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

Wind Cave National Park

GRI Ancillary Map Information Document

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

wica_geology.pdf

Version: 7/12/2018

Geologic Resources Inventory Map Document for Wind Cave National Park

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Geologic Resources Inventory Map Document

Wind Cave National Park, South Daktoa

Document to Accompany Digital Geologic-GIS Data

wica_geology.pdf

Version: 7/12/2018

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Wind Cave National Park, South Daktoa (WICA).

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 Maps and Source Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.

3) **Digital Geologic-GIS Map of Wind Cave National Park**

   a) **Map Unit Listing** – A listing of all map units present on the Digital Geologic-GIS Map of Wind Cave National Park.

   b) **Map Unit Descriptions** – Descriptions for all map units present on the Digital Geologic-GIS Map of Wind Cave National Park.

   c) **Geologic Cross Sections** – Geologic cross section graphics present on the Digital Geologic-GIS Map of Wind Cave National Park.

   d) **Ancillary Source Map Information** – Additional source map information present on the Digital Geologic-GIS Map of Wind Cave National Park.

4) **Digital Geologic-GIS Map of the Wind Cave National Park Area**

   a) **Map Unit Listing** – A listing of all map units present on the Digital Geologic-GIS Map of the Wind Cave National Park Area.

b) **Map Unit Descriptions** – Descriptions for all map units present on the Digital Geologic-GIS Map of the Wind Cave National Park Area.

5) **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:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

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 Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

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: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://go.nps.gov/gri_products

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. 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, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS map for Wind Cave National Park, South Daktoa (WICA):

Digital Geologic-GIS Map of Wind Cave National Park, South Dakota (*GRI MapCode WICA*)

Fagnan, B.A., Lincoln, B.Z., and Lincoln, T.N., 2013, Geologic Map of Wind Cave National Park: South Dakota Geological Survey, Geologic Quadrangle Map GQ24K-16, scale 1:24,000 (Wind Cave National Park). (*GRI Source Map ID 75678*).

The GRI used the full extent of the source digital GIS data and incorporated prominent components of the provided source map (e.g., unit colors and unit descriptions) into the GRI digital geologic-GIS dataset and product.

Digital Geologic-GIS Map of the Wind Cave National Park Area, South Dakota (*GRI MapCode WCAM*)

DeWitt, Ed, 2003, Unpublished Black Hills Geology Mylars: U.S. Geological Survey, unpublished mylars, scale 1:100,000. (Black Hills Geology). (*GRI Source Map ID 4145*).

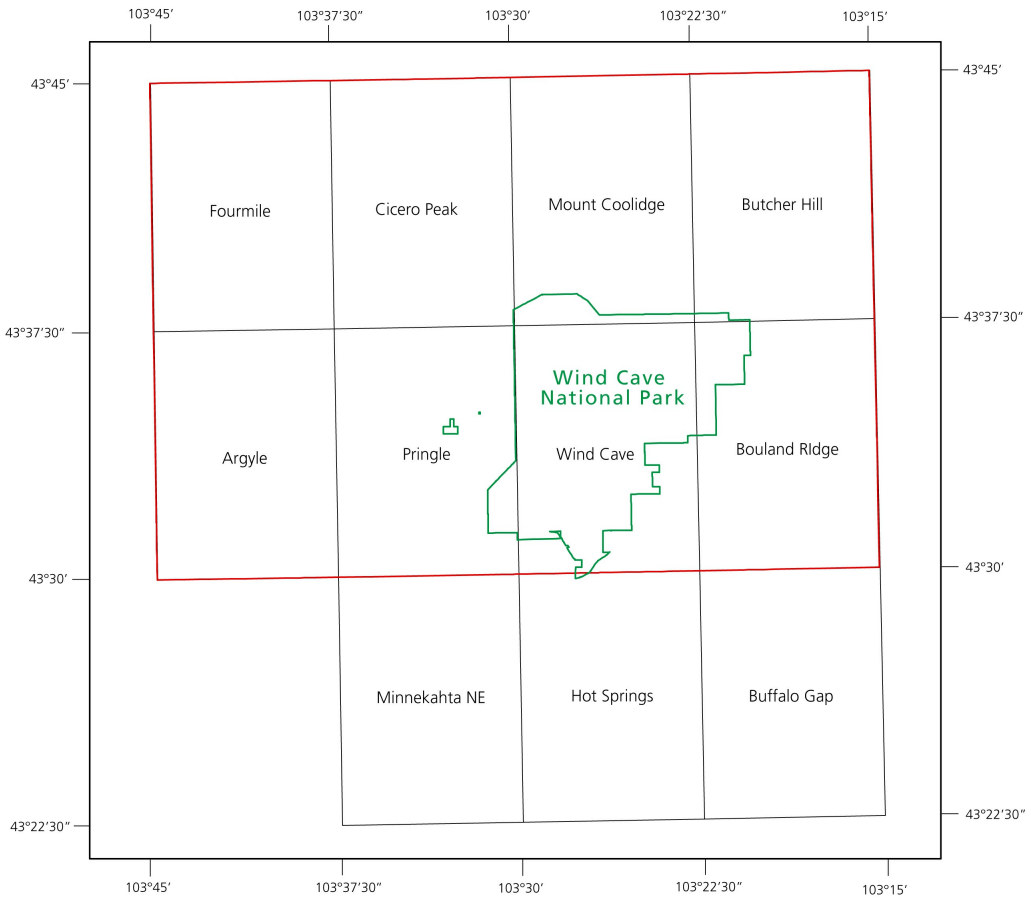
The GRI used a partial extent of the source digital GIS data and incorporated unit descriptions form the provided source mylars into the GRI digital geologic-GIS dataset and product.

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

Index Map

The following index map displays the extent of the GRI Digital Geologic-GIS Map Wind Cave National Park (in dark green, matches park boundary as of July, 2018). The extent of the GRI Digital Geologic-GIS Map of the Wind Cave National Park Area is outlined in red and includes (starting in the upper left corner); the Fourmile, Cicero Peak, Mount Coolidge, Butcher Hill, Argyle, Pringle, and Wind Cave, Bouland Ridge 7.5' Quadrangles.

*Note: although the park extends into the Hot Springs quadrangle no coverage beyond they extent covered by the Digital Geologic-GIS Map of Wind Cave National Park is included in the GRI digital geologic-GIS dataset. For coverage of the Hot Springs quadrangle (1:24,000 scale) see Geology of the Hot Springs quadrangle, Fall River and Custer Counties, South Dakota.



Index map produced by James Winter (Colorado State University).

Digital Geologic-GIS Map of Wind Cave National Park

Map Unit List

The geologic units present on the Digital Geologic-GIS Map of Wind Cave National Park, South Dakota (*GRI MapCode WICA*) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qaf - Artificial fill). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (WICAUNIT) table included with the GRI geologic-GIS data.

