GEOLOGIC MAP OF THE PIEDMONT QUADRANGLE, SOUTH DAKOTA

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
GEOLOGICAL SURVEY PROGRAM
7.5 MINUTE SERIES GEOLOGICAL QUADRANGLE MAP 10

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2018

State of South Dakota
Dennis Daugaard, Governor

South Dakota Geological Survey
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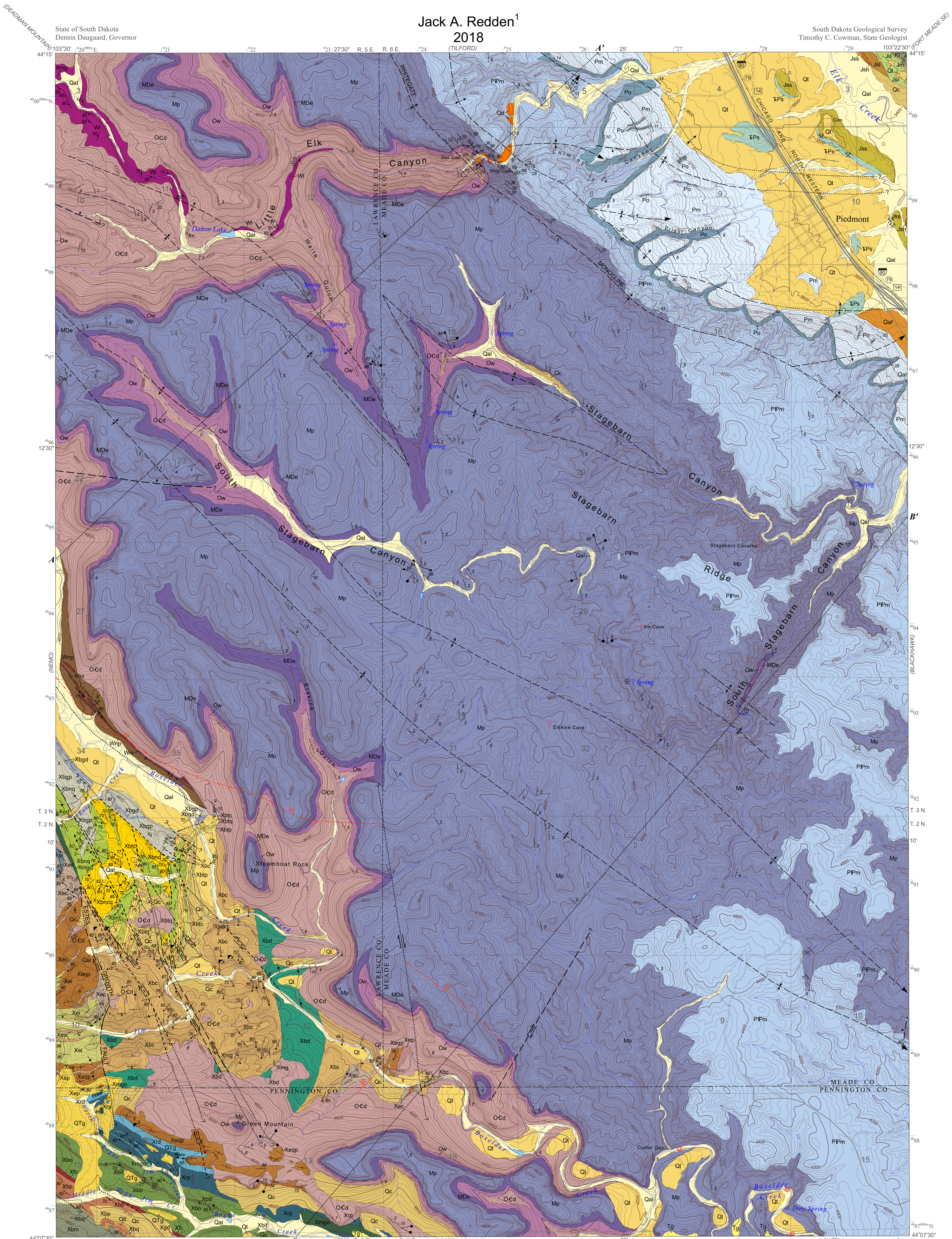


[1]South Dakota School of Mines and Technology, Rapid City, South Dakota

Declination and UTM coordinate system taken from 1971 U.S. Geological Survey 1:24,000-scale Piedmont quadrangle.
Map base modified from U.S. Geological Survey 1:24,000-scale Piedmont digital line graph.
Projection is Universal Transverse Mercator, Zone 13N.
Datum is 1983 North American.

