SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
GEOLOGICAL SURVEY PROGRAM
7.5 MINUTE SERIES GEOLOGIC QUADRANGLE MAP 31

GEOLOGIC MAP OF THE NEMO QUADRANGLE, SOUTH DAKOTA

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2020

State of South Dakota
Kristi Noem, Governor

South Dakota Geological Survey
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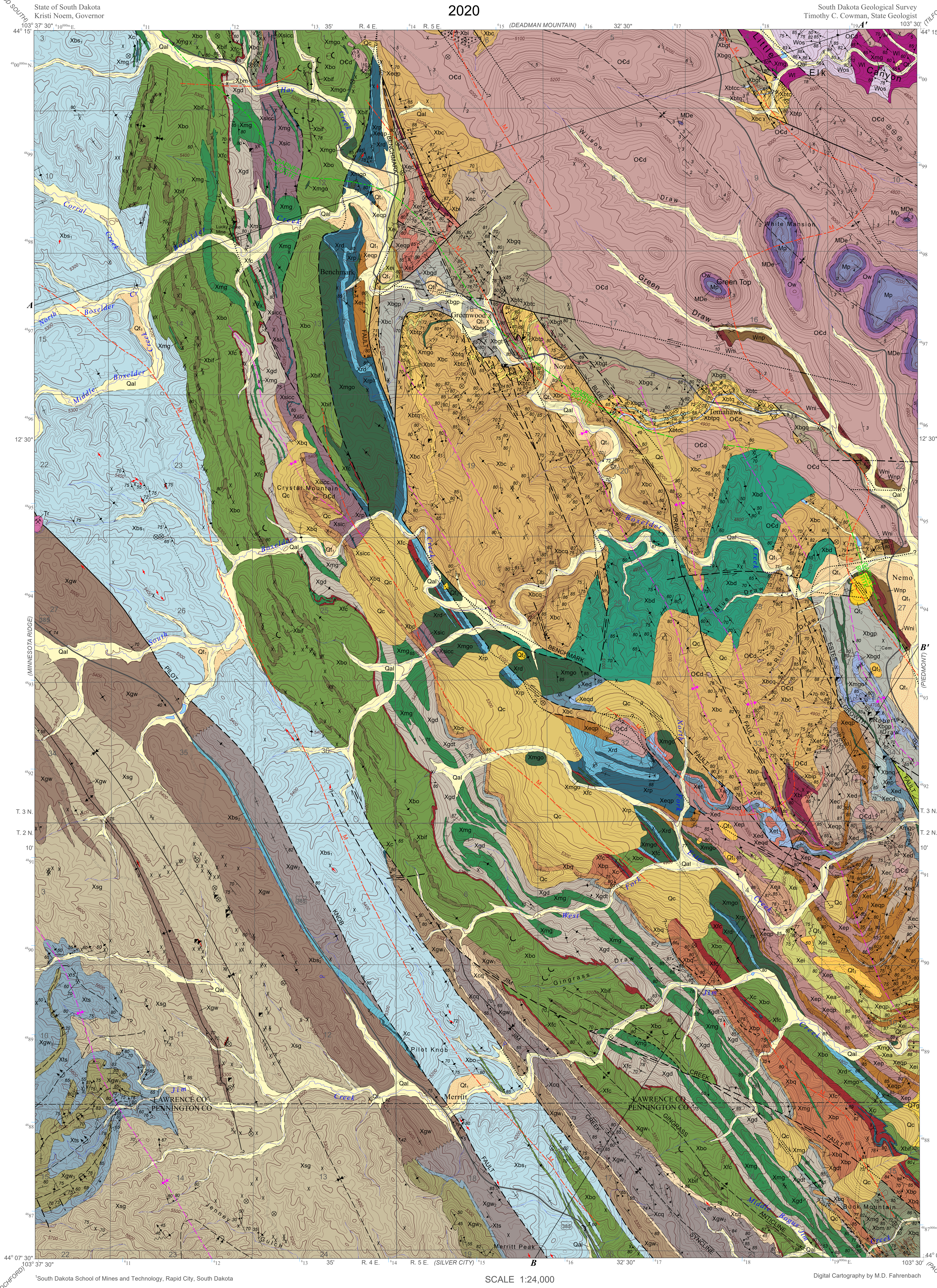

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Digital Cartography by M.D. Fahrenbach

Map base modified from U.S.G.S. 1:24,000-scale Nemo quadrangle digital line graph.
Projection is Universal Transverse Mercator, Zone 13 N.
Datum is 1983 North American.

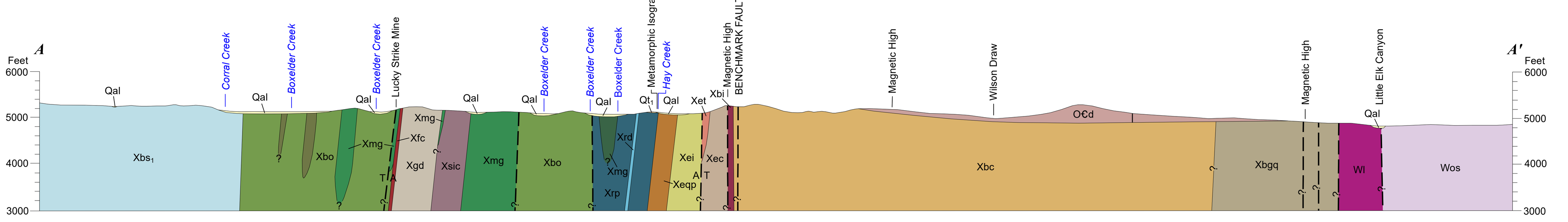
The Geological Survey Program, South Dakota Department of Environment and Natural Resources, engages in an ongoing data collection and interpretation process. An outcome of that process is to reflect those interpretations on maps such as this one. Reasonable efforts have been made to ensure that this map accurately reflects the source data used in its preparation. This map is date specific. As additional data become available, geologic interpretations may be revised and the map may be updated by the Geological Survey Program. This map should not be enlarged or otherwise used in an attempt to interpret more detail than can be seen at the 1:24,000 scale.