Cenozoic Era

Quaternary Period
Qaf - Artificial fill
Qal - Alluvium
Qcg - Conglomerate

Quaternary and Tertiary Periods
QTg - Gravel deposit

Eocene to Oligocene Periods
Tw - White River Group

Mesozoic Era

Cretaceous Period
Kf - Fall River Formation
Kl - Lakota Formation

Jurassic Period
Ju - Unkpapa Sandstone
Js - Sundance Formation

Mesozoic and Paleozoic Eras

Triassic and Permian Periods
TRPs - Spearfish Formation
TRPsg - Spearfish Formation, discontinuous gypsum beds

Paleozoic Era

Permian Period
Pm - Minnekahta Limestone
Po - Opeche Shale
Pm6 - Minnelusa Formation, unit 6

Permian and Pennsylvanian Periods
PPNm5 - Minnelusa Formation, unit 5

Pennsylvanian Period
PNm4 - Minnelusa Formation, unit 4
PNm3 - Minnelusa Formation, unit 3

PNm2 - Minnelusa Formation, unit 2
PNm1 - Minnelusa Formation, unit 1

Mississippian Period
Mp - Pahasapa Limestone

Mississippian and Devonian Periods
MDe - Englewood Limestone

Ordovician and Cambrian Periods
OCd - Deadwood Formation

Precambrian Eon

Proterozoic Eon
Xh - Harney Peak Granite
Unnamed formation Xq
- Xmgq - Micaceous metagraywacke, quartzite
- Xmgw - Micaceous metagraywacke
- Xcs - Cold Spring Creek quartzite
- Xrg - Reaves Gulch schist
- Xrr - Rankin Ridge quartzite
- Xst - Sanctuary Trail schist

Xu - Undifferentiated Lower Proterozoic rocks

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. All unit descriptions were taken from the source Wind Cave National Park.

Qaf - Artificial fill (Quaternary)

af - Artificial fill (Quaternary)
Compacted earth, indicated only where extensive.

Qal - Alluvium (Quaternary)

Unconsolidated to loosely consolidated clay, silt, and angular to rounded, sand and gravel. Deposited in present-day drainages.

Qcg - Conglomerate (Quaternary)

Well-cemented, angular to subangular, sand to pebble-sized clasts, derived mainly from the Minnekahata Limestone with minor quantities of Precambrian and Early Paleozoic lithologies. Matrix is composed of calcium carbonate and calcium sulfate probably derived from hot springs (Wolcott, 1967). Some conglomerate could be associated with the White River Group but was not differentiated in the study area. Approximate thickness 2-15 ft (0.6-4.6 m).

QTg - Gravel deposit (Quaternary and Tertiary)

Unconsolidated to loosely consolidated clay- to boulder-sized clasts comprised of Precambrian lithologies and minor Paleozoic carbonate and sandstone. All gravels are sub-rounded to rounded.

Some gravel deposits may be associated with the White River Group but were not differentiated in the study area.

Tw - White River Group (Eocene to Oligocene)

Tan, brown, and light-gray siltstone, claystone, and white to light-gray, vuggy, finely-crystalline, lacustrine limestone. Contains sparse lenses of conglomerate indicating possible stream channels. Some gravel deposits of unit QTg could be associated with the White River Group but were not differentiated in the study area. Exposed thickness greater than 200 ft (61 m).

Kf - Fall River Formation (Lower Cretaceous)

Gray to light-gray, fine- to very fine-grained, thin-bedded, carbonaceous sandstone interbedded with laminated, carbonaceous siltstone. Exposed thickness greater than 100 ft (30.5 m).

Kl - Lakota Formation (Lower Cretaceous)

Tan, brown, and light-gray, medium- to coarse-grained, crossbedded sandstone interbedded with mudstone. Middle of the formation contains lenses of sandy limestone. Forms prominent outcrops; large boulders may occur as colluvium or talus. Contains petrified wood. Approximate thickness 200-350 ft (61-106.7 m).

Ju - Unkpapa Sandstone (Upper Jurassic)

Buff to white, calcareous, well-sorted, friable, quartz sandstone. Locally pink to purple in the top of the formation. Fine- to medium-grained, crossbedded. Approximate thickness 10-50 ft (3.0-15.2 m).

Js - Sundance Formation (Upper and Middle Jurassic)

Includes the members listed below, which are observed in the field but not shown separated on the map or cross section. Approximate thickness 240-270 ft (73.2-82.3 m).

Redwater Shale Member - Light gray-green, calcareous, glauconitic siltstone and sandstone. Contains the fossil *Pachyteuthis* sp. Distinct as a marker bed when seen in outcrop.

Lak Shale Member - Red, fine-grained, calcareous, glauconitic siltstone and sandstone. Distinct as a marker bed when seen in outcrop.

Hulett Sandstone Member - Light-gray, fine-grained, calcareous, glauconitic sandstone interbedded with grayish-green claystone. Contains abundant ripple marks.

Stockade Beaver Shale Member - Tan to light gray-green, calcareous, glauconitic, thin-bedded shale, sandstone, and siltstone. Contains the fossil *Pachyteuthis* sp.

Canyon Springs Sandstone Member - Tan, gray, and yellow, medium-grained, crossbedded sandstone. Contains ripple marks.

TRPs - Spearfish Formation (Lower Triassic and Upper Permian)

Red to maroon shale and siltstone. Interbedded brecciated limestone beds up to 2 ft (0.6 m) thick locally near the base. Approximate thickness 350-400 ft (106.7-121.9 m).

TRPsg - Spearfish Formation, discontinuous gypsum beds (Lower Triassic and Upper Permian)

Discontinuous gypsum beds (TPsg) up to 3 ft (0.9 m) thick are abundant locally near the top, with small veins and lenses throughout the middle to the top of the formation. Dissolution features are indicated by fragments of shale and siltstone silicified in the gypsum.

Pm - Minnekahta Limestone (Upper and Lower Permian)

White, pink, and purple, finely crystalline, laminated to thin-bedded limestone. Interbedded with thin layers of shale at the middle and base. Forms prominent dip slopes and cliffs. Contains minor folds and box folds throughout the formation. Locally petroliferous odor when broken. Approximate thickness 40-50 ft (12.2-15.2 m).

Po - Opeche Shale (Lower Permian)

Unconsolidated red to maroon shale, mudstone, and siltstone having lavender coloring in the upper 5 ft (1.5 m). Erodes easily, weathering to a fine soil. Poorly exposed on slopes beneath the Minnekahta Limestone. Approximate thickness 80-100 ft (24.4-30.5 m).

Minnelusa Formation (Lower Permian and Upper Pennsylvanian)

Pm6 - Minnelusa Formation, unit 6 (Lower Permian)

Tan, gray, yellow, to red brecciated sandstone interbedded with thin beds of mostly brecciated limestone, discontinuous thin layers of anhydrite, and thin beds of unbrecciated sandstone, all poorly exposed. Limestone contains brachiopods.Top of unit contains bright-red interbedded shale and sandstone. Sandstone beds form prominent resistant benches. Approximate thickness 110-130 ft (33.5-39.6 m).

PPNm5 - Minnelusa Formation, unit 5 (Lower Permian and Upper Pennsylvanian)

Bright-red, yellow, light-tan, to gray, fine- to coarse-grained sandstone with light-blue-gray chert nodules near base. Upper portion is a red to light-red breccia with a carbonate matrix. A dark-red sandstone separates the lower and upper portions. Approximate thickness 80-100 ft (24.4-30.5 m).

PNm4 - Minnelusa Formation, unit 4 (Upper Pennsylvanian)

Brownish-yellow to tan dolomite interbedded with sandstone and laminated limestone. Dolomitic beds may contain manganese dendrites. Weathers into colluvial slopes. Approximate thickness 60-80 ft (18.3-24.4 m).

PNm3 - Minnelusa Formation, unit 3 (Upper Pennsylvanian)

Brownish-yellow to tan, locally silicified sandstone interbedded with shale. Poorly exposed, except for silicified sandstone interbedded with shale. Weathers into colluvial slopes. Top of unit may contain a brownish-yellow to light-gray, sandy limestone. Approximate thickness 100-120 ft (30.5-36.6 m).

