map area. Some dikes on this trend may be coextensive with the Kenora–Kabetogama swarm of northern and northwestern Minnesota and adjoining Canada, which is dated at 2076 ± 5 Ma (U-Pb on baddeleyite; Wirth and others, 1995; Buchan and others, 1996). Other reversed dikes on this trend may be substantially younger.

Ᵽd3, Ᵽd4 ***East-northeast trend (azimuth 075-085)***—Dikes of groups Ᵽd3 and Ᵽd4 cut Paleoproterozoic plutonic rocks in the eastern and southern parts of the map. Group Ᵽd3 is reversely polarized and group Ᵽd4 is normally polarized. Their trends and geophysical characteristics are similar to those of olivine tholeiite dikes in the St. Cloud area that cut rocks dated at approximately 1775 Ma (Van Schmus and others, 2001). The dikes themselves are undated.

Ᵽd5, Ᵽd6 ***North-northwest trend (azimuth 000-170)***—Dikes of groups Ᵽd5 and Ᵽd6 are associated with strong, pervasive geophysical anomalies and are interpreted to be relatively thick. Group Ᵽd5 is normally polarized and group Ᵽd6 is reversely polarized. No petrologic or geochronologic data are available.

Ᵽl **Lamprophyre, syenite, hornfels, and skarn**—The geophysical anomaly generated by an inferred intrusion near Garvin, in Lyon County, consists of high gravity and low magnetic signatures. This uncommon combination is suggestive of lamprophyre. Test hole SWG-5 intersected hornblende hornfels, marble, scapolite-vesuvianite skarn, and metasomatic garnet-biotite-calcite veins; these rocks are interpreted to have been produced by contact metamorphism in the roof zone of the lamprophyre intrusion (Southwick and others, 1993).

Ᵽgo **Gabbro, pyroxenite, hornblende gabbro, and hornblende diorite**—Small, pipe-like or plug-like intrusions, some of which are compositionally zoned; zoned bodies may contain minor amounts of granodiorite in addition to the dominant mafic, ultramafic, and intermediate rock types. Includes the Cedar Mountain Complex south of Franklin, dated by whole-rock Rb-Sr methods at approximately 1750 Ma (Goldich and others, 1970), and ultramafic plugs in the Minnesota River Valley northwest of Franklin.

Ᵽgg **Granite and granodiorite**—Geophysical expression resembles that of the Foley Granite of east-central Minnesota (Jirsa and Chandler, 1997).

Ᵽgn Non-magnetic border phase of granitic plutons cored by unit Ᵽgg. Interpreted provisionally as leucogranite.

Ᵽgd **Granite and granodiorite**—Inferred from geophysical expression to be similar to, or possibly equivalent to the Rockville Granite of the St. Cloud area (Jirsa and others, 1995; Boerboom and Holm, 2000).

Ᵽhg **Biotite-hornblende granite, monzogranite, and monzodiorite**—May include lesser amounts of diorite, tonalite, and mafic rock types. Rock recovered from core hole SQ-5 (102-36-11DDDD) is a mesocratic quartz monzodiorite petrographically similar to the Reformatory Granite at its type locality near St. Cloud. The rock in SQ-5 yields a discordant U-Pb zircon date of 1792 ± 31 Ma (Peterman, as reported in Southwick, 1994).

Ᵽhn Magnetic border phase of granitoid plutons cored by unit Ᵽhg. Interpreted provisionally as syenite-rich diorite or gabbro.

Ᵽhd **Diorite and tonalite**—May include lesser amounts of granite, monzogranite, monzodiorite, and gabbro.

Ᵽng **Norite and gabbro**—Geophysically continuous with rock sampled by core drilling near Spencer, Iowa (Yaghubpur, 1979).

Ᵽg **Granite**—In the southeast corner of the map beneath Paleozoic strata, it occupies the centers of compositionally zoned plutons in which the outer portions are denser, more magnetic rocks interpreted to be diorite, tonalite, and gabbro. Also forms isolated small plutons including a lensoid mass located west of Garvin. Relationships to granite and granodiorite units Ᵽgg and Ᵽgr are unknown.

Ᵽdt **Diorite, tonalite, and gabbro**—Relatively magnetic and dense rocks that form the outer parts of zoned plutons in which the central parts are granite of unit Ᵽg. Similar if not identical rocks are interpreted to form discrete, irregularly shaped plutons of various sizes throughout the map area. Rocks within some of the discrete plutons may be related to the gabbroic and dioritic rocks of unit Ᵽgo.