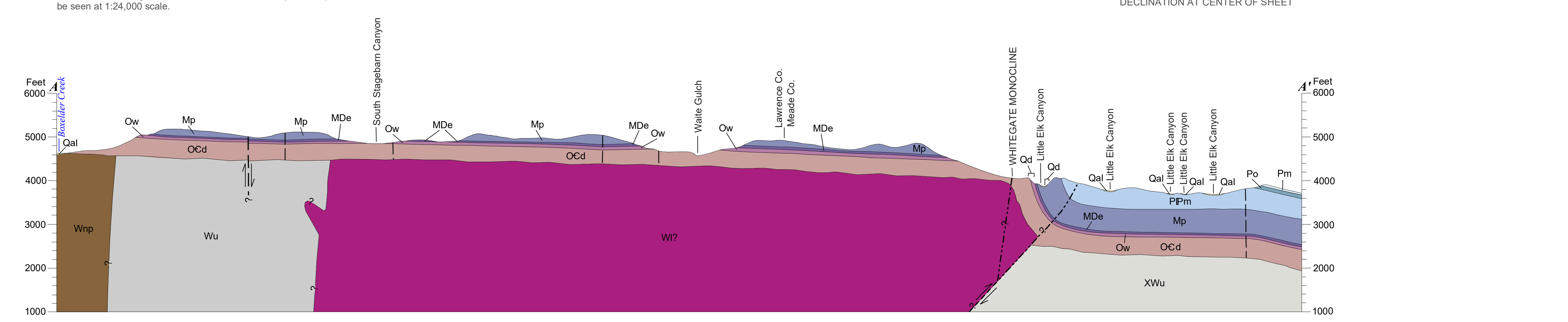
SCALE 1:24,000

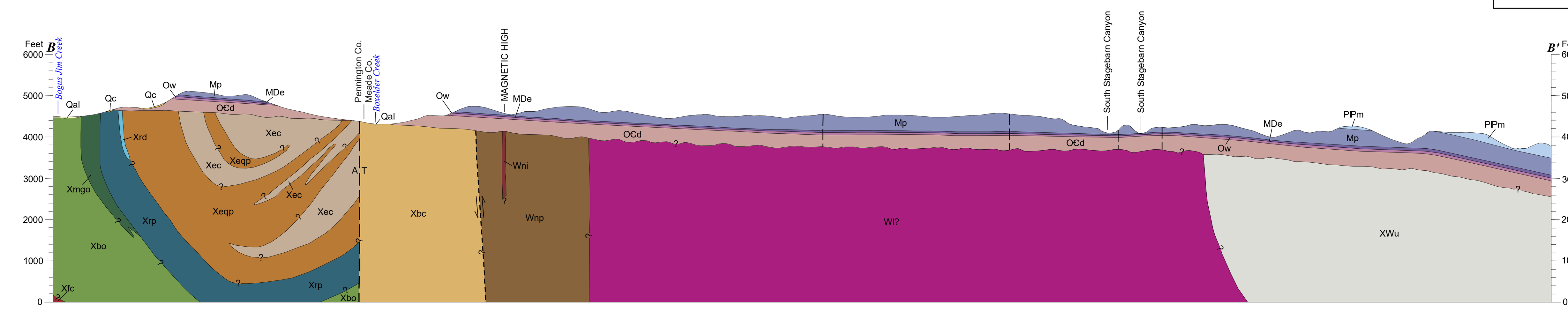
CONTOUR INTERVAL 20 FEET

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

Edited by M.D. Fahrenbach
Digital Cartography by E.S. Beck, L.L. Roinstad, M.D. Fahrenbach, and L.D. Schulz





Whitegate Monocline at the mouth of Little Elk Canyon. Gently dipping to steeply dipping Pahasapa Limestone along anticlinal hinge in background, and gently dipping Minnekahta Limestone east of synclinal hinge right foreground.

Custer Gap in the Pahasapa Limestone, where the Custer Expedition left the Black Hills August 13, 1874 to return to Ft. Abraham Lincoln, near Mandan, North Dakota. This area is a stream loss zone into the Pahasapa Limestone, which was noted by the Expedition.

