National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA)

Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory Digital Geologic Data for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA).

black_hills_geology.pdf

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Geologic Resources Inventory Map Document for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA)

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Geologic Resources Inventory Map Document

Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA), South Dakota

Document to Accompany Digital Geologic-GIS Data

black_hills_geology.pdf

Version: 4/6/2010

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (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.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park 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://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store site http://science.nature.nps.gov/nrdata/. To find GRI data select “geology” as a Category, and use “GRI” as a Word Search term.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, 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) program. For more information on the Inventory and Monitoring (I&M) program visit: http://science.nature.nps.gov/im/index.cfm

For more information on this and other Inventory and Monitoring (I&M) Natural Resource inventories visit: http://science.nature.nps.gov/im/inventory/index.cfm

Black Hills Parks Compiled Map Unit List

The geologic units present on the digital geologic-GIS data produced for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data.

Geologic Map Units

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

Meoszoic 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 and Gypsum Spring Formation, undivided

Triassic Period
TRPs Spearfish Formation

Paleozoic Era

Permain Period
Pm Minnekahta Limestone
Po Opeche Shale

Pennsylvanian Period
Phm Minnelusa Formation

Mississippian Period
Mp Pahasapa Limestone
MDe Englewood Limestone

Ordovician and Cambrian Periods
OCd Deadwood Formation

Precambrian Age

Proterozoic

Xh	Harney Peak Granite
Xgb	Metagabbro
Xgby	Younger metagabbro
Xgw	Metagraywacke
Xgwd	Distal metagraywacke
Xgwp	Proximal metagraywacke
Xgw2	Metagraywacke unit 2
Xgw1	Metagraywacke unit1
Xby	Metamorphosed younger alkalic basalt, tuff and volcaniclastic rocks
Xqc	Metamorphosed quartz, debris flow conglomerate, pelite, and graywacke
Xqs	Metamorphosed quartzite and pelite
Xts	Metamorphosed tuff and shale
Xbs2	Metamorphosed black shale
Xbs1	Metamorphosed black shale
Xif	Metamorphosed carbonate-facies iron-formation
Xeq	Quartzite

JECA Map Unit List

The geologic units present on digital geologic-GIS data produced for Jewel Cave National Monument, South Dakota (JECA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data for JECA.

Geologic Map Units

Cenozoic Era

Quaternary Period
Qal Alluvial Deposits
Qt Terrace gravel and alluvial-fan deposits

Meoszoic Era

Triassic Period
TRPs Spearfish Formation

Paleozoic Era

Permain Period
Pm Minnekahta Limestone
Po Opeche Shale

Pennsylvanian Period
Phm Minnelusa Formation

Mississippian Period
Mp Pahasapa Limestone

Mississippian and Devonian Periods
MDe Englewood Limestone

Ordovician and Cambrian Periods
OCd Deadwood Formation

Precambrian Age

Proterozoic
Xgb Metagabbro
Xgwd Distal metagraywacke

MORU Map Unit List

The geologic units present on digital geologic-GIS data produced for Mount Rushmore National Memorial, South Dakota (MORU) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data for MORU.

Geologic Map Units

Cenozoic Era

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

Tertiary Period
Tw White River Group

Paleozoic Era

Mississippian Period
Mp Pahasapa Limestone

Ordovician and Cambrian Periods
OCd Deadwood Formation

Precambrian Age

Proterozoic
Xh Harney Peak Granite
Xgb Metagabbro
Xgby Younger metagabbro
Xgw2 Metagraywacke unit 2
Xgw1 Metagraywacke unit1
Xby Metamorphosed younger alkalic basalt, tuff and volcaniclastic rocks
Xqc Metamorphosed quartz, debris flow conglomerate, pelite, and graywacke
Xqs Metamorphosed quartzite and pelite
Xts Metamorphosed tuff and shale
Xbs2 Metamorphosed black shale
Xbs1 Metamorphosed black shale
Xif Metamorphosed carbonate-facies iron-formation
Xeq Quartzite

WICA Map Unit List

The geologic units present on digital geologic-GIS data produced for Wind Cave National Park, South Dakota (WICA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data for WICA.

Geologic Map Units

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

Meoszoic 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 and Gypsum Spring Formation, undivided

Triassic Period
TRPs Spearfish Formation

Paleozoic Era

Permain Period
Pm Minnekahta Limestone
Po Opeche Shale

Pennsylvanian Period
Phm Minnelusa Formation

Mississippian Period
Mp Pahasapa Limestone

Mississippian and Devonian Periods
MDe Englewood Limestone

Ordovician and Cambrian Periods
OCd Deadwood Formation

Precambrian Age

Proterozoic
Xh Harney Peak Granite
Xgb Metagabbro
Xgwd Distal metagraywacke
Xgwp Proximal metagraywacke
Xgw2 Metagraywacke unit 2
Xby Metamorphosed younger alkalic basalt, tuff and volcaniclastic rocks
Xqc Metamorphosed quartz, 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 geologic map units, generally listed from youngest to oldest, are presented below.