Ᵽgb **Gabbro**—Fresh, two-pyroxene gabbro that forms discrete, widely scattered, stock-like intrusions. Several intrusions contain centrally located small bodies of low-density rock; these are mapped provisionally as granite (unit Ᵽgr).

Ᵽgr **Granite**—Forms the central parts of small, epizonal intrusions that are mainly gabbro; also forms independent small plugs and lenses. The Section 28 granite of Goldich and others (1970), located north of Granite Falls, is assigned provisionally to this map unit. The Section 28 granite yields a whole-rock Pb-Pb age of 1840 ± 50 Ma (Doe and Delevaux, 1980).

NEOARCHEAN AND/OR PALEOPROTEROZOIC ROCKS

Aᵽy **Mylonitic rocks**—Associated with the Yellow Medicine shear zone.

Aᵽb **Biotite schist**—In part mylonitic, located within and near the Yellow Medicine shear zone.

Aᵽm **Felsic metavolcanic rocks and their metaclastic equivalents**—Presence inferred from geophysical expression.

Aᵽi **Mafic to intermediate metavolcanic rocks.**

Aᵽf **Iron-formation**—Oxide-facies iron-formation mapped aeromagnetically and verified by very sparse drilling. Exploration hole E-1, drilled by New Jersey Zinc near Hendricks in Lincoln County, cut iron-formation that possesses oolitic to pelletoidal texture, and on that basis is inferred to be of Paleoproterozoic age.

Aᵽv **Mafic volcanic and volcaniclastic rocks**—Deformed and metamorphosed under conditions of the upper greenschist to amphibolite facies. Includes pillowed metabasalt and mafic breccia that crop out north of St. Leo in Yellow Medicine County.

Aᵽp **Peridotite and related ultramafic rocks**—Variably metamorphosed to serpentinite, talc-actinolite schist, and essentially monomineralic actinolite rock.

NEOARCHEAN ROCKS

Alg **Leucogranite**—In part mylonitic, located within and near the Yellow Medicine shear zone.

Ag **Granite**—Mapped exclusively from geophysical expression. Much of this unit is probably the same age as the Sacred Heart granite (Ags) or the Fort Ridgely granite (Agf).

Agf **Fort Ridgely granite**—Granite, biotite-bearing, massive to weakly foliated, medium- to coarse-grained, pink to gray.

Ags **Sacred Heart granite**—Granite, biotite-bearing, medium-grained, pink to gray. Rock is massive except near contacts with wall rocks where it is moderately foliated and locally gneissic. Yields a discordant whole-rock Pb-Pb age of 2605 ± 6 Ma (Doe and Delevaux, 1980).

Atg **Tonalite and granodiorite, undivided**—Forms large, poorly defined intrusive masses toward the eastern edge of the map area and in the west-central area west and north of Russell. The eastern mass is mostly beneath Paleozoic strata. Moderately foliated biotite-hornblende tonalite from core hole SQ-8 (Watonwan County, 107-31-11BCCC) yields a discordant U-Pb zircon date of 2624 ± 57 Ma (Van Schmus, reported in Southwick, 1994).

NEOARCHEAN AND MESOARCHEAN ROCKS

Agn **Granitic to tonalitic gneiss of the Jeffers block**—Drill samples include diverse quartzofeldspathic gneisses that are lithologically similar to gneisses of the Morton and Montevideo blocks (Fig. 2; Southwick and Chandler, 1996); however, temporal and genetic relationships to the Morton and Montevideo Gneisses (units Am and Amo, respectively) have not been established.

Amg **Mafic gneiss of the Jeffers block**—Inferred from geophysical expression.