Angular unconformity along Boxelder Creek between the nearly vertical Boxelder Creek Quartzite (Xbc) having bedding tops toward the viewer, and the nearly horizontal Deadwood Formation.

Near vertical bed of arkose (Xea) in the Estes Formation. Bedding tops are to the right. Hammer is 16 in (40.6 cm) long.

EXPLANATION

QUATERNARY

Qal — **Alluvium** - Unconsolidated to loosely consolidated, clay to boulder-sized clasts. Deposited in present-day drainages and on flood plains. Estimated thickness up to 35 ft (10.7 m)

Qc — **Colluvium** - Unconsolidated angular rock fragments up to boulder-size mixed with soil. Locally deposited by gravity along steep slopes. Estimated thickness up to 20 ft (6.1 m)

Qaf — **Alluvial fan** - Unconsolidated to loosely consolidated, clay- to boulder-sized clasts. Deposited proximal to present-day drainages

Qtl — **Talus** - Angular quartzite fragments up to boulder-size derived from Xbq. Locally deposited by gravity along steep slopes. Devoid of soil. Estimated thickness up to 33 ft (10.1 m)

Qt — **Terrace deposit** - Unconsolidated to loosely consolidated, clay to boulder-sized clasts. Deposited up to 140 ft (42.7 m) above present-day drainages. Some may include more than one terrace level. Estimated thickness up to 35 ft (10.7 m)

Qd — **Debris flow deposit** - Composed of very large boulders within finer debris. Formed from breached dams of landslides in lower Little Elk Canyon. Boulders may have been washed onto terrace deposits near Interstate 90. Indicated by brackets on cross section A-A' where too thin to show. Thickness up to 40 ft (12.2 m)

Disconformity

TERTIARY — Pliocene-Eocene

QTg — **Gravel deposit** - Unconsolidated to loosely consolidated, rounded to well-rounded, clay- to boulder-size clasts dominantly of Precambrian quartzite and metachert

Tg — **Gravel deposit** - Unconsolidated to loosely consolidated, rounded to well-rounded, clay- to boulder-size clasts dominantly of Precambrian quartzite and metachert. Generally gravel at surface. Excavations may disclose pale-red bentonitic beds at depth. Based on elevation, may be equivalent to known White River Group deposits in other areas. Thickness up to 30 ft (9.1 m)

Unconformity

CRETACEOUS — Lower Cretaceous

Kl — **Lakota Formation** - Sandstone, grayish-orange to light-brown, thick-bedded. Only basal portion present. Exposed thickness 30-45 ft (9.1-13.7 m)

Disconformity

JURASSIC

Upper Jurassic

Jm — **Morrison Formation** - Claystone, siltstone, and sandstone. Variegated, bentonitic. Typically grass-covered. Fossils of the sauropod *Barosaurus lentis* have been found in the Blackhawk quadrangle (Marsh, 1890; Szigeti, 1979). Approximate thickness 40-65 ft (12.2-19.8 m)

Ju — **Unkpapa Sandstone** - Sandstone, yellowish-gray to white. Calcareous, well sorted, friable. Typically grass covered. Sharp upper and lower contacts. Thickness approximately 60-80 ft (18.3-24.4 m)

Sundance Formation - Includes the Stockade Beaver Shale, Hulett Sandstone, Lak Shale, and Redwater Shale members

Jsr — **Redwater Shale Member** - Shale, siltstone, and minor sandstone and limestone. Grayish orange-pink to pale-olive, glauconitic. Laminated to thin-bedded, calcareous. The uppermost 10 ft (3.0 m) are ledges of calcareous sandstone with brachiopod fragments. Contains the belemnite *Pachyteuthis* sp. throughout. Thickness approximately 100-120 ft (30.5-36.6 m)

Middle Jurassic

Jsl — **Lak Shale Member** - Shale, siltstone, and sandstone. Moderate-red to moderate reddish-brown. Fine-grained, typically massive with indistinct bedding. Thickness approximately 40-60 ft (12.2-18.3 m)

Jsh — **Hulett Sandstone Member** - Sandstone, white, grayish-orange, to light-brown. Laminated to thin-bedded, calcareous, with abundant ripple marks. Thickness approximately 5-10 ft (1.5-3.0 m)