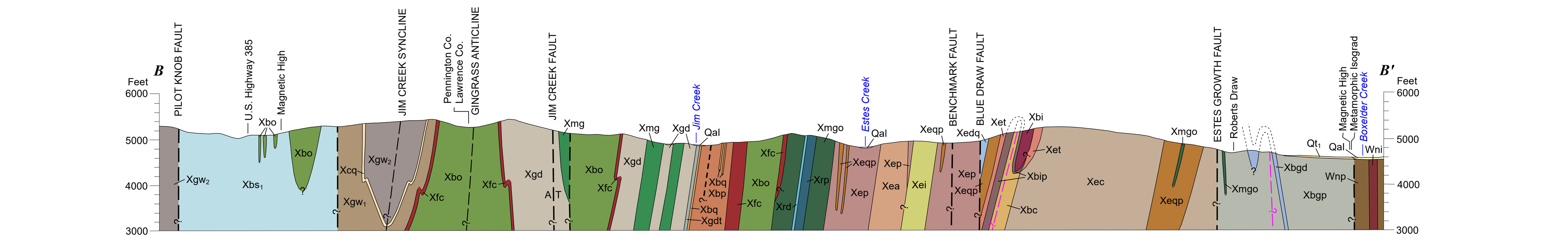
SCALE 1:24,000

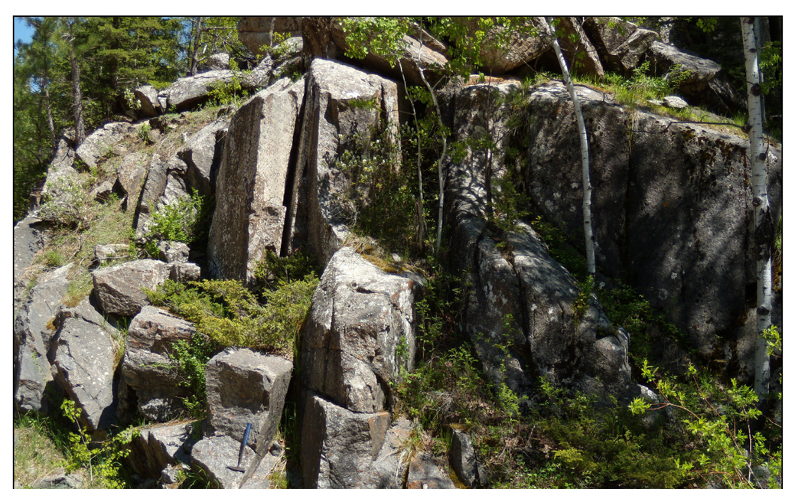
CONTOUR INTERVAL 20 FEET

UTM GRID AND 2020 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION





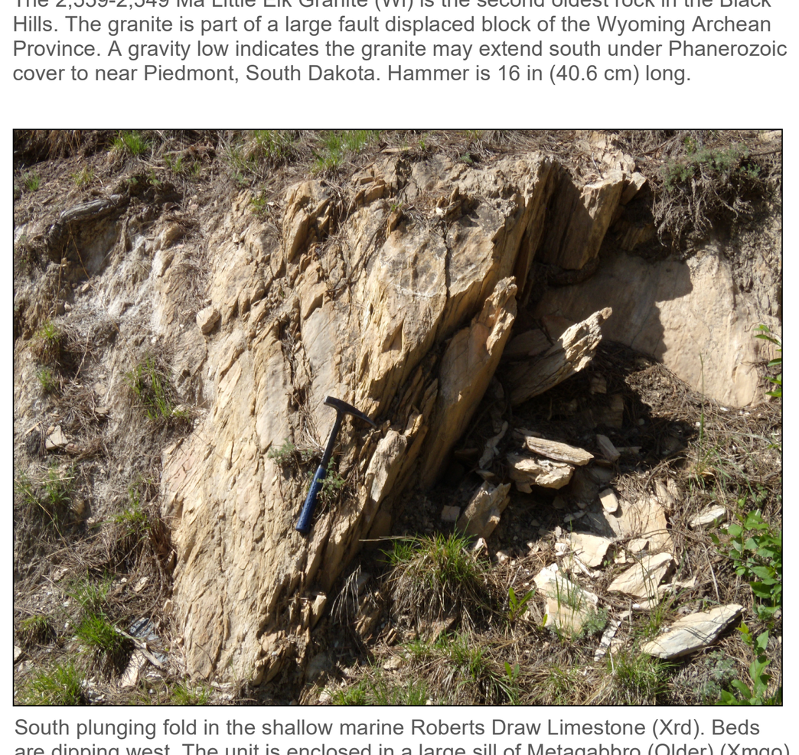


The 2,559-2,549 Ma Little Elk Granite (Wl) is the second oldest rock in the Black Hills. The granite is part of a large fault displaced block of the Wyoming Archean Province. A gravity low indicates the granite may extend south under Phanerozoic cover to near Piedmont, South Dakota. Hammer is 16 in (40.6 cm) long.

