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Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Great Basin National Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Great Basin National Park

grba_geology.pdf

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Geologic Resources Inventory Map Document for Great Basin National Park

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Geologic Resources Inventory Map Document

Great Basin National Park, Nevada

Document to Accompany Digital Geologic-GIS Data

grba_geology.pdf

Version: 2/18/2014

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Great Basin National Park, Nevada (GRBA).

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.

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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 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: 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) Division.

GRI Digital Map and Source Map Citations

The GRI digital geologic-GIS map for Great Basin National Park, Nevada (GRBA).

GRI Digital Geologic Map of Great Basin National Park and Vicinity, Nevada (GRI MapCode GRBA)

The source map and digital data,

Miller, E.L, and the Stanford Geological Survey, 2007 (mapping 1993-1997), Geologic Map of Great Basin National Park and Environs, Southern Snake Range, Nevada, Stanford Geological Survey, 1:24,000 scale. (*GRI Source Map ID 7455*).

Unit descriptions were produced from the following source,

Miller, Elizabeth L., and Gans, Phillip B., 1993, Geologic Map of the Wheeler Peak and Minerva Canyon 7.5' Quadrangle, White Pine County, Nevada, Department of Geology, Stanford University, OF93, 1:24,000 scale.

***Several references are cited in the unit descriptions of this document. Please refer to the actual source publications or the source map authors for complete citation (reference) information. As this source map is of the Wheeler Peak and Minerva Canyon 7.5' quadrangles, unit descriptions may have biased information or information applicable only to those quadrangles (no better descriptions were provided with the GRI source maps).*

Map Unit List

The geologic units present in the digital geologic-GIS data for Great Basin National Park, Nevada (GRBA) are listed below, from youngest unit to oldest unit. Detailed unit descriptions were taken from Miller and Gans,1993 (OF93). As this source map is of the Wheeler Peak and Minerva Canyon 7.5' quadrangles, unit descriptions may have biased information or information applicable only to those quadrangles (no better descriptions were provided with the GRI source maps).

Cenozoic Era

Quaternary Period

Qt - Talus
Qa - Alluvium
Qlg - Lacustrine gravels
Ql - Landslide deposits
Qg - Glacial deposits
Qoa - Older alluvium

Quaternary-Tertiary Periods

QTc - Conglomerate, younger

Tertiary Period

Tc - Conglomerate, older
  Tcmb - Conglomerate, older, marker bed
Tnr - Needles Range Formation
Tl - Lacustrine deposits
Tlf - Latite flows
Trdi - Rhyodacite flows and subvolcanic intrusive rocks
Toc - Older conglomerate
Tmp - Muscovite-bearing rhyolite porphyry dikes and sills
Tgr - Granite

Mesozoic Era

Cretaceous Period

Kgr - Granite

Jurassic Period

Jr - Granite

Paleozoic Era

Pennsylvanian Period

PNe - Ely Limestone

Mississippian Period

Mc - Chainman Shale
Mj - Joana Limestone

Mississippian-Devonian Periods

MDp - Pilot Shale

Devonian Period
Dg - Guilmette Formation
Ds - Simonson Dolomite
Dse - Sevy Dolomite

Ordovician-Silurian Periods
OSfl - Fish haven and Laketown Dolomites, undifferentiated

Ordovician Period
Oe - Eureka Quartzite
Op - Pogonip Group, undifferentiated
- Opl - Lehman Formation
- Opk - Kanosh Shale
- Opj - Juab Limestone
- Opw - Wahwah Limestone
- Opf - Fillmore Limestone
- Oph - House Limestone

Ordovician-Cambrian Periods
OCn - Notch Peak Limestone

Cambrian Period
Ccs - Corset Spring Shale
Cjw - Johns Wash Limestone
Clp - Lincoln Peak Formation
- Clpmb - Lincoln Peak Formation, conglomerate marker bed

Middle Cambrian Period
Cpc - Pole Canyon Limestone, undifferentiated
- Cpcmb - Pole Canyon Limestone, undifferentiated, conglomerate marker bed
- Cpce - Pole Canyon Limestone, e member
- Cpcd - Pole Canyon Limestone, d member
- Cpcc - Pole Canyon Limestone, c member
- Cpcb - Pole Canyon Limestone, b member
- Cpca - Pole Canyon Limestone, a member

Lower Cambrian Period
Cpi - Pioche Shale

Paleozoic Era-Proterozoic Eon

Lower Cambrian Period-Late Proterozoic
CZpm - Prospect Mountain Quartzite

Proterozoic Eon

Late Proterozoic
Zm - McCoy Group, undifferentiated
Zmoa - Osceola Argillite of the McCoy Creek Group
Zmsc - McCoy Creek Group, Shingle Creek Shale
Zmq - McCoy Group, quartzite

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qt- Talus (Quaternary)

Talus. No additional information was provided on source map. (Miller e. al., 2007).