Jss — **Stockade Beaver Shale Member** - Shale, siltstone, and minor sandstone. Grayish-orange to grayish-green, glauconitic. Laminated to thin-bedded, calcareous. Contains the belemnite *Pachyteuthis* sp. throughout. Thickness approximately 100-120 ft (30.5-36.6 m)

Disconformity

TRIASSIC — Lower Triassic

ŦPs — **Spearfish Formation** - Siltstone, shale, and minor limestone. Light-red to moderate reddish-brown. Includes white to light-gray gypsum interbeds. May include gypsum of the Gypsum Spring Formation at the top, which thins to the south. Thickness 500-530 ft (152.4-161.5 m)

Disconformity

PERMIAN

Upper Permian

Pm — **Minnekahta Limestone** - Limestone, pinkish-gray, pale-red, to pale-purple. Thin-bedded, with shale partings occurring near the middle. Contains abundant stylolites. Thickness 36-42 ft (11.0-12.8 m)

Disconformity

Lower Permian

Po — **Opeche Shale** - Shale and siltstone, light-red to moderate reddish-brown. Laminated to thin-bedded. Thickness 80-110 ft (24.4-33.5 m)

PENNSYLVANIAN — Upper Pennsylvanian

PIPm — **Minnelusa Formation** - Sandstone, limestone, and shale, light-brown, pale reddish-brown, to grayish-orange. Thin- to thick-bedded. Thickness 565-645 ft (172.2-196.6 m)

Disconformity

MISSISSIPPIAN — Lower Mississippian

Mp — **Pahasapa Limestone** - Limestone and dolomite, yellowish-gray to white, weathering to light gray. Thin- to thick-bedded, karstic. Upper contact has a moderate-red terra rossa. Thickness 480-510 ft (146.3-155.4 m)

DEVONIAN — Upper Devonian

MDe — **Englewood Limestone** - Shale, limestone, and dolomite. Light-gray, pale red-purple, to pale-purple. Laminated to thin-bedded, finely crystalline. Sparsely fossiliferous, highly bioturbated. Thickness 36-55 ft (11.0-16.8 m)

Disconformity

ORDOVICIAN

Upper Ordovician

Ow — **Winnipeg Formation** - Shale, light-gray to pale-green. Laminated to thin-bedded, fissile. Thickness 10-80 ft (3.0-24.4 m). Exposures north of Little Elk Canyon may include up to 5 ft (1.5 m) of overlying Whitewood Limestone, which is undifferentiated on the map

Disconformity

Lower Ordovician

CAMBRIAN — Middle to Upper Cambrian

O€d — **Deadwood Formation** - Glauconitic sandstone, shale, limestone pebble conglomerate, and local basal conglomerate. Pale-red, greenish-gray, to moderate brown. Thick-bedded, iron-stained orthoquartzite from 55-90 ft thick (16.8-27.4 m) occurs at the top. Total thickness 350-425 ft (106.7-129.5 m)

Unconformity

PRECAMBRIAN

Lower Proterozoic

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 metagabbro sills in the Pactola Dam quadrangle (Redden et al., 1990). It is uncertain that all bodies shown as Xmg are of the same age

Xbm, Xbq, Xbp — **Buck Mountain Quartzite** - **Xbm** - Phyllite, medium-gray to pale-olive, and quartzite and quartzose slate, yellowish-gray, light-gray, to white. Thin- to thick-bedded. A magnetic cherty ferruginous schist occurs near the base of the formation (Bayley, 1972a). Metasiltstone beds contain abundant ripple marks. Age 2,170-1,960 Ma (Redden et al., 1990). Protolith is shallow shelf deposits of sandstone, siltstone, and shale. **Xbq** - Quartzite, yellowish-gray, light-gray, to medium bluish-gray. Fine- to medium-grained, thick-bedded to very thick-bedded. **Xbp** - Dominantly phyllite, greenish-gray, medium bluish-gray, to light-brown. Laminated to thin-bedded. Contains few quartzite beds

Xgd — **Gingrass Draw Slate** - Slate and phyllite, greenish-gray, medium-gray, to yellowish-gray, thin-bedded (Bayley, 1972a). Lower portion contains quartzite and metasilt beds that increase in abundance to the south in the Pactola Dam quadrangle, and are difficult to distinguish from parts of the Buck Mountain Quartzite. Age 1,974 +/- 8 Ma (Dahl et al., 2006). Protolith is likely reworked submarine volcanic tuff