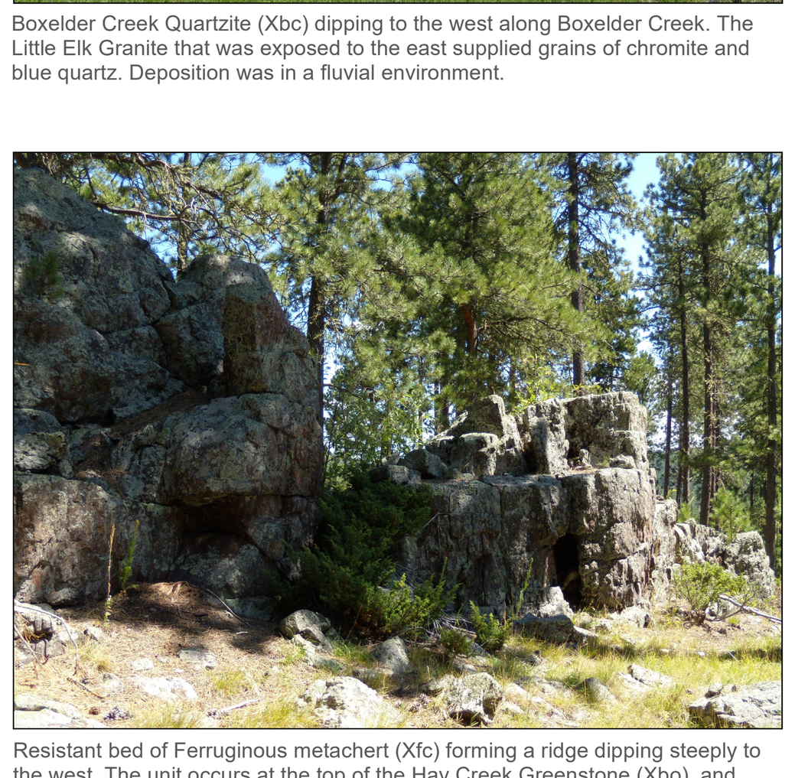
Boxelder Creek Quartzite (Xbc) dipping to the west along Boxelder Creek. The Little Elk Granite that was exposed to the east supplied grains of chromite and blue quartz. Deposition was in a fluvial environment.

Metaconglomerate, quartzite, and chloritic schist (Xbgq) in the Greenwood Tongue of the Boxelder Creek Quartzite (Xbq). Clasts are dominantly quartzite, metachert, and taconite and have been greatly flattened and elongated perpendicular to compressional stress. The soft, chloritic schist is deformed around the clasts.

Fractured amphibolite of the Blue Draw Metagabbro (Xbd), a large gravity differentiated sill that intruded the Boxelder Creek Quartzite (Xbc). At 2,484-2,480 Ma, it is the earliest mafic magmatism in the Black Hills.



South plunging fold in the shallow marine Roberts Draw Limestone (Xrd). Beds are dipping west. The unit is enclosed in a large sill of Metagabbro (Older) (Xmgo) which is out of view. Hammer is 16 in (40.6 cm) long.



Resistant bed of Ferruginous metachert (Xfc) forming a ridge dipping steeply to the west. The unit occurs at the top of the Hay Creek Greenstone (Xbo), and typically has thin, light and dark laminae and is iron-stained.

Quartz veins in a narrow shear zone in Metagraywacke (Xgw). The veins were later deformed and folded.

Prospect pit with rounded boulders of Benchmark Iron-Formation (Xbi) at the base of the Deadwood Formation (O€d). Wave action has washed the clasts into an elongate spit on the leeward side of the island-forming, iron-formation outcrop. The boulders grade laterally into sandstone.

EXPLANATION

QUATERNARY

Qal — Alluvium - Unconsolidated to poorly consolidated, angular to rounded clay to boulder-size clasts. Deposited in present-day stream drainages and on flood plains. Estimated maximum thickness up to 35 ft (10.7 m)

Qc — Colluvium - Unconsolidated angular rock debris to boulder-size mixed with soil. Typically deposited on steep slopes below resistant rock units

Qt_1 — Terrace deposit 1 - Unconsolidated to poorly consolidated, angular to rounded clay to boulder-size clasts. Deposited as much as 40 ft (12.2 m) above present stream levels. Typically less than 20 ft (6.1 m) thick

Qt_2 — Terrace deposit 2 - Unconsolidated to poorly consolidated, angular to rounded clay to boulder-size clasts. Deposited approximately 40-80 ft (12.2-24.4 m) above present stream levels. Typically less than 20 ft (6.1 m) thick

Qt_3 — Terrace deposit 3 - Unconsolidated to poorly consolidated, angular to rounded clay to boulder-size clasts. Deposited approximately 80-120 ft (24.4-36.6 m) above present stream levels. Typically less than 20 ft (6.1 m) thick

Unconformity

TERTIARY — Pliocene-Eocene; Eocene-Paleocene

QTg — Gravel deposit - Unconsolidated to poorly consolidated, angular to rounded clay to boulder-size clasts. Generally gravel at surface, but artificial exposures may disclose pinkish bentonitic beds at depth. Based on elevation, interpreted to be equivalent to known Oligocene White River Group deposits in adjacent areas. Thickness up to 30 ft (9.1 m)