Qa - Alluvium (Quaternary)

Generally unconsolidated sands and gravels deposited within modern drainage systems. (OF93).

Qlg - Lacustrine gravels (Quaternary)

Lacustrine gravels. No additional information was provided on source map. (Miller e. al., 2007).

Ql - Landslide deposits (Quaternary)

Chaotic mass of blocks of various sizes deposited on modern slopes. (OF93). Qls (Quaternary landslide deposits) on source map.

Qg - Glacial deposits (Quaternary)

Chiefly ground moraine deposited during two glacial stages. Younger morainal surfaces are hummocky, whereas older morainal surfaces have a more subdued topography. (OF93). Qg (Quaternary glacial morraine) on source map.

Qoa - Older alluvium (Quaternary)

Flat lying or gently dipping consolidated to unconsolidated alluvial-fan and gravel deposits that form pediment surfaces, rest in sharp angular discordance above older rocks and are incised by present day drainage systems. Clast types and morphology of these deposits indicate they are derived from the major present-day drainage systems developed in flanking mountain ranges. (OF93).

QTc - Conglomerate, younger (Quaternary or Tertiary)

QTc - Conglomerate (Quaternary or Tertiary)
The Quaternary or Tertiary conglomerate is a generally flat lying conglomerate, whose age is uncertain. The unit is best exposed in the hilly region leading into Decathon Canyon and crops out in several drainages in and around the road to Decathon Canyon, to the east of the area of detailed study. In the Minerva Canyon quadrangle there are few outcrops or it is unexposed, and the unit is seen only in float. Whitebread (1969) mapped the western contact of this unit with bedrock as a depositional contact. However, close examination of these contacts by us suggest that the poorly exposed conglomerate adjacent to bedrock exposures may actually be in fault contact with bedrock units. In several locations we were able to observe and measure fault planes where the conglomerate is in contact with the Ordovician - Silurian undifferentiated Dolomites to the west, and with the Devonian Sevy Dolomite to the southwest. The conglomerate is also in fault contact with the Devonian Guilmette Formation to the north.

The conglomerate appears to contain clasts of all Paleozoic units down to at least the Pogonip group. Positively identified clast types include those derived from the Ordovician Eureka Quartzite, the Ordovician Fillmore Limestone, the Ordovician Kanosh Limestone, and few Ordovician - Silurian undifferentiated Dolomites. Most noticeable are the car size Eureka Quartzite boulders that litter the landscape at the northern exposures of the conglomerate. The conglomerate also contains abundant clasts of the Needles Range Formation in its more southerly exposures which indicates that exposure of the Needles Range Formation was once much more widespread than its current extent. Because these clasts were not seen in float further to the north, however, it is presumed that exposures of the Needles Range Formation did not extend much further up the present valley than their present day location. Based on these relationships we conclude that the conglomerate on the eastern side of the Minerva Canyon quadrangle is younger than the Needles Range Formation. The conglomerate predates Quaternary older alluvium, but it is unclear how much older it is relative to this alluvium.

The thickness of the Quaternary or Tertiary conglomerate is estimated to be about 153 -183 m from the relief of the unit. (OF93).

Tc - Conglomerate, older (Tertiary)

QTc - Conglomerate (Quaternary or Tertiary)
Conglomerate. Includes the following sub unit: Tcmb - Conglomerate marker bed. (Miller e. al., 2007).

Tcmb - Conglomerate, older, marker bed (Tertiary)

QTc - Conglomerate (Quaternary or Tertiary)
Marker bed within Tc (Conglomerate, older). No additional information was provided on source map. (Miller e. al., 2007).