PNm2 - Minnelusa Formation, unit 2 (Upper Pennsylvanian)

Yellowish-gray to light-gray, thinbedded limestone. Contains distinctive red and white chert nodules, especially near the top. Limestone beds are up to 2 ft (0.6 m) thick and interbedded with sandstone and shale layers up to 0.5 ft (0.2 m) thick. Poorly exposed. Approximate thickness is 40-60 ft (12.2-18.3 m).

PNm1 - Minnelusa Formation, unit 1 (Upper Pennsylvanian)

Tan or red, medium- to coarsegrained, cross-bedded, basal sandstone. Overlain by tan or red, finegrained, upper siltstone which is compensatory in thickness with the basal sandstone. Poorly exposed and weathers into colluvial slopes. Approximate thickness is 25-90 ft (7.6-27.4 m).

Mp - Pahasapa Limestone (Lower Mississippian)

Gray to light-tan, cavernous limestone and dolomitic limestone. Massive limestone with sparse chert nodules in the upper portion; thin- to medium-bedded, dolomitic, sandy limestone in the lower portion. Forms prominent cliffs. Disconformity between the Pahasapa Limestone and the overlying Minnelusa Formation (unit 1) is a paleokarst surface containing terra rosa-filled sinkholes and breccia pipes.

Contains abundant tabulate corals, spiriferid brachiopods, burrows, sparse gastropods and rugose corals. Approximate thickness 275-375 ft (83.8-114.3 m).

MDe - Englewood Limestone (Lower Mississippian and Upper Devonian)

Lavender, mauve to pink, interbedded limestone, dolomitic limestone, and purple-gray shale. Laminated to medium-bedded. Finely to medium crystalline with some coarse-grained crinoidal beds. Bioturbated; contains sparse rugose corals, spiriferid brachiopods, and crinoid columnals. Thickness 35-50 ft (10.7-15.2 m).

OCd - Deadwood Formation (Lower Ordovician, and Upper and Middle Cambrian)

Reddish-brown, basal conglomeratic sandstone and local conglomerate; middle glauconitic sandstone, siltstone, and shale; upper coarse-grained sandstone having nodular weathering. Laminated to thick-bedded. Contains trilobite and inarticulate brachiopod fragments. Approximate thickness 65-75 ft (19.8-22.9 m).

Xh - Harney Peak Granite (Lower Proterozoic)

Sills and dikes of predominantly coarse-grained to pegmatitic, tan to pink S-type granite. Age 1,715 Ma ± 3 Ma (Redden et al, 1990).

Unnamed formation Xq

(Redden and DeWitt, 2008) Possibly equivalent to Buck Mountain Quartzite of Bayley (1972). Here subdivided into the following units:

Xmgq - Micaceous metagraywacke, quartzite (Lower Proterozoic)

Quartzite, reddish-brown to gray. Thinbedded to massive, fine- to medium-grained, micaceous. A massive bed up to 30 ft (9.1 m) thick occurs at the top of the unit.

*Unit is mapped only as a linear geologic feature (WICAGLN) in the GRI digital geologic-GIS data.

Xmgw - Micaceous metagraywacke (Lower Proterozoic)

Muscovite schist to quartz-mica schist. Brown, grayish-brown to gray. Laminated to thin-bedded.

*Unit is mapped as both an area feature (WICAGLG) and a linear geologic feature (WICAGLN) in the GRI digital geologic-GIS data.

Xcs - Cold Spring Creek quartzite (Lower Proterozoic)

Interbedded quartzite and micaceous schist. Some quartzite layers near base are biotite-bearing, upper quartzite layers are typically pure. Includes sections of thick-bedded quartzite without interbedded schist, resulting in cliff- and ridge-forming quartzite intervals up to 40 ft (12.2 m) thick. Interbedded schists include laminated microcline-biotite schist, muscovite-biotite schist, and garnetmuscovite-biotite-quartz schist.

Xrg - Reaves Gulch schist (Lower Proterozoic)

Biotite schist and thick- to thin-bedded impure quartzite and biotite quartzite interbedded with thin-bedded to laminated biotite-quartz schist, plagioclasebiotite- quartz schist, and muscovite-biotite-quartz schist. Also contains minor thick quartzite beds, intervals of uniform, muscovite-biotite-rich schist, and minor garnet-rich layers which contain up to 3 percent manganese. Contains abundant amphibolite layers outside of Wind Cave National Park.

Xrr - Rankin Ridge quartzite (Lower Proterozoic)

Quartzite and siliceous schist. Thick-bedded, clean quartzite and minor biotite quartzite interbedded with poorly exposed, fine-grained quartzite with muscovite partings, fine-grained muscovite-quartz schist, fine-grained biotite-quartz schist, and thin coarse-grained sillimanitebiotite- quartz schist. Includes thick-bedded quartzite without interbedded schist, forming cliffs and ridges of quartzite intervals up to 70 ft (21.3 m) thick. Some quartzite beds are graded allowing determination of tops.

Xst - Sanctuary Trail schist (Lower Proterozoic)

Schist, plagioclase-quartz gneiss and granofels, and quartzite. Coarse-grained muscovitesillimanite-microcline-biotite-quartz schist containing less than 50 percent quartz is abundant in lower section but occurs throughout the unit. Characteristic thin-bedded, muscovite-biotite-plagioclase-quartz gneiss and granofels, with and without microcline, are abundant in the upper part of the unit. Biotite- and feldsparbearing quartzite and pure quartzite occur throughout, but are more abundant near the top.

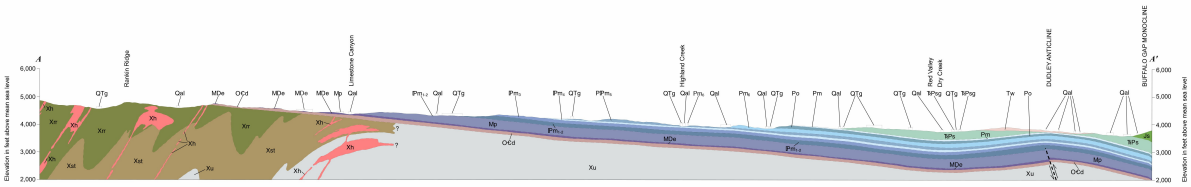
Xu - Undifferentiated Lower Proterozoic rocks (Lower Proterozoic)

Unit shown only in cross section.

Geologic Cross Sections

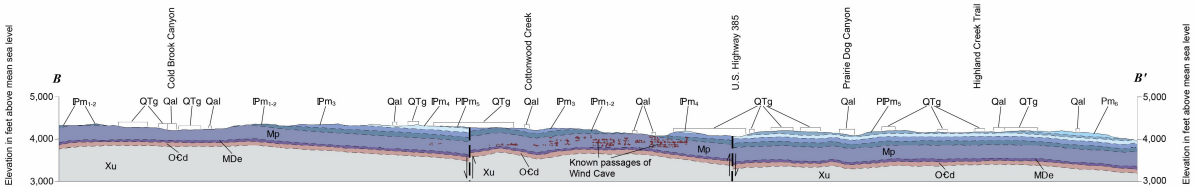
The geologic cross sections present in the GRI digital geologic-GIS data produced for Wind Cave National Park, South Daktoa (WICA) are presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document). Both cross sections were taken from the source Wind Cave National Park.

Cross Section A-A'



Cross section created with no vertical exaggeration.

Cross Section B-B'



Cross section created with no vertical exaggeration.

Ancillary Source Map Information

The following section presents ancillary source map information associated with the source used for this project.

The formal citation for this source.