Tr — Rhyolite - Leucocratic, tan to pinkish white, weathering gray to yellowish-brown and iron-stained. Finely crystalline to aphanitc groundmass dominantly of potassium feldspar. Locally flow banded

Unconformity

MISSISSIPPIAN — Lower Mississippian

Mp — Pahasapa Limestone - Limestone and dolomite, beige to white, medium- to thick-bedded, finely to coarsely crystalline. Typically vuggy to cavernous. Exposed thickness as much as 180 ft (54.9 m)

DEVONIAN — Upper Devonian

MDe — Englewood Formation - Shale, limestone, dolomitic limestone, and dolomite. Pale-purple, reddish-purple, to pinkish-gray. Typically bioturbated. Shaly beds thinly laminated and fissile. Carbonate beds are thin- to medium-bedded, finely crystalline; some are bioclastic. Thickness 35-60 ft (10.7-18.3 m)

Disconformity

ORDOVICIAN — Upper Ordovician

Ow — Winnipeg Formation - Shale, gray to greenish-gray, fissile to thin-bedded. Thickness 40-60 ft (12.2-18.3 m). May include Whitewood Limestone which is too thin to differentiate at this map scale

Disconformity

Lower Ordovician; **CAMBRIAN** — Upper Cambrian

O€d — Deadwood Formation - Glauconitic sandstone, shale, limestone pebble conglomerate, and local basal conglomerate. Thick-bedded, massive, iron-stained orthoquartzite from 55-90 ft (16.8-27.4 m) thick occurs at the top of the formation, becoming shaly in the middle. Cross pattern indicates basal conglomerate of angular to rounded clasts of Benchmark Iron-Formation (Xbi) as much as 3 ft (0.9 m) across. Some portions lack matrix and are clast supported. Located in the center of section 6, T. 3 N., R. 5 E. Thickness of formation 350-425 ft (106.7-129.5 m)

Unconformity

PRECAMBRIAN — Lower Proterozoic

Xsg — Swede Gulch Formation - Slate and phyllite, gray, black, and greenish-tan, thin- to medium-bedded. The lower portion contains one to two beds of thick-bedded streaky ferruginous metachert overlain by graphitic slate and schist (Bayley, 1972b). Includes thin graphitic and pyrrhotite-bearing subunits. Calc-silicate concretions occur locally in quartzose Bouma A metagraywacke units. Initially included with the undivided Roubaix Group of Berg (1946). Later mapped as part of the Roubaix Formation (Bayley, 1972a), then subdivided and named for exposures along Swede Gulch on the Rochford quadrangle (Bayley, 1972b). Protolith is shale

Xgw — Metagraywacke - Quartz-mica schist, phyllite, and quartzose schist. Gray to brownish- and reddish-gray. May be equivalent in part to Xgw_1, Xgw_2, and Xgw_3. Initially mapped as part of the Roubaix Formation by Bayley (1972a). Protolith is distal to proximal turbidite deposits

Unconformity ?

Xgw_3 — Metagraywacke unit 3 - Quartzose schist and phyllite, tan to gray, thin- to thick-bedded. Calcareous and calc-silicate concretions occur locally in quartzose Bouma A beds. Protolith is proximal graywacke deposits with minor shale interbeds

Xts — Tenderfoot Formation - Micaceous phyllite and schist, green to silver-gray, thin-bedded. Typically has accessory magnetite and ilmenite. Locally with malachite-stained muscovite-rich schist and thin spessartine-bearing beds. Includes some metagraywacke beds that are difficult to distinguish from adjacent metagraywacke units. Equivalent to ash flow tuffs in the Rochford quadrangle which have a Pb^{207}/Pb^{206} zircon age of 1,884 +/- 29 Ma (Redden and others, 1990). Protolith is submarine weathered volcanic tuff and shale

Xc — Metachert - Light- and dark-banded, finely to medium crystalline. Typically associated with the Ferruginous metachert (Xfc), but also occurs at other stratigraphic levels. Protolith is likely submarine thermal spring deposits

Xbs_2 — Biotite schist and phyllite - Biotite-garnet schist, gray to black, thin-bedded, and phyllite and quartz-mica schist, gray to tan. Some beds contain abundant garnet, graphite, or pyrite. Equivalent in part to the Oreville Formation of the southern Black Hills. Protolith is black shale and siltstone

Xgw_2 — Metagraywacke unit 2 - Quartzose schist and phyllite. Tan to gray, thick- to thin-bedded. Calcareous and calc-silicate concretions occur locally in quartzose Bouma A beds

Xcq — Metaconglomerate, quartzite, and metapelite - Schist, quartzite, and metaconglomerate. Gray, dark-gray, and tan, thin- to thick-bedded. Clasts are mainly quartzite in a pelitic matrix. Includes subunits of metagraywacke that increase in abundance in a northwesterly direction as metaconglomerate and quartzite decrease. May be equivalent to part of Metagraywacke unit 2 (Xgw_2). Protolith is debris flow deposits

Unconformity

Xgw_1 — Metagraywacke unit 1 - Quartzose schist and phyllite. Tan to gray, thick- to thin-bedded. Calcareous and calc-silicate concretions occur in quartz-rich Bouma A beds