Tnr - Needles Range Formation (Tertiary)

The Tertiary Needles Range Formation underlies a plateau-like area in the southern part of Johns Wash. It is best exposed at the north end of this plateau where it conformably overlies older Tertiary conglomerate. A second exposure of the Needles Range Formation occurs in the southeast corner of the Minerva Canyon quadrangle along the road in West Fork Canyon. Here it is more poorly exposed, and rests depositionally on the Devonian Guilmette Formation. There is also another small patch of exposure by the spring where Murphy Wash originates.

Several divisions are visible in the Needles Range Formation beginning with a grey basal surge layer about 60 to 90 cm thick, followed by a pink ash flow that is about 1.5 to 3 m thick. Overlying these two is ~60 cm of conglomerate with a volcanic matrix. Imbricated pebbles in both conglomerate intervals indicate south-directed paleocurrents. Above the second conglomerate is another laminated, grey, ~1 m thick basal surge layer of crystal-rich tuffaceous sediments, overlain by pink to red ashflow tuff that forms the conspicuous red to red-brown vertically jointed cliffs which make up most of the mapped the Needles Range Formation. Portions of the area mapped as Needles Range by Whitebread (1969) in the lower portions of Murphy Wash area we have reinterpreted as landslide deposits based on the hummocky topography and random orientation of compaction foliation.

The Needles Range tuff is rhyolitic to rhyodacitic in composition and is generally moderately welded. The basal surge layer is rich in hornblende and biotite phenocrysts and the main overlying pink-colored ashflow tuff is exclusively biotite bearing. The tuff also contains plagioclase feldspar, quartz and lesser sanidine phenocrysts. The biotite books are up to half a centimeter in diameter. Generally, the phenocryst to matrix ratio is constant throughout the tuff and is estimated to be about 35% phenocryst and 65% matrix.

The source of the various cooling units that comprises the Needles Range Formation is the Indian Peak caldera complex, which lies south of the Minerva Canyon quadrangle. The Needles Range Formation has been dated at 33-27 Ma (Best and others, 1989). Its maximum exposed thickness is approximately 110 m but its top is erosional. (OF93).

Tl - Lacustrine deposits (Tertiary)

Lacustrine deposits. No additional information was provided on source map. (Miller e. al., 2007).

Tlf- Latite flows (Tertiary)

Latite flows. No additional information was provided on source map. (Miller e. al., 2007).

Trdi - Rhyodacite flows and subvolcanic intrusive rocks (Tertiary)

Rhyodacite flows and subvolcanic intrusive rocks. No additional information was provided on source map. (Miller e. al., 2007).

Toc - Older conglomerate (Tertiary)

The Older Tertiary Conglomerate unit is a sequence of flat lying conglomerate that is conformably overlain by the Tertiary Needles Range Formation. Although generally poorly exposed, it is locally well exposed in several areas immediately beneath the more resistant overlying Needles Range Formation. There is especially good exposure of the conglomerate in the hillside just east of the upper Johns Wash road spring, between the road going down Johns Wash and the road going down Murphy Wash. Measured here, its thickness ranges from 30 to 60 m. Within the unit two somewhat different conglomerates were distinguished and are referred to here as the upper division and the lower division. Their description is from the excellently exposed area mentioned above.

The upper division of the conglomerate is pebbly with occasional cobbles. It is a clast supported conglomerate and is poorly sorted. The clasts are subangular to subrounded and occur within a sand and silt matrix. A few beds of sandstone up to 5 cm thick are interbedded with the conglomerate. The lower division of the conglomerate is very similar to the upper division but it is not as well bedded. A few granite clasts were found in the outcrop; these were several inches in diameter. No imbrication was discernable from the clasts.

Two clast counts were done on the conglomerate at this outcrop. One hundred clasts were counted in each location. See source report. (OF93). Tco (Older Tertiary conglomerate) on source map.

Tmp - Muscovite-bearing rhyolite porpyhyry dikes and sills (Tertiary)

Muscovite-bearing rhyolite porpyhyry dikes and sills. No additional information was provided on source map. (Miller e. al., 2007).

** Unit is present in the GRI GIS digital data as both an area (polygon) and linear (line) feature.

Tgr - Biotite granite (Tertiary)

Biotite granite. No additional information was provided on source map. (Miller e. al., 2007).