Fagnan, B.A., Lincoln, B.Z., and Lincoln, T.N., 2013, Geologic Map of Wind Cave National Park: South Dakota Geological Survey, Geologic Quadrangle Map GQ24K-16, scale 1:24,000 (*GRI Source Map ID 75678*).

Prominent graphics and text associated with this source.

Correlation of Units

Quaternary

Qal — **Alluvium** - Unconsolidated to loosely consolidated clay, silt, and angular to rounded, sand and gravel. Deposited in present-day drainages

Qcg — **Conglomerate** - Well-cemented, angular to subangular, sand- to pebble-sized clasts, derived mainly from the Minnekahata Limestone with minor quantities of Precambrian and Early Paleozoic lithologies. Matrix is composed of calcium carbonate and calcium sulfate probably derived from hot springs (Wolcott, 1967). Some conglomerate could be associated with the White River Group but was not differentiated in the study area. Approximate thickness 2-15 ft (0.6-4.6 m)

QTg — **Gravel deposit** - Unconsolidated to loosely consolidated clay- to boulder-sized clasts comprised of Precambrian lithologies and minor Paleozoic carbonate and sandstone. All gravels are sub-rounded to rounded. Some gravel deposits may be associated with the White River Group but were not differentiated in the study area

Disconformity

Tertiary — Oligocene to Eocene

Tw — **White River Group** - Tan, brown, and light-gray siltstone, claystone, and white to light-gray, vuggy, finely-crystalline, lacustrine limestone. Contains sparse lenses of conglomerate indicating possible stream channels. Some gravel deposits of unit QTg could be associated with the White River Group but were not differentiated in the study area. Exposed thickness greater than 200 ft (61 m)

Disconformity

Cretaceous — Lower Cretaceous

Kf — **Fall River Formation** - Gray to light-gray, fine- to very fine-grained, thin-bedded, carbonaceous sandstone interbedded with laminated, carbonaceous siltstone. Exposed thickness greater than 100 ft (30.5 m)

Disconformity

Kl — **Lakota Formation** - Tan, brown, and light-gray, medium- to coarse-grained, crossbedded sandstone interbedded with mudstone. Middle of the formation contains lenses of sandy limestone. Forms prominent outcrops; large boulders may occur as colluvium or talus. Contains petrified wood. Approximate thickness 200-350 ft (61-106.7 m)

Disconformity

Jurassic — Upper Jurassic

Ju — **Unkpapa Sandstone** - Buff to white, calcareous, well-sorted, friable, quartz sandstone. Locally pink to purple in the top of the formation. Fine- to medium-grained, crossbedded. Approximate thickness 10-50 ft (3.0-15.2 m)

Disconformity

Middle Jurassic

Js — **Sundance Formation** - Includes the members listed below, which are observed in the field but not shown separated on the map or cross section. Approximate thickness 240-270 ft (73.2-82.3 m)

Redwater Shale Member - Light gray-green, calcareous, glauconitic siltstone and sandstone. Contains the fossil *Pachyteuthis* sp. Distinct as a marker bed when seen in outcrop

Disconformity

Lak Shale Member - Red, fine-grained, calcareous, glauconitic siltstone and sandstone. Distinct as a marker bed when seen in outcrop

Hulett Sandstone Member - Light-gray, fine-grained, calcareous, glauconitic sandstone interbedded with grayish-green claystone. Contains abundant ripple marks

Stockade Beaver Shale Member - Tan to light gray-green, calcareous, glauconitic, thin-bedded shale, sandstone, and siltstone. Contains the fossil *Pachyteuthis* sp.

Canyon Springs Sandstone Member - Tan, gray, and yellow, medium-grained, crossbedded sandstone. Contains ripple marks

Disconformity

Triassic — Lower Triassic

TRPsg, TRPs — **Spearfish Formation** - Red to maroon shale and siltstone. Interbedded brecciated limestone beds up to 2 ft (0.6 m) thick locally near the base. Discontinuous gypsum beds (TPsg) up to 3 ft (0.9 m) thick are abundant locally near the top, with small veins and lenses throughout the middle to the top of the formation. Dissolution features are indicated by fragments of shale and siltstone silicified in the gypsum. Approximate thickness 350-400 ft (106.7-121.9 m)

Disconformity

Permian — Upper Permian

Pm — **Minnekahta Limestone** - White, pink, and purple, finely crystalline, laminated to thin-bedded limestone. Interbedded with thin layers of shale at the middle and base. Forms prominent dip slopes and cliffs. Contains minor folds and box folds throughout the formation. Locally petroliferous odor when broken. Approximate thickness 40-50 ft (12.2-15.2 m)

Disconformity

Po — **Opeche Shale** - Unconsolidated red to maroon shale, mudstone, and siltstone having lavender coloring in the upper 5 ft (1.5 m). Erodes easily, weathering to a fine soil. Poorly exposed on slopes beneath the Minnekahta Limestone. Approximate thickness 80-100 ft (24.4-30.5 m)

Disconformity

Lower Permian

Pm_6 — **Minnelusa Formation (unit 6)** - Tan, gray, yellow, to red brecciated sandstone interbedded with thin beds of mostly brecciated limestone, discontinuous thin layers of anhydrite, and thin beds of unbrecciated sandstone, all poorly exposed. Limestone contains brachiopods.Top of unit contains bright-red interbedded shale and sandstone. Sandstone beds form prominent resistant benches. Approximate thickness 110-130 ft (33.5-39.6 m)

Disconformity

$PIPm_5$ — **Minnelusa Formation (unit 5)** - Bright-red, yellow, light-tan, to gray, fine- to coarse-grained sandstone with light-blue-gray chert nodules near base. Upper portion is a red to light-red breccia with a carbonate matrix. A dark-red sandstone separates the lower and upper portions. Approximate thickness 80-100 ft (24.4-30.5 m)

Disconformity

IPm_4 — **Minnelusa Formation (unit 4)** - Brownish-yellow to tan dolomite interbedded with sandstone and laminated limestone. Dolomitic beds may contain manganese dendrites. Weathers into colluvial slopes. Approximate thickness 60-80 ft (18.3-24.4 m)

Disconformity

Pennsylvanian — Upper Pennsylvanian

IPm_3 — **Minnelusa Formation (unit 3)** - Brownish-yellow to tan, locally silicified sandstone interbedded with shale. Poorly exposed, except for silicified sandstone interbedded with shale. Weathers into colluvial slopes. Top of unit may contain a brownish-yellow to light-gray, sandy limestone. Approximate thickness 100-120 ft (30.5-36.6 m)

IPm_2 — **Minnelusa Formation (unit 2)** - Yellowish-gray to light-gray, thin-bedded limestone. Contains distinctive red and white chert nodules, especially near the top. Limestone beds are up to 2 ft (0.6 m) thick and interbedded with sandstone and shale layers up to 0.5 ft (0.2 m) thick. Poorly exposed. Approximate thickness is 40-60 ft (12.2-18.3 m)

IPm_1 — **Minnelusa Formation (unit 1)** - Tan or red, medium- to coarse-grained, cross-bedded, basal sandstone. Overlain by tan or red, fine-grained, upper siltstone which is compensatory in thickness with the basal sandstone. Poorly exposed and weathers into colluvial slopes. Approximate thickness is 25-90 ft (7.6-27.4 m)

Disconformity

Mississippian — Lower Mississippian

Mp — **Pahasapa Limestone** - Gray to light-tan, cavernous limestone and dolomitic limestone. Massive limestone with sparse chert nodules in the upper portion; thin- to medium-bedded, dolomitic, sandy limestone in the lower portion. Forms prominent cliffs. Disconformity between the Pahasapa Limestone and the overlying Minnelusa Formation (unit 1) is a paleokarst surface containing terra rosa-filled sinkholes and breccia pipes. Contains abundant tabulate corals, spirferid brachiopods, burrows, sparse gastropods and rugose corals. Approximate thickness 275-375 ft (83.8-114.3 m)