Xfc — **Ferruginous metachert** - Metachert, magnetic cherty ferruginous schist, and carbonate-facies iron-formation. Thin-bedded to very thick-bedded, banded, 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, locally with pillow structures (Bayley, 1972a). Grayish-green, greenish-gray, to black. Very finely to coarsely crystalline. May have a speckled appearance, or a moldic texture from dissolved amphibole laths. Age estimated at 1,974-1,964 Ma (Redden et al., 1990) to 2,020-1,970 Ma (Frei et al., 2008). Protolith is pillowed tholeiitic basalt flows and associated volcanic tuff, carbonaceous shale, and chert from submarine thermal spring deposits. **Xbif** - Interflow deposits of thin-bedded to very thick-bedded, banded ferruginous metachert with carbonaceous slate and phyllite, carbonate facies iron-formation, and few thin dolomite beds resembling the Roberts Draw Limestone (Xrd). Only thicker intervals shown

Xmgo — **Metagabbro (older)** - Amphibolite. Occurs as greenish-black to black, finely to medium crystalline, homogeneous to schistose sills and dikes. A sill 0.75 mi (1.2 km) southeast of Green Mountain has a Pb-Pb zircon age of 1,964 +/- 15 Ma (Redden et al., 1990) to approximately 2,015-1,975 Ma (Dahl et al., 2006). It is uncertain that all bodies shown as Xmgo are of the same age

Xrd, Xrp — **Roberts Draw Limestone** - **Xrd** - Siliceous dolomite, yellowish-gray to medium-gray, finely to coarsely crystalline. Typically thick-bedded, and locally containing lenses of pebbly metaconglomerate and quartzite (Bayley, 1972a). Very rare small stromatolites occur locally in the more pure dolomite units. Age approximately 2,170-1,960 Ma (Redden et al., 1990) to 2,015-1,975 Ma (Dahl et al., 2006). **Xrp** - Greenish-gray, dark-gray, to black slate and phyllite. Locally contains 5-25% dolomite and thin quartzose beds. Some magnetite occurs where adjacent to carbonate rocks

Xei, Xea, Xep, Xeqp, Xec, Xed — **Estes Formation** - Subdivided from the Estes System of Runner (1934). Age approximately 2,170-1,960 Ma (Redden et al., 1990) to 2,100-2,015 Ma (Dahl et al., 2006). Protolith is heterogeneous intertonguing marine fan deposits, deposited west of the Estes Growth Fault in a rifting environment, Deposition was contemporaneous with faulting. **Xei** - Interbedded quartzite, phyllite, and arkose. **Xea** - Arkosic quartzite and metagrit with local phyllite interbeds. **Xep** - Phyllite, medium dark-gray. **Xeqp** - Quartzite, medium-gray, grayish-yellow, to pale yellowish-brown. Thin- to thick-bedded. Includes lenses of metaconglomerate and medium-gray phyllite. **Xec** - Metaconglomerate, paraconglomerate, and impure quartzite. Cross pattern indicates clasts of taconite derived from the Benchmark Iron-Formation (Xbi). **Xed** - Dolomite, dolomitic quartzite, chloritic quartzite, and phyllite

Unconformity

Xbd — **Blue Draw Metagabbro** - Serpentine, hornblendite, and amphibolite, grayish-green to grayish blue-green. Homogeneous to foliated, gravity differentiated sill consisting of a mafic lower cumulate zone that is altered to serpentine overlain by amphibolite, and a metagabbro interior metamorphosed to hornblendite and amphibolite. An upper, thin, granitic to granodioritic differentiate is exposed in the Nemo quadrangle from which a $^{207}Pb/^{206}Pb$ age of 2,478 +/- 6 Ma to 2,482 +/- 9 Ma (Dahl et al., 2003) to 2,484 +/- 11 Ma (Redden and DeWitt, 2008) was obtained. Carbonate replacement of the country rock is typical near contacts. Separate small body of serpentinite along upper Jim Creek inferred to be correlative