Xmg — Metagabbro - Amphibolite and chloritic amphibole schist. Occurs as greenish-gray sills and dikes. Finely to medium crystalline except where sheared or well foliated. A Pb-Pb zircon age of 1,883 +/- 5 Ma was obtained from a sill in the Pactola Dam quadrangle (Redden and others, 1990). It is uncertain that all bodies shown as Xmg are of the same age

Xsicc, Xsic — Schist, metachert, and iron-formation - **Xsic**- Schist, phyllite, and banded metachert with iron-rich carbonate units. Grayish-tan. Includes biotite-feldspar schist derived from tuffaceous beds. May be a facies of the Gingrass Draw Slate (Xgd) (Redden and DeWitt, 2008). Age estimated at 2,015-1,975 Ma (Dahl and others, 2006). **Xsicc** - Banded metachert. Thick-bedded, iron-stained and sulfide-bearing

Xbq, Xbp, Xbm — Buck Mountain Quartzite - **Xbm** - Phyllite, gray to olive-drab, and quartzite and quartzose slate, tan, gray, to white, thin- to thick-bedded (Bayley, 1972a). Metasiltstone beds contain abundant ripple marks. Age 2,170-1,960 Ma (Redden and others, 1990). Protolith of formation is shallow shelf deposits of sandstone, siltstone, and shale. Type locality at Buck Mountain, section 15, T. 2 N., R. 5 E. (Bayley, 1972a). **Xbq** - Quartzite, tan, gray, to dark bluish-gray, fine- to medium-grained, thin- to thick-bedded. **Xbp** - Dominantly phyllite, gray, greenish-gray, to reddish-brown, laminated to thin-bedded, with sparse quartzite beds. A thick-bedded, massive quartzite occurs at the base

Xgdt, Xgd — Gingrass Draw Slate - **Xgd** - Slate and phyllite, olive-drab to tan, thin-bedded. (Bayley, 1972a). Upper portion contains thin quartzite and metasilt beds that increase in abundance to the southeast in the Pactola Dam quadrangle, and are very difficult to distinguish from parts of the Buck Mountain Quartzite (Xbm). Age of 1,974 +/- 8 Ma (Dahl and others, 2006). Protolith of formation is likely reworked submarine volcanic tuff and shale. Type locality in the vicinity of Gingrass Draw, sections 5 and 8, T. 2 N., R. 5 E. (Bayley, 1972a). **Xgdt** - Tuffaceous garnetiferous biotite-rich phyllite and schist, gray to black, thin-bedded. Occurs at top of formation

Xbs_1 — Reausaw Slate - Biotite phyllite, garnet schist, and graphitic slate and schist. Reddish-brown, dark-gray, to black. Laminated to thin-bedded, fissile, very fine-grained, carbonaceous. Contains sulfides, iron carbonate, and thin veinlets of milky quartz. Includes units of magnetic cherty ferruginous schist with grunerite or cummingtonite. Intertongues with the Hay Creek Greenstone (Xbo) in section 6, T. 2 N., R. 5 E. Unit is poorly exposed. Protolith is black shale with thin chert beds and minor siltstone (Bayley, 1972a)

Xmgo — Metagabbro (Older) - Amphibolite, greenish-gray to black. Finely to medium crystalline, massive to schistose sills and dikes. Dahl and others (2006) estimate an age of 2,015-1,975 Ma. A sill 0.75 mi (1.2 km) southeast of Green Mountain on the Piedmont quadrangle has a Pb-Pb zircon age of 1,964 +/- 15 Ma (Redden and others, 1990). It is uncertain that all bodies shown as Xmgo are of the same age. Inferred to be comagmatic with the Hay Creek Greenstone (Xbo). Protolith is gabbroic sills and dikes

Xfc — Ferruginous metachert - Metachert, magnetic cherty ferruginous schist, and carbonate-facies iron-formation. Thin- to thick-bedded and massive. Interlayered with lenses of minor sulfidic and graphitic phyllite. Locally transitional to carbonate facies iron-formation. Forms prominent iron-stained outcrops. Protolith is likely submarine thermal spring deposits

Xbo, Xbif — Hay Creek Greenstone - **Xbo** - Tholeiitic metabasalt and amphibolite (Bayley, 1972a). Grayish-green, pale olive-green, moderate yellowish-green, to black. Very finely to moderately crystalline, often having a speckled appearance. May have a moldic texture from dissolved amphibole laths. Contains pillow structures. Typically highly fractured. Intertongues with unit Xbs_1 in section 6, T. 2 N., R. 5 E. Type locality north of Hay Creek, particularly section 1, T. 3 N., R. 4 E. (Bayley, 1972a). Age 2,020-1,970 Ma (Frei and others, 2008) to 1,974-1,964 Ma (Redden and others, 1990). Inferred to be comagmatic with Metagabbro (Older) (Xmgo). Protolith is pillowed tholeiitic basalt flows with interflow deposits of volcanic tuf and carbonaceous shale, and chert from submarine thermal spring deposits. **Xbif** - Interflow deposit of thin- to thick-bedded and massive, banded ferruginous metachert with carbonaceous slate and phyllite, and carbonate-facies iron-formation

Xrp, Xrd — Roberts Draw Limestone - **Xrd** - Siliceous limestone and dolomite, tan to gray, finely to medium crystalline. Typically thick-bedded, locally containing lenses of pebbly metaconglomerate and quartzite (Bayley, 1972a). Very rare small stromatolites occur in the more pure dolomite units. Age of formation approximately 2,170-1,960 Ma (Redden and others, 1990) to 2,100-2,015 Ma (Dahl and others, 2006). Protolith is shallow marine limestone and siliceous shale. **Xrp** - Slate and phyllite, greenish-gray, dark-gray, to black. Thin- to medium-bedded, locally graphitic. Contains 5-25% dolomite and thin quartzose beds. Some magnetite occurs where adjacent to carbonate beds