Devonian — Upper Devonian

MDe — **Englewood Limestone** - Lavender, mauve to pink, interbedded limestone, dolomitic limestone, and purple-gray shale. Laminated to medium-bedded. Finely to medium crystalline with some coarse-grained crinoidal beds. Bioturbated; contains sparse rugose corals, spirferid brachiopods, and crinoid columnals. Thickness 35-50 ft (10.7-15.2 m)

Disconformity

Ordovician — Lower Ordovician

Cambrian — Middle to Upper Cambrian

OCd — **Deadwood Formation** - Reddish-brown, basal conglomeratic sandstone and local conglomerate; middle glauconitic sandstone, siltstone, and shale; upper coarse-grained sandstone having nodular weathering. Laminated to thick-bedded. Contains trilobite and inarticulate brachiopod fragments. Approximate thickness 65-75 ft (19.8-22.9 m)

Unconformity

Precambrian — Lower Proterozoic

Xh — **Harney Peak Granite** - Sills and dikes of predominantly coarse-grained to pegmatitic, tan to pink S-type granite. Age 1,715 Ma ± 3 Ma (Redden et al, 1990)

Unnamed formation Xq (Redden and DeWitt, 2008) Possibly equivalant to Buck Mountain Quartzite of Bayley (1972). Here subdivided into the following units:

Xmgq, Xmgw — **Micaceous metagraywacke unit** - Muscovite schist to quartz-mica schist. Brown, grayish-brown to gray. Laminated to thin-bedded. Xmgq - Quartzite, reddish-brown to gray. Thin-bedded to massive, fine- to medium-grained, micaceous. A massive bed up to 30 ft (9.1 m) thick occurs at the top of the unit

Xcs — **Cold Spring Creek quartzite unit** - Interbedded quartzite and micaceous schist. Some quartzite layers near base are biotite-bearing, upper quartzite layers are typically pure. Includes sections of thick-bedded quartzite without interbedded schist, resulting in cliff- and ridge-forming quartzite intervals up to 40 ft (12.2 m) thick. Interbedded schists include laminated microcline-biotite schist, muscovite-biotite schist, and garnet-muscovite-biotite-quartz schist

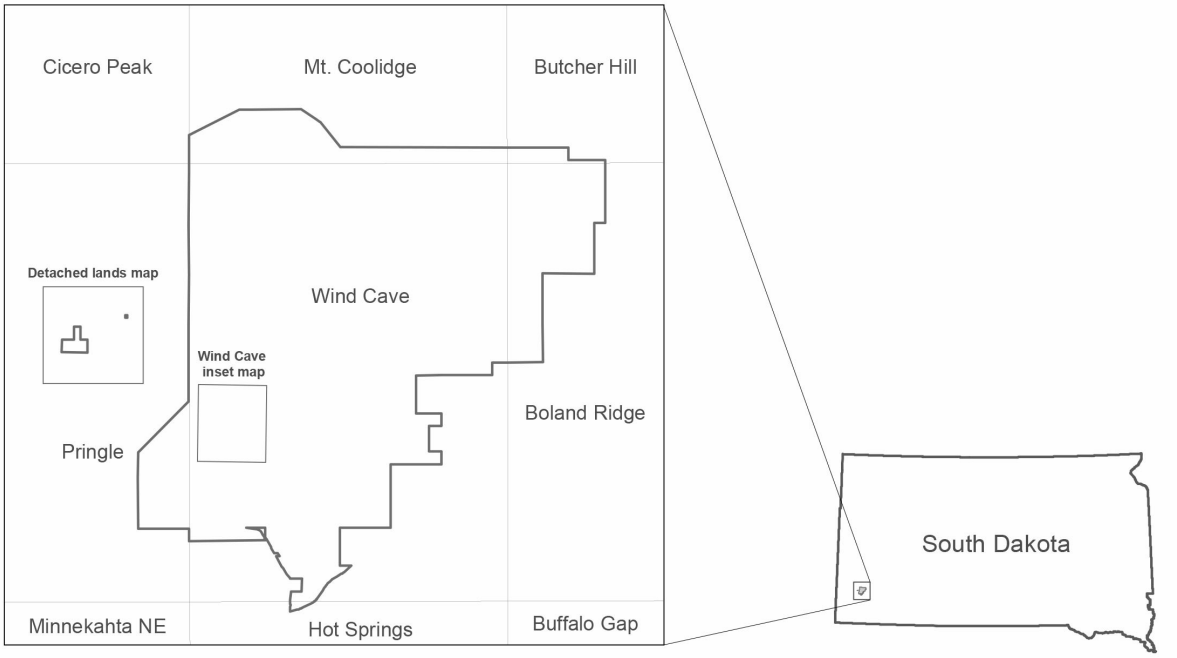
Xrg — **Reaves Gulch schist unit** - Biotite schist and thick- to thin-bedded impure quartzite and biotite quartzite interbedded with thin-bedded to laminated biotite-quartz schist, plagioclase-biotite-quartz schist, and muscovite-biotite-quartz schist. Also contains minor thick quartzite beds, intervals of uniform, muscovite-biotite-rich schist, and minor garnet-rich layers which contain up to 3 percent manganese. Contains abundant amphibolite layers outside of Wind Cave National Park

Xrr — **Rankin Ridge quartzite unit** - Quartzite and siliceous schist. Thick-bedded, clean quartzite and minor biotite quartzite interbedded with poorly exposed, fine-grained quartzite with muscovite partings, fine-grained muscovite-quartz schist, fine-grained biotite-quartz schist, and thin coarse-grained sillimanite-biotite-quartz schist. Includes thick-bedded quartzite without interbedded schist, forming cliffs and ridges of quartzite intervals up to 70 ft (21.3 m) thick. Some quartzite beds are graded allowing determination of tops

Xst — **Sanctuary Trail schist unit** - Schist, plagioclase-quartz gneiss and granofels, and quartzite. Coarse-grained muscovite-sillimanite-microcline-biotite-quartz schist containing less than 50 percent quartz is abundant in lower section but occurs throughout the unit. Characteristic thin-bedded, muscovite-biotite-plagioclase-quartz gneiss and granofels, with and without microcline, are abundant in the upper part of the unit. Biotite- and feldspar-bearing quartzite and pure quartzite occur throughout, but are more abundant near the top

Xu — **Undifferentiated Lower Proterozoic rocks** - Shown only in cross section

Index Map



Index map displaying locations of U.S. Geological Survey 7.5 minute quadrangles, inset map, and detached lands map

Wind Cave National Park Location

Map Legend

47

Contact
Long dashed where approximately located; short dashed where inferred only in cross section; arrow indicates contact dip direction and amount

Form line
Tic indicates dip direction of beds

FAULT

Fault
Long dashed where approximately located; short dashed where inferred; dotted where concealed. Bar and ball on downthrown side

FOLDS

Anticline
Showing crestline and direction of plunge. Long dashed where approximately located; short dashed where inferred; dotted where concealed

Syncline
Showing troughline and direction of plunge. Long dashed where approximately located; short dashed where inferred; dotted where concealed

Monocline, anticlinal bend
Axis located on steepest part of structure. Shorter arrow indicates steeper beds. Long dashed where approximately located; dotted where concealed

Overturned anticline
Location of trace of axial surface and dip direction of limbs; long dashed where approximately located; dotted where concealed