Qal - Alluvial Deposits (Holocene and Pleistocene)

Stream-laid deposits of mud, silt, sand, and gravel. Narrow deposits not shown. Maximum thickness 10 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Ql - Landslide deposits (Holocene and Pleistocene)

Small deposits typically along escarpments of Pierre Shale. Localized very small slumps in Jurassic rocks not shown. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Qc - Colluvium or talus (Holocene and Pleistocene)

Angular blocks and debris masking bedrock. Many small deposits not shown. Thickness as much as 10 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kn - Niobrara Formation (Upper Cretaceous)

Gray to yellowish-tan, thin-bedded limestone and calcareous shale. Contains bentonite beds. Thickness 60–100 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kc - Carlile Shale (Upper Cretaceous)

Gray shale and a few tan siltstone and resistant sandstone beds. Thickness 100–200 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kg - Greenhorn Limestone (Upper Cretaceous)

Light gray to tan thin-bedded limestone and calcareous shale. Bentonite beds. Thickness 70–120 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kb - Belle Fourche Shale (Upper Cretaceous)

Gray to black bentonitic shale containing small concretions and thin bentonite beds. Thickness 70–200 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Km - Mowry Shale (Lower Cretaceous)

Dark-gray shale, locally somewhat siliceous. Contains minor thin bentonite beds. Thickness 40–70 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Ks - Skull Creek Shale (Lower Cretaceous)

Dark-gray to black shale. Thickness 55–80 m. Underlies minor valleys where Newcastle Sandstone is present. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kf - Fall River Formation (Lower Cretaceous)

Sandstone interbedded with gray to dark-gray shale near top. Thickness 35–70 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Kl - Lakota Formation (Lower Cretaceous)

Sandstone, mudstone and shale. Upper part is hard siltstone. Thickness 85–150 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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

Morrison Formation—Shale and sandstone; minor limestone. Thickness as much as 50 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Unkpapa Sandstone—Fine-grained aeolian sandstone. Lenses out to the west. Thickness as much as 85 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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

Sundance Formation—Interbedded shale, siltstone, and sandstone. Thickness 70–160 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Gypsum Spring Formation—Gypsum and shale. Thickness as much as 25 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

TRPs - Spearfish Formation (Triassic and Upper Permian)

Red shale and siltstone, minor limestone and gypsum. Thickness 70–275 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Pm - Minnekahta Limestone (Lower Permian)

Pinkish-gray, thin–bedded limestone. Thickness 10–18 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Po - Opeche Shale (Lower Permian)

Maroon shale and siltstone. Thickness 20–40 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Phm - Minnelusa Formation (Lower Permian and Pennsylvanian)

Sandstone, limestone, and minor shale. Thickness 120 to about 350 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

MDe - Englewood Limestone (Lower Mississippian and Upper Devonian)

Lavender impure limestone. Shown in combination with Pahasapa Limestone (Mp) in areas of steep terrane . Thickness 10–20 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

OCd - Deadwood Formation (Lower Ordovician and Upper Cambrian)

Glauconitic sandstone, shale, siltstone, and conglomerate. Thickness 0–200 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xs - Metamorphosed shale (Early Proterozoic)

Gray to black slate, phyllite, or schist. In part, garnetiferous at higher metamorphic grade. Locally contains graphite and sulfide minerals. Includes Grizzly Formation (Dodge, 1942), part of Swede Gulch Formation (Bayley, 1972c), and part of Oreville Formation (Ratté and Wayland, 1969). Thickness poorly known due to homogeneity and intense folding, but estimated to be at least 2,000 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xgby - Younger metagabbro (Early Proterozoic)

Lithologically similar to unit Xgb. Sills and dikes spatially distributed with or near shale, tuff, and volcaniclastic rock (unit Xtv - Metamorphosed tuffaceous shale, tuff, and volcaniclastic rocks). Compositions of selected bodies are alkalic gabbro. Emplaced about 1,900 Ma. Differentiated sill intruding quartzite and pelite (unit Xqs) in Prairie Creek area (T. 1 N., R. 5 E.) has U-Pb zircon age of 1,883±5 Ma (Redden and others, 1990). *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xgw - Metagraywacke (Early Proterozoic)

Greenish-gray to grayish-tan siliceous schist. Minor chlorite, garnet, staurolite, or sillimanite in pelitic interbeds at various metamorphic grades. Protoliths are turbidite deposits having readily recognizable Bouma sequences. Calc-silicate ellipsoidal structures develop from carbonate-rich concretions near the garnet isograd. Local discordances within units probably indicate penecontemporaneous slump, but a disconformity is inferred to exist in the lower part of the unit. Subdivided into units Xgw1, Xgw2, and Xgw3 where possible. Subunits pinch out northwest of Pactola Lake. Includes part of Oreville Formation in Hill City 7½-minute quadrangle (Ratté and Wayland, 1969). Thickness possibly as much as 2,200 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