Xea, Xei, Xeqd, Xecd, Xed, Xep, Xeqp, Xec, Xet — Estes Formation - Subdivided from the Estes System of Runner (1934). Age approximately 2,170-1,960 Ma (Redden and others, 1990) to 2,100-2,015 Ma (Dahl and others, 2006). Protolith is heterogeneous intertonguing marine fan sediments deposited west of the Estes Growth Fault in a rifting environment. Deposition was contemporaneous with faulting. Part of type locality north of Bogus Jim Creek, section 10, T. 2 N., R. 5 E. (Bayley, 1972a). Includes Xea, Xei, Xeqd, Xecd, Xed, Xec, Xep, Xeqp, and Xet. **Xea** - Arkosic quartzite and metagrit with local phyllite interbeds. Medium- to coarse-grained, medium- to thick-bedded. Contains pink feldspar and blue quartz. **Xei** - Interbedded quartzite, phyllite, and arkose. **Xeqd** - Dolomitic quartzite. **Xecd** - Metaconglomerate with dolomite matrix. **Xed** - Dolomite, dolomitic quartzite, chloritic quartzite, and phyllite. Siliceous, medium- to thick-bedded. Grades laterally into dolomite-cemented conglomerate. **Xec** - Metaconglomerate, metaparaconglomerate, and impure quartzite. Thick-bedded, massive, fining upward and laterally. Clasts to boulder-size of taconite, metachert, phyllite, quartzite, and rarely dolomite. **Xep** - Phyllite, gray to dark-gray. Thin- to medium-bedded, interbedded with arkose and quartzite. **Xeqp** - Quartzite, gray, tan, to grayish-white. Medium- to coarse-grained, thin- to thick-bedded, typically feldspathic. Includes medium-gray phyllite and lenses of metaconglomerate. **Xet** - Taconitic metaconglomerate with angular to subrounded clasts to cobble-size derived from the Benchmark Iron-Formation (Xbi). Thick-bedded

Unconformity

Xbd — Blue Draw Metagabbro - Serpentine, hornblendite, and amphibolite. Grayish-green to grayish blue-green, homogeneous to foliated and schistose, gravity differentiated sill dipping steeply northwest. Consists of a mafic lower cumulate zone altered to serpentine, an interior of hornblendite and amphibolite that is transitional to diorite, and an uppermost discontinuous biotite-granodiorite that is locally granitic. Carbonate replacement of the country rock is typical near contacts. Thickness approximately 3,281 ft (1000 m). The upper granitic to granodioritic differentiate yielded a $^{207}Pb/^{206}Pb$ age of 2,480 +/- 6 Ma (Dahl and others, 2006), and a U-Pb age of 2,484 +/- 11 Ma (Redden and DeWitt, 2008)

Unconformity

Xbi, Xbip — Benchmark Iron-Formation - **Xbi** - Banded metachert and magnetite-hematite taconitic iron-formation, thin- to medium-bedded. Approximately 30 percent iron (Bayley, 1972a). Age of formation estimated to be greater than 2,170 Ma (Redden and DeWitt, 2008) to 2,560-2,480 Ma (Dahl and others, 2006). Type locality northeast of Benchmark in W 1/2, section 7, T. 3 N., R. 5 E. (Bayley, 1972a). **Xbip** - Phyllite, gray to black, thin-bedded

Xbcq, Xbc, Xbtp, Xbtcc, Xbtpq, Xbtq, Xbtc, Xbnq, Xbgp, Xbgc, Xbgd, Xbgq, Xbgt — Boxelder Creek Quartzite - Includes the Greenwood, Novak, and Tomahawk tongues that are gradational into overlying quartzite

Boxelder Creek Quartzite - **Xbc** - Quartzite, grayish-white to tan. Thick-bedded, medium- to coarse-grained, having abundant small-scale trough and planar cross bedding. Includes quartz-muscovite schist but very little chlorite (Bayley, 1972a). Thickness appxoximately 10,000 ft (3,047.8 m). Age estimated to be greater than 2,170 Ma (Redden and DeWitt, 2008) to 2,560-2,480 Ma (Dahl and others, 2003). Protolith is fluvial and alluvial fan deposits in a rift environment. Type locality along Boxelder Creek, section 20, T. 3 N., R. 5 E. (Bayley, 1972a). **Xbcq** - Quartzite, thick-bedded, massive

Tomahawk Tongue
Dominantly interbedded granular quartzite and metaconglomerate. Micaceous, fuschitic, pyritic, and iron-stained. Thin- to thick-bedded, with abundant trough and planar cross bedding in granular quartzite beds. Metaconglomerate beds are uraniferous and generally ungraded, with some having reverse grading, and intertongue with quartzite to the west. Taconite clasts are absent. Coarsens to the east, and is interpreted to be alluvial fan deposits having an eastern source. Thickness approximately 400 ft (121.9 m) (Redden, 1980). Includes Xbtp, Xbtcc, Xbtpq, Xbtq, and Xbtc. **Xbtp** - Phyllite, gray to green. Locally with metachert pebbles. Thin- to medium-bedded overbank deposit. Poorly exposed. **Xbtcc** - Pyritic cobble metaconglomerate. Typically matrix supported. **Xbtpq** - Pebbly granule quartzite. **Xbtq** - Granular quartzite and metagrit, gray, tan, to greenish-gray. Thick- to medium-bedded, pyritiferous, and uraniferous. Blue quartz grains common. Locally with pebble-size clasts and metaconglomerate beds. **Xbtc** - Pebble metaconglomerate grading to metagrit. Clasts of metachert, vein quartz, quartzite, and phyllite are matrix to grain supported. Pyritiferous, uraniferous, and auriferous. Typically has chromite and fuchsite. Only thicker units shown