Overturned syncline
Location of trace of axial surface and dip direction of limbs; long dashed where approximately located; dotted where concealed

Small anticline
Showing bearing and plunge

Small syncline
Showing bearing and plunge

33 **Minor fold**
Axis and plunge of single fold

Dome

STRIKE AND DIP OF BEDDING

33 **Inclined**

Horizontal

33 **Overturned**
Where direction of younging is known

STRIKE AND DIP OF FOLIATION

33 **Inclined**

STRIKE AND DIP OF FRACTURES

33 **Inclined**

Vertical

65 **Multiple**
Point of observation where symbols join

KARST FEATURE

Area of collapse
Due to dissolution of underlying beds

Breccia pipe or sinkhole

Stream loss zone

OTHER FEATURES

af **Artificial fill**
Compacted earth, indicated only where extensive

Wind Cave passages
Showing mapped subsurface extent in Pahasapa Limestone

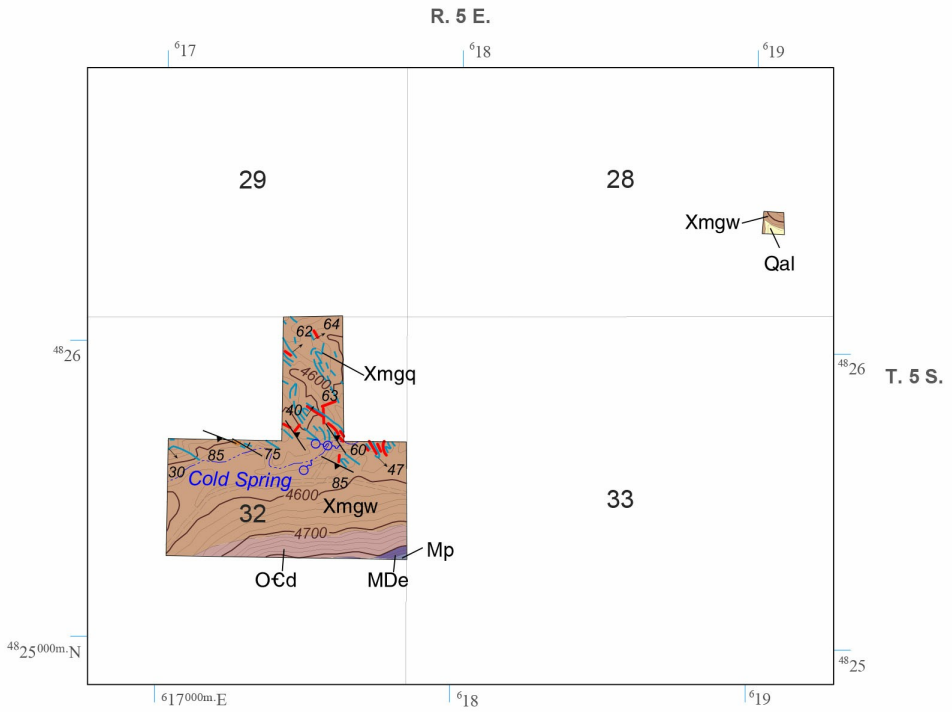
Mine adit or cave

Prospect pit

Gravel pit

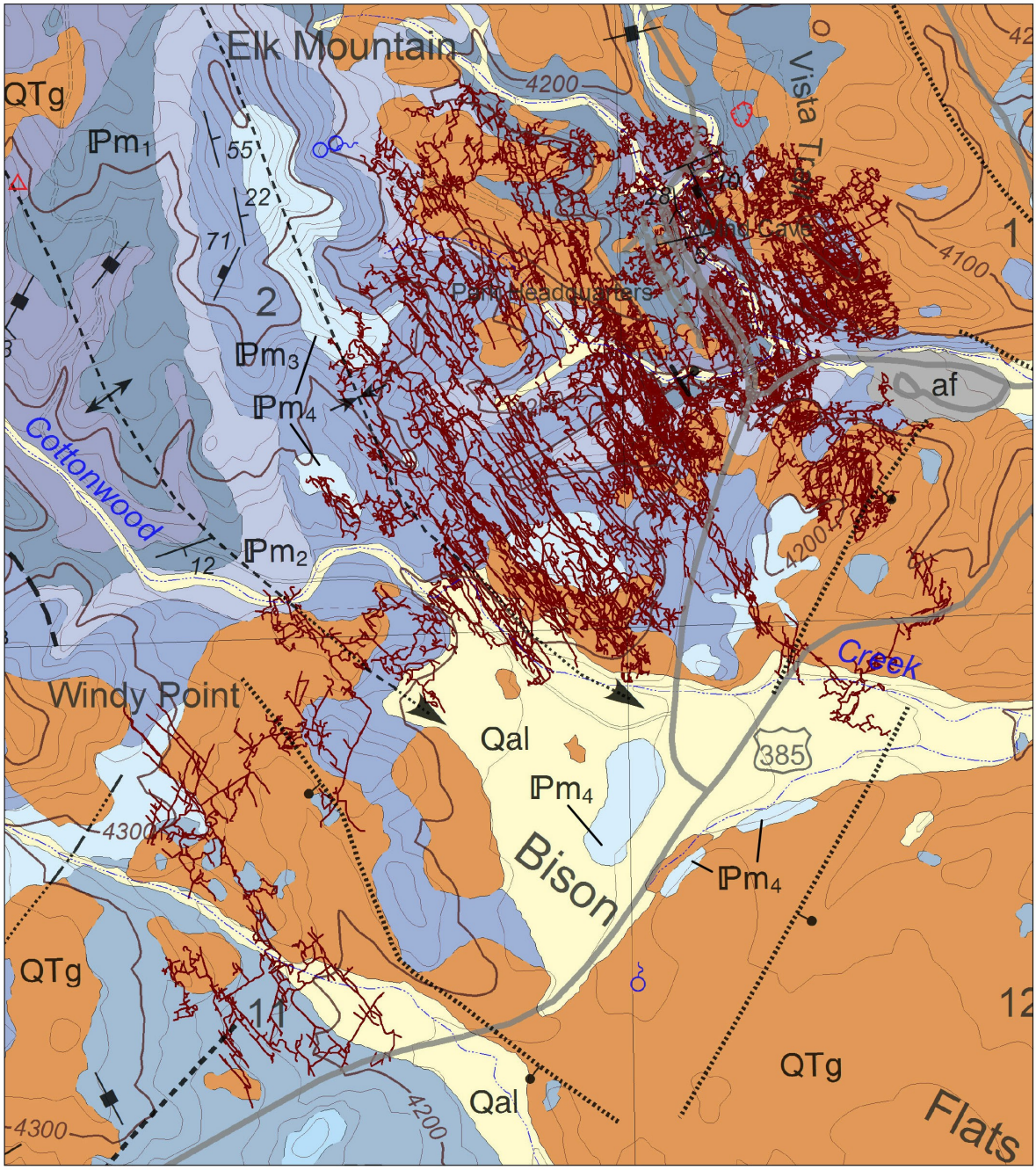
*Note: Wind Cave passages are not included in the GRI digital geologic-GIS data for this project.

Detached Lands Map



Wind Cave National Park detached lands map

Inset Map



Wind Cave inset map at a scale of 1:12,000.
Map base and geology are 20% lighter to display cave passages.

Digital Geologic-GIS Map of the Wind Cave National Park Area

Map Unit List

The geologic units present on the Digital Geologic-GIS Map of the Wind Cave National Park Area, South Dakota (*GRI MapCode WCAM*) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvial deposits). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (WCAMUNIT) table included with the GRI geologic-GIS data.