Xbc (Xbtp, Xbtc, Xbtq, Xbncq, Xbnc, Xbnq, Xbgp, Xbgd) — **Boxelder Creek Quartzite - Includes the Tomahawk, Greenwood, and Novak tongues**
Boxelder Creek Quartzite - **Xbc** - Quartize, white, light-gray, to grayish-orange, and quartz-mica schist. Thick-bedded, medium- to coarse grained, with abundant small scale cross bedding. Dolomite cemented breccias occur, especially along faults. Muscovitic, rarely with fuchsite. Pyrite occurs in the coarser-grained units (Bayley, 1972a; Redden, 1980). Age estimated at greater than 2,170 Ma (Redden and Dewitt, 2008) to 2,560-2,480 Ma (Dahl et al., 2003). Protolith is fluvial-dominated alluvial fan deposits intertonguing with shallow marine deposits in a rift environment
Tomahawk Tongue - Dominantly interbedded granular quartzite and conglomerate. Fuschitic, micaceous, pyritic and iron-stained. Thin- to thick-bedded, with abundant cross bedding in granular quartzite beds. Conglomerate beds are typically radioactive and generally ungraded, with some having reverse grading. Taconite clasts absent. Coarsens eastward, and is interpreted to be an alluvial fan deposit having an eastern source (Redden, 1980). Includes Xbtp, Xbtq, and Xbtc. **Xbtp** - Phyllite, medium light-gray to greenish-gray, thin-bedded, poorly exposed. Protolith is an overbank deposit. **Xbtq** - Granular quartzite and metagrit, grayish-green. Fuschitic and micaceous, locally with pebble clasts and metaconglomerate beds. Thin- to thick-bedded. Contains trough and planar cross bedding, some truncated. **Xbtc** - Pebble metaconglomerate and metagrit, matrix- to grain-supported, with pebble-bearing quartzite interbeds.Thin- to thick-bedded. Typically pyritiferous, uraniferous, and auriferous. Contains chromite and fuchsite. Granules of blue quartz probably derived from the Little Elk Granite are common. Only thicker units shown.
Novak Tongue - Dominantly chloritic quartzite and metaconglomerate having taconite clasts. Protolith is alluvial fan deposits probably having an eastern source, and intertonguing with quartzites to the west. Includes Xbncq, Xbnc, and Xbnq. **Xbncq** - Metaparaconglomerate and quartzite. Abundant taconite clasts of hematite and metachert iron-formation typically decrease to the north, with metaparaconglomerate interfingering with chloritic phyllite of Xbgp. **Xbnc** - Metaconglomerate containing taconite clasts **Xbnq** - Chloritic quartzite, locally having scattered pebbles and thin phyllite interbeds
Greenwood Tongue - Interbedded coarse- to fine-grained chloritic metasedimentary rocks with scattered angular clasts of taconite and grains of blue quartz. Most other clasts typically well rounded. Bedding is generally thick to unrecognizable in poorly sorted units. Cross bedding absent except in chloritic quartzite lithologies. Contacts gradational, lithologies fine laterally. Magnetite is a common accessory. Protolith is alluvial fan deposits having a western source, intertonguing with marine deposits to the northeast (Redden, 1980). Includes units Xbgp and Xbgd. **Xbgp** - Chloritic phyllite, greenish-gray. Contains sparse chloritic quartzite beds and metachert clasts probably of Archean age, which decrease in abundance to the north. Interpreted to be the distal portion of an alluvial fan deposit. **Xbgd** - Dolomite, very pale-orange to medium-gray, thin-bedded, siliceous, and minor medium-gray, micaceous phyllite

Unconformity

Upper Archean

Wl — **Little Elk Granite** - Augen granite and augen gneissic granite, I-type, containing medium to coarsely crystalline feldspar megacrysts. Foliated to very foliated. Contains 25-38% quartz, 20-30% plagioclase, 21-31% microcline, 3.5-17% biotite, and accessory muscovite, sphene, apatite, epidote, zircon, allanite, and calcite. Locally contains blue quartz. U-Pb zircon age of 2,549 +/- 11 Ma (Gosselin et al., 1988) to a $^{207}Pb/^{206}Pb$ age of 2,559 +/- 6 Ma (McCombs et al., 2004)