Novak Tongue
Dominantly chloritic quartzite and metaconglomerate having taconite clasts. Interpreted to be an alluvial fan deposit having an eastern source, and intertonguing with quartzite to the west. Includes Xbnq. **Xbnq** - Chloritic quartzite, green to gray. Thin- to medium-bedded. Locally with few pebble-size clasts and thin phyllite interbeds

Greenwood Tongue
Interbedded, coarse- to fine-grained, chloritic, with few angular clasts of taconite and grains of blue quartz. Most other clasts are typically well-rounded. Bedding is generally thick to unrecognizable in poorly sorted units. Cross bedding absent except in chloritic quartzites. Contacts gradational, lithologies fine laterally. Accessory magnetite is common. Protolith is alluvial fan deposits having a western source, and intertonguing with marine deposits to the northeast. Includes Xbgp, Xbgc, Xbgd, Xbgq, and Xbgt. **Xbgp** - Chloritic phyllite, green. Moderately well-bedded with local chloritic quartzite. **Xbgc** - Chloritic metaparaconglomerate with metachert, quartzite, taconite, and rare phyllite and dolomite clasts. Thick-bedded. **Xbgd** - Dolomite, light-tan to gray, weathers brown. Medium-bedded, siliceous. **Xbgq** - Chloritic quartzite, greenish-tan, with metaparaconglomerate and metaconglomerate. Medium- to thick-bedded with some trough cross bedding. Clasts are metachert, quartzite, and taconite. Locally with blue quartz grains and typically magnetite-bearing. **Xbgt** - Taconitic metaconglomerate, reddish-black. Thick-bedded, gradational to chloritic quartzite or conglomerate. Clasts derived from the Nemo Iron-Formation (Wni)

Unconformity

Upper Archean

Wl — Little Elk Granite - Augen granite and augen gneissic granite, I-type, having medium to coarsely crystalline feldspar megacrysts. Moderately to well-foliated. Contains 25-38% quartz, 20-30% plagioclase, 21-31% microcline, 3.5-17% biotite, and accessory blue quartz, muscovite, titanite, apatite, epidote, zircon, allanite, and calcite. Locally cut by aplite dikes and has sparse inclusions of biotite schist (Gosselin, 1987). Has a U-Pb zircon age of 2,549 +/- 11 Ma (Gosselin and others, 1988) and a $^{207}Pb/^{206}Pb$ age of 2,559 +/- 6 Ma (McCombs and others, 2004)

Wnp, Wni — Nemo Iron-Formation - **Wni** - Banded metachert and magnetite-hematite iron-formation. Locally consists of three or more iron-formation beds 15-56 ft (4.6-17.1 m) thick separated by similar thicknesses of thin-bedded gray to greenish phyllite typically containing magnetite (Redden, 1980). Wni is in fault contact with Proterozoic rocks but is believed to be the source of banded iron-formation clasts in the Greenwood tongue of the lower Boxelder Creek Quartzite. Age of formation estimated greater than 2,560 Ma to 2,900 Ma (Dahl and others, 2006). **Wnp** - Phyllite, gray to green. Thin- to medium-bedded, with thin metachert beds in the greenish phyllite. Unit largely inferred, but present in drill cores. No exposures known north of unit Wni, but inferred to be of similar rock type (Redden, 1980)

Wos — Older metasediments - Quartz-biotite-feldspar gneiss and schist with local matrix-supported metaconglomerate and minor bedded amphibolite-bearing rocks. Melanocratic, fine- to medium-grained, moderately- to well-foliated, and lacking microcline megacrysts. Composed of quartz, plagioclase, biotite, and microcline with accessory muscovite, titanite, epidote, zircon, allanite, and almandite. Thickness approximately 1968.6 ft (600 m) (Gosselin, 1987). Has a $^{207}Pb/^{206}Pb$ age of 2,532 Ma (Gosselin and others, 1988) and 2,563 +/- 6 Ma (McCombs and others, 2004). Protolith is possibly igneous rock, or arkosic sandstone and/or tuffaceous felsic volcanics (Gosselin, 1987).