Cenozoic Era

Quaternary Period
Qal - Alluvial deposits
Ql - Landslide deposits
Qc - Colluvium or talus
Qt - Terrace gravel and alluvial-fan deposits

Tertiary Period
Tw - White River Group

Mesozoic Era

Cretaceous Period
Kp - Pierre Shale
Kn - Niobrara Formation
Kc - Carlile Shale
Kg - Greenhorn Limestone
Kb - Belle Fourche Shale
Km - Mowry Shale
Ks - Skull Creek Shale
Kf - Fall River Formation
Kl - Lakota Formation

Jurassic Period
Jmu - Morrison Formation and Unkpapa Sandstone, undivided
Jsg - Sundance Formation and Gypsum Spring Formation, undivided

Triassic and Permian Periods
TRPs - Spearfish Formation

Paleozoic Era

Permian Period
Pm - Minnekahta Limestone
Po - Opeche Shale

Permian and Pennsylvanian Periods
PPNm - Minnelusa Formation

Mississippian Period
Mp - Pahasapa Limestone

Mississippian and Devonian Periods
MDe - Englewood Limestone

Ordovician and Cambrian Periods
OCd - Deadwood Formation

Precambrian Eon

Proterozoic Eon
Xh - Harney Peak Granite
Xgb - Metagabbro
Xgwd - Distal metagraywacke
Xgwp - Proximal metagraywacke
Xgw2 - Metagraywacke unit 2
Xby - Metamorphosed younger alkalic basal, tuff and volcaniclastic rocks
Xqc - Metamorphosed quartzite, debris flow conglomerate, pelite and graywacke
Xqs - Metamorphosed quartzite and pelite
Xbs2 - Metamorphosed black shale
Xif - Metamorphosed carbonate-facies iron-formation

Map Unit Descriptions

Descriptions of all bedrock map units, generally listed from youngest to oldest, are presented below. All unit descriptions were taken from the source Black Hills Geology.

Qal - Alluvial deposits (Holocene and Pleistocene)

Stream-laid deposits of mud, silt, sand, and gravel. Narrow deposits not shown. Maximum thickness 10 m.

Ql - Landslide deposits (Holocene and Pleistocene)

Small deposits typically along escarpments of Pierre Shale. Localized very small slumps in Jurassic rocks not shown.

Qc - Colluvium or talus (Holocene and Pleistocene)

Angular blocks and debris masking bedrock. Many small deposits not shown. Thickness as much as 10 m.

Qt - Terrace gravel and alluvial-fan deposits (Pleistocene)

Gravel, sand, silt soil. Maximum thickness about 30 m. Some higher elevation terrace deposits could be of Pliocene age.

Tw - White River Group (Oligocene and Upper Eocene)

Silty claystone and poorly indurated sandstone, arkose, and conglomerate. Gravel at higher elevations. Thickness as much as 120 m.

Kp - Pierre Shale (Upper Cretaceous)

Dark-gray to black shale containing concretions and bentonite beds. Maximum thickness about 500 m within map area. Teepee buttes underlain by fossiliferous limestone formed by methane-rich spring deposits.

Kn - Niobrara Formation (Upper Cretaceous)

Gray to yellowish-tan, thin-bedded limestone and calcareous shale. Contains bentonite beds. Thickness 60–100 m.

Kc - Carlile Shale (Upper Cretaceous)

Gray shale and a few tan siltstone and resistant sandstone beds. Thickness 100–200 m.

Kg - Greenhorn Limestone (Upper Cretaceous)

Light gray to tan thin-bedded limestone and calcareous shale. Bentonite beds. Thickness 70–120 m.

Kb - Belle Fourche Shale (Upper Cretaceous)

Gray to black bentonitic shale containing small concretions and thin bentonite beds. Thickness 70–200 m.

Km - Mowry Shale (Lower Cretaceous)

Dark-gray shale, locally somewhat siliceous. Contains minor thin bentonite beds. Thickness 40–70 m.

Ks - Skull Creek Shale (Lower Cretaceous)

Dark-gray to black shale. Thickness 55–80 m. Underlies minor valleys where Newcastle Sandstone is present.

Kf - Fall River Formation (Lower Cretaceous)

Sandstone interbedded with gray to dark-gray shale near top. Thickness 35–70 m.

Kl - Lakota Formation (Lower Cretaceous)

Sandstone, mudstone and shale. Upper part is hard siltstone. Thickness 85–150 m.

Jmu - Morrison Formation and Unkpapa Sandstone, undivided (Upper Jurassic)

Morrison Formation—Shale and sandstone; minor limestone. Thickness as much as 50 m.

Unkpapa Sandstone—Fine-grained aeolian sandstone. Lenses out to the west. Thickness as much as 85 m.

Jsg - Sundance Formation and Gypsum Spring Formation, undivided (Upper and Middle Jurassic)

Sundance Formation—Interbedded shale, siltstone, and sandstone. Thickness 70–160 m.

Gypsum Spring Formation—Gypsum and shale. Thickness as much as 25 m.

TRPs - Spearfish Formation (Triassic and Upper Permian)

dPs - Spearfish Formation (Triassic and Upper Permian)
Red shale and siltstone, minor limestone and gypsum. Thickness 70–275 m.

Pm - Minnekahta Limestone (Lower Permain)

Pinkish-gray, thin–bedded limestone. Thickness 10–18 m.

Po - Opeche Shale (Lower Permain)

Maroon shale and siltstone. Thickness 20–40 m.

PPNm - Minnelusa Formation (Lower Permain and Pennsylvanian)

Phm - Minnelusa Formation (Lower Permian and Pennsylvanian)
Sandstone, limestone, and minor shale. Thickness 120 to about 350 m.

Mp - Pahasapa Limestone (Lower Mississippian)

Mainly thick-bedded dolomitic limestone. Reef-like bluish limestone in uppermost part. Includes Englewood Limestone (unit MDe) in areas of steep terrane. Thickness 80–210 m.

MDe - Englewood Limestone (Lower Mississippian and Upper Devonian)

Lavender impure limestone. Shown in combination with Pahasapa Limestone (Mp) in areas of steep terrane.

OCd - Deadwood Formation (Lower Ordovician and Upper Cambrian)

Glauconitic sandstone, shale, siltstone, and conglomerate. Thickness 0–200 m.

Xh - Harney Peak Granite (Early Proterozoic)

Layered granite, pegmatitic granite, and pegmatite. Leucocratic, peraluminous, plagioclase-microcline-quartz-muscovite S-type granite. Tourmaline and biotite common, but biotite mainly in inner part of central mass. Central mass consists of hundreds of intrusions. More than 24,000 separate bodies of pegmatite and granite are known between the central mass and the line defining the outer limit of pegmatite and granite bodies (map A). Several hundred zoned pegmatites in a peripheral zone contain deposits of feldspar, mica, beryl and other rare-element minerals. Emplacement age of 1,715 ±3 Ma for the main granite based on concordant U-Pb date for monazite (Redden and others, 1990), but the emplacement of some pegmatite bodies may have continued for ~10 Ma.

Xgb - Metagabbro (Early Proterozoic)

Dark-green amphibolite, actinolite schist, or greenstone. Small bodies and margins of larger bodies well foliated. Predominantly sill-like bodies. Minor chemical differences in selected samples indicate at least two distinct types of probable different ages. Types are not lithologically distinct and are shown as a single unit where age is uncertain. Thin dikes cutting Xgw2 a few kilometers northwest of Rockerville have rafted inclusions of metabasalt and metachert apparently derived from units Xby and Xqc. Minor bodies not shown.