Kgr - Granite (Cretaceous)

The very westward edge of the Pole Canyon pluton of Cretaceous age occurs along the eastern boundary of the Wheeler Peak quadrangle, and is mainly exposed in the Kious Spring quadrangle to the east, where it has been described by McGrew and Miller (1992). The Pole Canyon pluton belongs to a family of Cretaceous two mica granites that occur in a north-trending band through eastern Nevada (Miller and Bradfish, 1980; Lee and others, 1981; Lee and others, 1986; Miller and Gans, 1989). The main phase of this granite is characterized by large, euhedral muscovite phenocrysts up to 2 cm in diameter that contain tiny euhedral biotite inclusions. Biotite and muscovite are also intimately intergrown in the equigranular matrix. A Rb-Sr whole rock isochron of 79.1 ± 0.5 Ma (Lee, Kistler, Robinson, 1986) agrees well with a minimum age of 79.7 Ma from K-Ar analysis of muscovite (Lee and others, 1970). A dense swarm of approximately E-W trending aplite and pegmatite dikes forms a second major intrusive phase within the outcrop area of this pluton, but may well be derived from the Tertiary Young Canyon-Kious Basin pluton neighboring it to the east. (OF93).

Jg - Granite (Jurassic)

Several large Jurassic plutons of diverse composition occur in the northern and southern Snake Range. This group of plutons is represented in the Wheeler Peak Quadrangle by the Snake Creek/Williams Canyon pluton. A variety of isotopic geochronologic techniques, including U-Pb analyses of monazite and Sr whole rock analyses, yield an intrusive age of approximately 160 Ma for this body (Lee et al., 1986). The elongate, undeformed Snake Creek/Williams Canyon pluton is oriented roughly E-W with a larger eastern lobe in Snake Creek and has a total exposed area of 35 km2 (Lee et al., 1984; 1986). It is a compositionally zoned calc-alkaline pluton from a biotite-tonalite (63% SiO2) to the east grading into a biotite-granite (76% SiO2) to the west (Lee et al., 1986). The most mafic compositions are represented by rounded, cognate biotite-rich granodiorite xenoliths ranging in diameter from 3-15 cm, found throughout the pluton.

Accessory minerals in the eastern portion of the pluton include biotite, epidote, titanite, magnetite, and allanite, whereas the central and western portions locally include garnet, ilmenite, and monazite primarily in aplite/pegmatite dikes and in felsic border phase rocks; apatite and zircon are ubiquitous throughout (Lee and Van Loenen, 1971). Within 10-20 m of the country rock contact, muscovite is often present together with or in place of biotite. West of Pyramid Peak in the Wheeler Peak quadrangle, extensive areas of the intrusion have been altered to a pyrite-muscovite quartz griesen, labeled Jgra on Plate 1A, associated with abundant quartz veins. These 0.05-5-meter-thick quartz veins strike approximately N60E, are steeply dipping, and have steeply plunging slickensides (Fig.9). They often contain the mineral assemblage muscovite-galena-wolframite (Smith, 1976). A hornblende-bearing, fine-grained granodiorite dike was mapped east of Pyramid Peak, and garnet-bearing aplite dikes are often found cutting the pluton near its contact with the country rock. Occasionally, somewhat more porphyritic equivalents of the pluton are found as dikes and in some parts of the pluton itself. In these, quartz, biotite, and plagioclase occur as phenocryst phases.

The Snake Creek/Williams Canyon pluton has a sharp intrusive contact with the several units that surround it, including the Precambrian McCoy Creek Group Quartzite and the Osceola Argillite, and the Cambrian Prospect Mountain Quartzite, Pioche Shale, and Pole Canyon Limestone. Contact effects include the growth of muscovite, chlorite, biotite, and aluminum silicate minerals within argillaceous layers and calc-silicate minerals within calcareous layers. Pervasive retrogression of schists and slates prevents conclusive identification of the aluminum silicate porhyroblasts that grew in the aureole of the

pluton, but euhedral outlines allow identification of the pseudomorphs as staurolite. Staurolite porphyroblasts increase in size and quality towards the pluton. Grey, elongate, prismatic grains with square cross-sections were tentatively identified in the field as andalusite, and other retrograded aluminum silicate porphyroblasts may include chloritoid and/or cordierite. Skarn assemblages in calc-silicate rocks include epidote, garnet, diopside, and actinolite. Metamorphic grade in the contact aureole rises from greenschist to amphibolite facies over horizontal distances of less than 1.5 km (McGrew and Miller, 1993). In addition to the observed growth of certain minerals in the aureole of the granite, a penetrative cleavage is developed in pelitic units adjacent to the pluton. Systematic observation of the relationship of cleavage development to growth of contact metamorphic minerals indicate the two are coeval and that deformation was synchronous with granite emplacement (Miller, et al., 1988). This cleavage is discussed in more detail elsewhere in the text (source report). (OF93).