CONTACTS
Long dashed where approximately located; short dashed where inferred; dotted where concealed or where projected above ground surface in cross section; queried where uncertain. Arrow indicates dip direction and amount

FAULTS
Long dashed where approximately located; short dashed where inferred; dotted where concealed; queried where uncertain. Bar and ball on downthrown side. Arrows indicate lateral movement. Tic indicates dip direction and amount. A (away) and T (toward) indicate relative movement on cross section B-B'. Southern extension of Pilot Knob Fault is equivalent to the Pactola Lake Fault

FOLDS (Laramide)
Syncline — Location of trace of axial plane. Long dashed where approximately located
Anticline — Location of trace of axial plane. Long dashed where approximately located

FOLDS (Early Proterozoic)
D_1 FOLDS
Shown only where stratigraphic sequence known. Original plunge angles were low, and were modified and steepened by later deformation. Minor folds not shown
Anticline — Location of trace of axial plane. Long dashed where approximately located; dotted where concealed; queried where uncertain
Syncline — Location of trace of axial plane. Long dashed where approximately located; dotted where concealed
Overturned anticline — Location of trace of axial plane and dip direction of limbs. Long dashed where approximately located; dotted where concealed; queried where uncertain
Overturned syncline — Location of trace of axial plane and dip direction of limbs. Long dashed where approximately located; dotted where concealed; queried where uncertain

D_2 FOLDS
Axial surface generally steeply dipping and parallel to north-northwest foliation. Fold plunges variable due to crossing of earlier folds that are not shown. May locally parallel, modify, and accentuate D_1 folds. Many small D_2 folds not shown
Antiform — Location of trace of axial plane. Long dashed where approximately located; dotted where concealed; queried where uncertain
Synform — Location of trace of axial plane. Long dashed where approximately located; dotted where concealed; queried where uncertain
Undifferentiated fold — Location of trace of axial plane. Long dashed where approximately located; dotted where concealed

MINOR FOLD
Minor fold — Showing bearing and plunge

BEDDING
Inclined
Inclined — Ball indicates top direction of beds known to be in dip direction
Crenulated bedding
Vertical
Vertical — Ball indicates top direction of beds
Overturned — Where direction of younging is known
Overturned — Ball indicates top direction of beds known to be opposite dip direction
Top of bed — Interpreted from sedimentary structures
Basalt pillow — Arrow indicates top direction

METAMORPHIC FOLIATION
Inclined
Inclined, parallel to bedding
Vertical
Vertical, parallel to bedding

LINEATION
Showing bearing and plunge

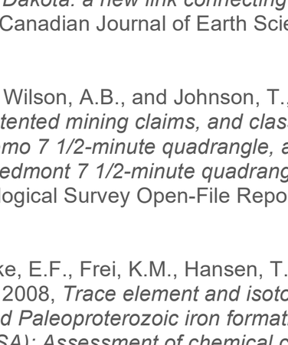
QUARTZ VEIN

METAMORPHIC ISOGRAD
GARNET / BIOTITE — First appearance of index mineral noted on side of isograd

MAGNETIC HIGH
M — Located by aerial magnetic survey (Meuschke and others, 1962) and ground magnetic survey (Bayley, 1972a)

SILICIFIED ZONE
Associated with the Blue Draw fault in NE 1/4, section 20, T. 3 N., R. 5 E., about 0.5 mi (1 km) southeast of the former town of Novak. Contains abundant authigenic magnetite crystals and quartz veins

OTHER FEATURES
Open pit mine or glory hole
Mine shaft
Mine adit
Trench
Group of prospect pits
Prospect pit



INDEX MAP OF SELECTED REFERENCES

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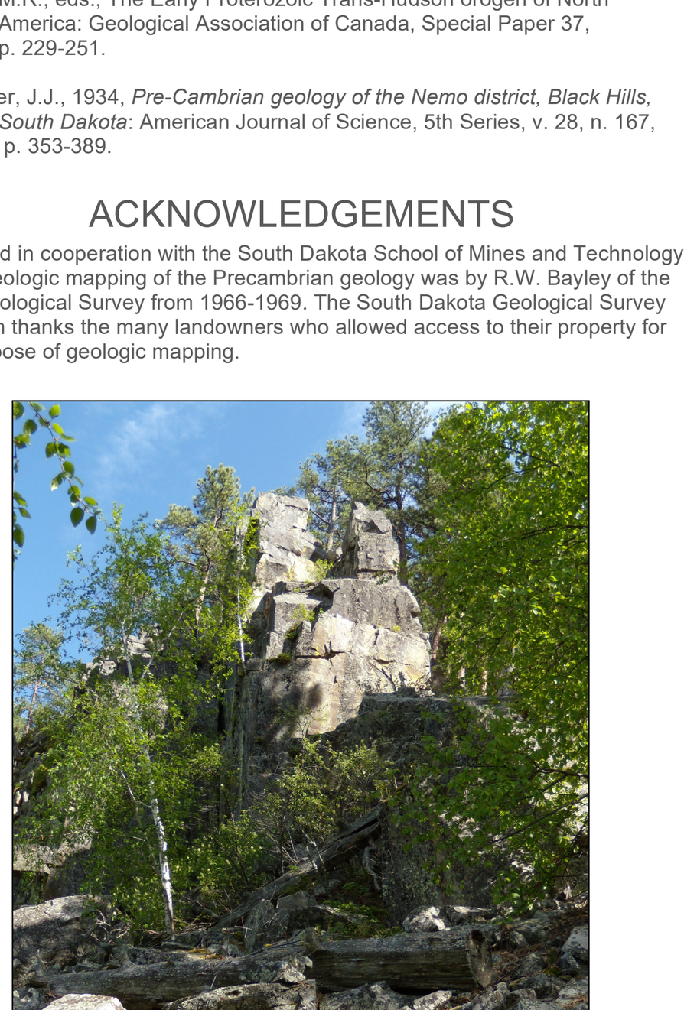

Talus below massive bed of quartzite (Xbq) in the Buck Mountain Quartzite (Xbm), just south of the type locality at Buck Mountain. Strike of bedding is into the picture and to the right.