*Unit is mapped as both an area feature (WCAMGLG) and a linear geologic feature (WCAMGLN) in the GRI digital geologic-GIS data.

Xgwd - Distal metagraywacke (Early Proterozoic)

Grayish-tan schist and siliceous schist including considerable garnet, staurolite, and sillimanite. Calc-silicate lenses developed from former concretions. Restricted to area southwest of Grand Junction fault. Includes Mayo Formation and middle part of Bugtown Formation (Redden, 1963). Correlation of Mayo Formation uncertain due to faulting but may be equivalent to upper graywacke (Xgw3). Thickness of Mayo part of unit about 3,600 m.

Xgwp - Proximal metagraywacke (Early Proterozoic)

Light-tan, thick-bedded quartzose schist southwest of Grand Junction fault. Predominantly thick Bouma beds of turbidite deposits. Calc-silicate lenses developed from former concretions. Includes lower and upper part of Bugtown Formation (Redden, 1963). Correlation of Bugtown Formation uncertain due to truncation by Grand Junction fault. Total thickness about 2,200m.

Xgw2 - Metagraywacke unit 2 (Early Proterozoic)

Middle part of unit Xgw. Lithologically similar to unit Xgw3. Pelitic parts may contain sillimanite near Harney Peak Granite. Unit underlies the mica schist unit (unit Xts) in the Pactola Lake area but is shown as Xgw where Xts pinches out to the north. Overlies unit Xqc to the southeast in the Rockerville-Keystone area, where the unit may be as much as 2,000 m thick and is largely proximal turbidites. North of Hill City, the unit apparently pinches out.

Xby - Metamorphosed younger alkalic basal, tuff and volcaniclastic rocks (Early Proterozoic)

Pillowed chloritic greenstone or amphibolite, and layered amphibole schist and amphibole-bearing or biotite-rich schist. Thin interflow deposits include various dark-gray and black schists, typically containing some sulfide minerals or graphite, and lenses of massive metachert and banded siderite-metachert or cummingtonite-rich beds. In Lead area this unit is part of Flag Rock Group (Hosted and Wright, 1923) and in Rochford area it is equivalent to Rapid Creek Greenstone of the Flag Rock Group (Bayley, 1972b). In the Mount Rushmore quadrangle the unit occurs as two apparent separate volcanic centers largely within Xqc unit. Correlated with the Crow Formation west of Custer (Redden, 1963), which has flows and agglomerate containing generally similar trace-element abundances and is locally enriched in niobium and cesium, suggestive of alkalic volcanism. In the Rochford area, unit intertongues with tuffaceous shale, tuff, and volcaniclastic rocks (unit Xtv - Metamorphosed tuffaceous shale, tuff, and volcaniclastic rocks) that have U-Pb zircon age of 1,884±29 Ma (Redden and others, 1990). Maximum thickness about 1,000 m.

Xqc - Metamorphosed quartzite, debris flow conglomerate, pelite and graywacke (Early Proterozoic)

Heterogeneous, gray to tan quartzite, metaconglomerate, and phyllite or schist. Garnet-, staurolite-, andalusite-, and sillimanite-bearing at different metamorphic grades. Contains local lenses of unit Xif and massive metachert (not shown everywhere). Matrix-supported metaconglomerate clasts range from quartzite to pelitic schist. Amphibole-schist clasts noted locally in Bitter Creek area (T. 1 S., R. 6 E.) adjacent to exposures of unit Xby (metamorphosed younger alkalic basalt, tuff, and volcaniclastic rocks). Easternmost exposures in Pactola Dam quadrangle include clast-supported metaconglomerate apparently derived from adjacent older units Xqs and Xfc (metamorphosed ferruginous chert). Locally contains thick, lensoid, structureless quartzite beds. Unsorted, typically paraconglomerate, locally containing giant boulders, has pelitic matrix characteristic of debris flows. Unit decreases in thickness to northwest and southwest from north half of Mount Rushmore 7½-minute quadrangle. Quartzite and thin metagabbro sills are widespread east of a north-south line through Pactola Lake dam and extending south to middle of the Harney Peak Granite (Xh). Metagraywacke interbeds are more numerous west of this line, and unit not recognized north of Silver City fault in Pactola Lake area. The lower contact is unconformable in much of the Pactola Lake quadrangle and possibly in part of the Mount Rushmore quadrangle. Elsewhere the lower contact is apparently concordant with adjacent graywacke and the contact is inferred to be a disconformity separating younger from older packages of Early Proterozoic rocks. Because of facies changes to deeper water turbidites to the west and north, the disconformity may lie within or along graywacke units which are lateral equivalents of unit Xqc. The Xqc unit in Hill City area may be at a somewhat different stratigraphic level than elsewhere. Thickness 30–700 m.

Xqs - Metamorphosed quartzite and pelite (Early Proterozoic)

Interbedded quartzite, grayish-tan schist, and phyllite. Massive, thick-bedded quartzite subunits as much as 70 m thick underlie major ridges north of Rockerville and are interbedded with thin-bedded phyllite. Sizable areas of predominantly phyllite are probable in larger fold noses. Thick, ripple-structured quartzite indicates shelf depositional environment. Northern part equivalent to most of Buck Mountain Quartzite (Bayley, 1972b). Correlated with higher metamorphic grade quartzite and sillimanite schist east and southeast of Custer. Unit decreases in thickness to the north and may pinch out near Crystal Mountain. Thickness as much as 1,200 m in east and northeastern part of map area.

Xbs2 - Metamorphosed black shale (Early Proterozoic)

Thin-bedded dark phyllite, biotite schist, or garnet schist, depending on metamorphic grade. Resembles unit Xbs1 but contains thin units of metagraywacke. Equivalent to part of Oreville Formation (Ratté and Wayland, 1969). Interpreted to be stratigraphically higher than unit Xbs1 in central Black Hills but pinches out north of Pactola Lake. Thickness as much as 700 m in the Hill City 7½-minute quadrangle.

Xif - Metamorphosed carbonate-facies iron-formation (Early Proterozoic)

Banded metachert containing ankerite and siderite, and schist. Present at various stratigraphic levels including both younger and older Early Proterozoic units. Contains cummingtonite-grunerite, and garnet at higher metamorphic grade. Locally sulfide-rich and graphitic, such as at Bluelead Mountain (T. 1 S., R. 6 E.). In areas where unit is thick, includes considerable biotite-garnet schist and lenses of massive metachert. Commonly associated with metabasalt, volcaniclastic rocks, or conglomerate and quartzite (unit Xqc); rarely as lenses in metagraywacke. Many thin lensoid occurrences between basaltic flows not shown on map A. In the Lead area includes the Homestake Formation (Hosted and Wright, 1923), which separates the Ellison and Poorman Formations (units Xqg - Metamorphosed quartzite, pelite, and graywacke, and Xbs1). In the Rochford area includes Rochford and Montana Mine Formations (Bayley, 1972c) and unnamed subunits. Locally transitional to thin-bedded chert and dark phyllite or schist. Poor exposures are typical in areas of low metamorphic grade, and unit

mapped largely on metachert float. Some units may contain iron-poor strata. Lensoid distribution, composition, and associated rocks suggest deposition by thermal springs. Laterally continuous units apparently represent larger trough ponding of similar springs. Thickness highly variable; average thickness about 25 m.

*Unit is mapped as both an area feature (WCAMGLG) and a linear geologic feature (WCAMGLN) in the GRI digital geologic-GIS data.

GRI Digital Data Credits

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

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