**unit isn't present in GIS data, however, several subdivided units of Xgw (Xgwd, Xgwp, Xgw2, and Xgw1) are present.

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xgw1 - Metagraywacke unit 1 (Early Proterozoic)

Lower part of unit Xgw. Lithologically similar to unit Xgw3 but contains higher metamorphic grade minerals such as sillimanite near the Harney Peak Granite (Xh). In the Hill City and Sheridan Lake areas, the unit is largely proximal turbidites having thick Bouma A units. A disconformity is inferred to occur within or at the top of the unit. The maximum thickness is probably about 1,500 m, but the unit pinches out or is removed by erosion to the west. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xby - Metamorphosed younger alkalic basalt, 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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xts - Metamorphosed tuff and shale (Early Proterozoic)

Greenish-gray to tan phyllite and muscovite-biotite schist. At higher metamorphic grades muscovite schist may contain andalusite, sillimanite, garnet, staurolite, or cordierite. Manganese-rich garnet coticle, magnetite octahedra, and traces of chalcopyrite are distinctive components in Berne, Hill City, Silver City, Medicine Mountain, and Deerfield 7½-minute quadrangles. Subunits rich in magnetite and ilmenite produce strong magnetic anomalies. Included as part of Oreville Formation in Hill City area by Ratté and Wayland (1969). Unit includes increasing number of metagraywacke beds to the northeast and loses distinctive identity a few kilometers north of Pactola Lake. East of Mystic (T. 1 N., R. 3 E.), unit includes thin alkalic metabasalt (unit Xby). West toward Rochford, the unit is equivalent to tuffaceous shale, tuff, and volcaniclastic rocks (unit Xtv - Metamorphosed tuffaceous shale, tuff, and volcaniclastic rocks), in which tuff within the volcaniclastic rocks has a U-Pb zircon age of 1,883±5 Ma (Redden and others, 1990). Thickness as much as 700 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xbs1 - Metamorphosed black shale (Early Proterozoic)

Dark, thin-bedded slate, phyllite, or schist, and local thin beds of metachert. Generally biotite-rich and contains thin garnet-rich beds at higher metamorphic grade. Graphitic and sulfide-rich locally. Equivalent to Reausaw Slate (Bayley, 1972b) and upper part of Poorman Formation in Lead area. Interfingers with individual metabasalt flows (unit Xbo - Metamorphosed older basaltic rocks) north-northwest of Pactola Lake. Thickness estimated to range from about 30 m to possibly 1,000 m. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

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. *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

Xeq - Quartzite (Early Proterozoic)

Predominantly thick-bedded quartzite and minor meta-arkose, both grading distally to quartzose phyllite. Near Nemo units Xeq and Xec (metamorphosed conglomerate and quartzite) intertongue in three fans. Combined thickness of units Xec and Xeq in the well-exposed middle fan ranges from about 500 m to 3,300 m. In Bear Mountain area unit Xeq is arkosic quartzite that contains a local, very thin basal metaconglomerate equivalent to arkosic part of the Vanderlehr Formation (Ratté, 1986). Thickness near Bear Mountain about 100 m. In Harney Peak area, unit Xeq includes quartzite and gneissic metaconglomerate inliers within Harney Peak Granite (unit Xh). *GRI Source Map 4145* (***BLACK HILLS GEOLOGY***).

GRI Source Map Citations

The GRI digital geologic-GIS maps for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA), South Dakota were compiled from the following source:

DeWitt, Ed, 2004, Geologic Map of the Mount Rushmore and Rapid City 60' x 60' Quadrangle, South Dakota, U.S. Geological Survey, unpublished mylars, 1:100,000 scale. (*GRI Source Map 4145*)

Additional information pertaining to each source map is also presented in the Source Map Information (MAP) table included with the GRI geology-GIS data.

GRI Digital Data Credits

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

The information contained here was compiled to accompany the digital geologic-GIS map(s) and other digital data for Jewel Cave National Monument (JECA), Mount Rushmore National Memorial (MORU) and Wind Cave National Park (WICA), South Dakota (JECA, MORU and WICA) first developed by Stephanie O'Meara, Jim Chappell and Heather Stanton (Colorado State University) using source mylars provided by the map author (DeWitt, Ed, 2004). This digital data was then "migrated" to the NPS GRI Geology-GIS Data Model v. 2.1 and to a 9.3 ESRI geodatabase format by Stephanie O'Meara, Dave Green, Ethan Schaeffer and John Gilbert (Colorado State University student interns).

GRI finalization by Stephanie O'Meara (Colorado State University).

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