PNe - Ely Limestone (Pennsylvanian)

The Pennsylvanian Ely Limestone is exposed in the southern section of the Minerva Canyon Quadrangle between Murphy Wash and Johns Wash as well as farther north in Johns Wash. No complete section of the Pennsylvanian Ely Limestone is found in the map area, but a partial thickness of 260 m was measured in the northernmost exposed section of Ely Limestone in Johns Wash. Whitebread (1969) estimates a total unit thickness of 550-720 m. The Pennsylvanian Ely Limestone is a medium to coarse grained, slope-forming limestone characterized by alternating limestone ledges with gentle slopes. The ledge-forming sections of the Ely Limestone are thin-bedded (2-30 cm thick), light- to medium-light-grey, and consist of organic detrital limestone (containing brachiopod, crinoid, foram, and coral debris). The slope-forming sections of the Ely are a platy, medium grey to tannish-grey silty limestone. Rounded chert nodules 2-10 cm in diameter (not parallel to bedding) are common throughout the section. The Ely Limestone is very fossiliferous, with *Chaeletes* (string coral), crinoid stems, silicified brachiopods, and forams common throughout the section. Although there is little variation in the Pennsylvanian Ely Limestone, there is a section of tan to red, noncalcareous, silicified brachiopod-rich sandstone (5-10 m thick) present near the top of the Ely Limestone. The contact with the underlying Mississippian Chainman Shale is poorly exposed, and no contact with the overlying Permian Arcturus Formation is present in the Wheeler Peak or Minerva Canyon Quadrangles. (OF93).

Mc - Chainman Shale (Mississippian)

The Mississippian Chainman Shale (map unit Mc) is best exposed between Murphy Wash and Johns Wash in the Minerva quadrangle, about half a mile from where Johns Wash and Murphy Wash intersect. The Mississippian Chainman Shale is a slope-former and generally only the more quartzose beds within the unit actually crop out. Otherwise, the Mississippian Chainman Shale is found primarily as small float of brownish- red weathering shaley and silty rocks with occasional larger blocks and pieces of thin quartz sand beds, black, siliceous argillite, and calcareous sand and shale. The more shaly float of the Mississippian Chainman Shale consists of a dark grey to pale yellow-brown shale and siltstone. The basal contact of the Mississippian Chainman Shale with the Mississippian Joana Limestone, as well as its upper contact with the Pennsylvanian Ely Limestone, is evidenced by an abrupt change in slope and is not well exposed or easily studied in the Minerva Canyon quadrangle.

Although there is no complete section of Mississippian Chainman Shale in the Minerva Canyon quadrangle, it is at least 366 m where it is best exposed. Whitebread (1969) has estimated the thickness of the Mississippian Chainman in the old Wheeler Peak and Garrison 15" quadrangle to be 305 - 610 m. (OF93).

Mj - Joana Limestone (Mississippian)

The Mississippian Joana Limestone is exposed in several locations in the Minerva Quadrangle between Murphy Wash and Johns Wash as well as northward along Johns Wash. The best section is found in Murphy Wash adjacent to the Murphy Wash Fault in the southern section of the Minerva Canyon Quadrangle. Here, the Joana Limestone has a partial thickness of 100 m. The Mississippian Joana Limestone is a resistant, cliff-forming, medium grey to medium light grey limestone that unconformable overlies the Pilot Shale. A quartzite bed 1-3 m thick is present near the base of the Joana unit. The Joana Limestone is mostly a massive, light grey limestone with thin, sometimes lenticular, bedding (5-30 cm thick) present in the lowermost and uppermost sections. The limestone is medium to coarse grained and consists primarily of organic detrital material including crinoid stems, coral, and brachiopod debris. Rounded nodules and stringers of chert, developed subparallel to bedding, are locally abundant. The Joana Limestone-Chainman Shale contact is poorly exposed in the area but can be inferred from the break in slope from the more resistant, cliff-forming Joana unit to the overlying, less resistant, slope-forming Chainman Shale. (OF93).