Wni, Wnp — **Nemo Iron-Formation** - **Wni** - Metachert and hematite banded 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, dark-gray to dark greenish-gray phyllite typically containing magnetite (Redden, 1980). Formation is in fault contact with Proterozoic rocks but is believed to be the source of banded iron-formation clasts in the lower Boxelder Creek Quartzite. Age estimated to be greater than 2,560 Ma to 2,900 Ma (Dahl et al., 2006). **Wnp** - Phyllite, dark-gray to dark greenish-gray, very thin- to thin-bedded, with thin metachert beds. Unit is largely inferred, but present in drill cores. No exposures known north of unit Wni, but inferred to be of similar rock type

XWu — **Undifferentiated Lower Proterozoic and Upper Archean rocks** - Shown only in cross section

Wu — **Undifferentiated Upper Archean rocks** - Shown only in cross section

CONTACTS

Long dashed where approximately located; dotted where concealed; queried where inferred on cross section

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'. The Estes Fault is interpreted as a growth fault with erosion contemporaneous with faulting

Boundary of tri-shear zone which forms the Whitegate monocline. Shown on cross section A-A'

FOLDS

Anticline
Location of trace of axial plane and direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

Syncline
Location of trace of axial plane and direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

Monocline, anticlinal bend
Shorter arrow indicates steeper beds. Long dashed where approximately located; dotted where concealed; queried where uncertain

Monocline, synclinal bend
Shorter arrow indicates steeper beds. Long dashed where approximately located; dotted where concealed; queried where uncertain

MINOR FOLD

Minor fold
Showing bearing and plunge

BEDDING

Horizontal
Inclined
Inclined
Top direction of beds known to be in dip direction
Vertical
Vertical
Ball indicates top direction of beds
Overturned
Top direction of beds known to be opposite dip direction
Top of bed
Interpreted from sedimentary structures

METAMORPHIC FOLIATIONS

Inclined
Vertical

FRACTURES

Inclined
Vertical
Multiple
Point of observation at join of strike lines

MAGNETIC HIGH

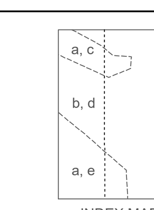
Located by ground magnetic survey (Bayley, 1972a), and aerial magnetic survey (Meuschke et al., 1962). Queried where uncertain

KARST FEATURES

Stream loss zone
Cave

OTHER FEATURES

Open pit mine or quarry
fm - fill materials
ir - iron ore
Open pit mine
Mine shaft
Adit
Group of prospect pits
Prospect pit



INDEX MAP OF SELECTED REFERENCES

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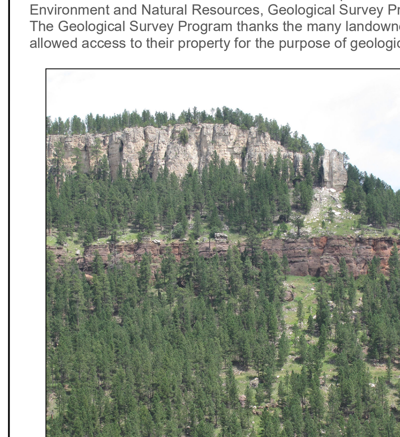
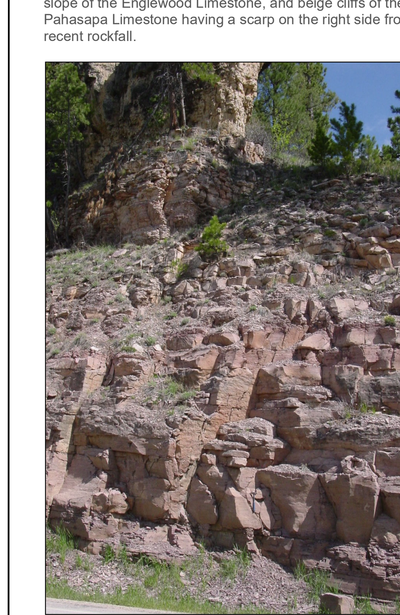


Bluff along Nemo Road with covered Archean rocks and Deadwood Formation at the base, overlain by reddish-brown orthoquartzite of the upper Deadwood Formation, covered slope of the Englewood Limestone, and beige cliffs of the Pahasapa Limestone having a scarp on the right side from a recent rockfall.



Pinkish Englewood Limestone overlain by beige Pahasapa Limestone along Nemo Road. The Englewood was deposited on a generally restricted, shallow, carbonate shelf. At this locality, the Devonian-Mississippian boundary is about 10 feet below the contact with the Pahasapa Limestone.