Am **Morton Gneiss**—Gneiss complex composed of several intermingled rock types of generally quartzofeldspathic composition. The most voluminous variants exposed along the Minnesota River are: 1. Homogeneous, medium- to coarse-grained biotite tonalite gneiss that contains scattered inclusions of amphibolite; 2. Strongly layered tonalite gneiss (layers centimeters to decimeters in thickness) that contains conformable sheets and disconformable blocks of amphibolite; 3. Homogeneous, coarse-grained to pegmatitic granodiorite gneiss; 4. Massive, fine- to medium-grained granoblastic leucogneiss of granodiorite and tonalite composition; and 5. Anatectic granite. Rock types 1 through 4 are shades of gray; rock type 5 is pink. "Rainbow granite" building stone, quarried at Morton, is a somewhat local variant in which the pink anatectic phase is uncommonly abundant. The principal gneissic layering in the Morton Gneiss is subhorizontal and folded into broad warps that plunge gently to the northeast. Geochronologically, the Morton Gneiss yields published dates that range between 3624 ± 46 Ma on rock type 1 (discordant U-Pb zircon determination; Goldich and Fischer, 1986) and 3043 ± ? Ma on rock type 5 (whole-rock Pb-Pb determination; Goldich and Wooden, 1980). See Goldich and Wooden (1980) for detailed interpretations of the geochronologic data.

Amo, Ama, Amn **Montevideo Gneiss**—Gneiss complex composed of diverse quartzofeldspathic rock types of probable intrusive origin and interstratified mafic and aluminous rock types of probable supracrustal origin, at least in part. Mapped as unit Amo where undivided. The most abundant quartzofeldspathic variant is a medium-grained, biotite-bearing, streakily layered gray to gray-pink gneiss of generally granodioritic composition; this rock type yields dates as old as 3680 ± 70 Ma (whole-rock Rb-Sr determination; Goldich and others, 1980). Gneiss varieties mapped separately in the vicinity of Granite Falls (after Himmelberg, 1968) are hornblende-pyroxene granulite and amphibolite of basaltic composition (unit Ama), and biotite-garnet gneiss of broadly graywacke-like composition (unit Amn). The principal gneissic layering in all components of the Montevideo Gneiss forms low-amplitude folds that plunge gently to the northeast. Earlier minor folds of several generations are reoriented by the regional broad warps. See Bauer (1980) and Goldich and others (1980) for detailed interpretations of structure, geochemistry, and geochronology.

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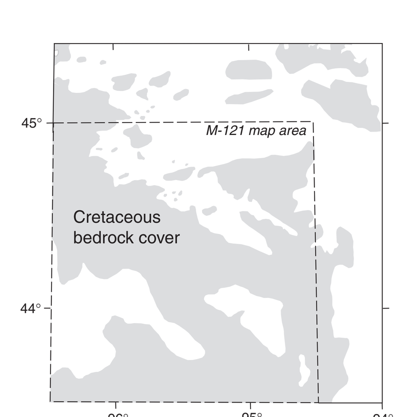


Figure 1. Sketch map showing the distribution of Cretaceous bedrock cover in southwestern Minnesota (modified from Setterholm, 1990; Patterson and others, 1999).

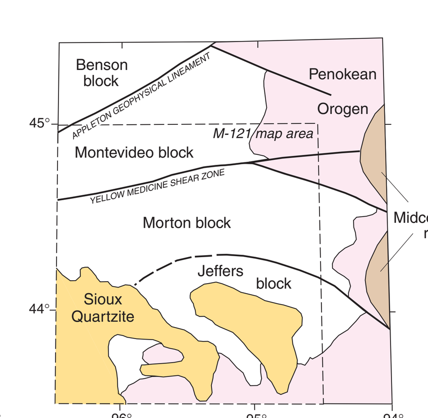
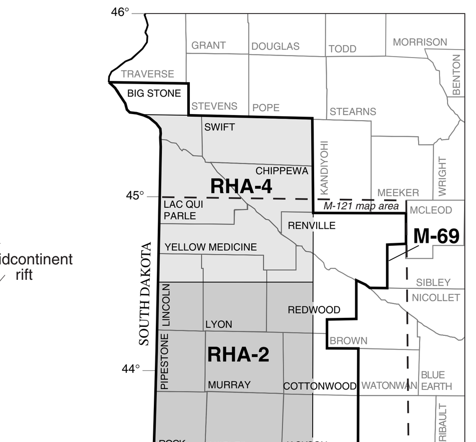


Figure 2. Tectonic sketch map of Precambrian terranes in southwest Minnesota showing subdivision of the Archean Minnesota River Valley subprovince (white), Paleoproterozoic Penokean Orogen (pink) and Sioux Quartzite (orange), and Mesoproterozoic Midcontinent rift system (brown). Paleozoic and Cretaceous cover is not shown. Modified from Southwick and others, 1993.



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M-69 (Setterholm, 1990)
RHA-2 (Setterholm, 1995)
RHA-4 (Patterson, 1999)