MDp - Pilot Shale (Mississippian-Devonian)

The Mississippian-Devonian Pilot Shale (map unit MDp) is a slope-former that is generally very poorly exposed and is found primarily in float. Rare exposure of this elusive unit can be found near the spring on the east side of Johns Wash where it intersects Murphy Wash. At this location, it is underlain conformably by the Devonian Guilmette Formation and overlain, but in fault contact, with the Mississippian Joana Limestone. Further south on the western side of Johns Wash, the Mississippian Devonian Pilot Shale can be seen in depositional contact with the Mississippian Joana Limestone and the transition is marked by a noticeable change in slope.

The Mississippian-Devonian Pilot Shale is a pink weathering grey to yellow calcareous shale with thin limestone interbeds and occasional chert stringers. It is usually evidenced by shaley float.

The thickness of the Mississippian Devonian Pilot Shale appears to be variable in the map area although this is probably related to faulting of the sequence. Whitebread (1969) has estimated its thickness to be between 122-244 m. We have estimated an apparent thickness of only 91 m in the Minerva Canyon quadrangle. (OF93).

Dg - Guilmette Formation (Devonian)

The Devonian Guilmette Formation (Dg) is a slope- to cliff-forming limestone. The best exposures of the Guilmette Formation occurs on the southern edge of the study area, east of Johns Wash, and these continue to the south into the Red Ledges quadrangle. Here the base of the Guilmette Formation is in fault contact with the underlying Simonson Dolomite. The upper contact and presumably most of the Formation is not exposed in the map area. Whitebread (1969) estimates the Guilmette Formation to be 760 m thick - more complete sections are exposed in the adjacent Arches and Red Ledges quadrangles. The Guilmette Formation is generally massive, but locally it is thinly bedded with shaly partings. According to Whitebread, dolomite is more common in the upper part of the section. The limestone is generally massive and dark bluish grey which becomes progressively more well bedded and more shaly up-section. A well-developed stromatolite boundstone up to 2 m thick was seen approximately halfway between the base and the uppermost exposure. 20 m above the stromatolite bed the Guilmette there are several 1 to 2 m shale layers which interbed with the limestone but are less resistant to weathering and thus are generally seen as float, not as outcrops. They weather to orangish-red to yellow and contain abundant grazing trace fossils. Other fossils seen in the Guillmette Formation include brachiopods, crinoids, gastropods, and stromatoperoids. (OF93).

Ds - Simonson Dolomite (Devonian)

The Devonian Simonson Dolomite occurs in various locations in the southern portion of the Minerva Canyon quadrangle, mostly in the eastern and east-central portion of the quadrangle. It is best exposed to the east of Johns Wash about 1 km from the southern boundary of the quadrangle.

The Devonian Simonson Dolomite is predominantly a ledgy slope-former. It consists of light to dark brown, thin to medium bedded, laminated, microcrystalline to coarsely crystalline dolomite. Its basal part is thicker bedded and uniformly light brown. Fossils present in the unit include gastropods, crinoids, brachiopods, and stromatoperoids.

At the above location, the transition from the underlying light-colored Devonian Sevy Dolomite to the Devonian Simonson Dolomite is quite clear and has been described in the previous section. The stratigraphic contact with the overlying Devonian Guilmette is everywhere a fault contact in the Minerva Canyon quadrangle. Whitebread (1969) reports an estimated thickness of 575 ft. (175 m) of Devonian Simonson Dolomite which was measured west of Big Springs Ranch, 3 miles south of the Garrison quadrangle. In the Minerva Canyon quadrangle, the minimum thickness estimated for the Devonian Simonson Dolomite is about 168 m. (OF93).

Dse - Sevy Dolomite (Devonian)

The Devonian Sevy Dolomite is well exposed throughout the southeastern corner of the Minerva Canyon quadrangle and is best exposed to the east of hill 7922T on the west side of the road in Johns Wash. It is a light-weathering ledgy slope-former, that is easily distinguished from a distance from the underlying and overlying darker dolomites of the Ordovician-Silurian section and the Devonian Simonson, respectively.

The Devonian Sevy Dolomite consists of distinctive white-weathering, light grey, thin to medium-bedded, very fine-grained, nonfossiliferous, generally well laminated dolomite. Quartz sand occurs in small stringers and lenses and as isolated grains "floating" in a dolomite matrix. These sand occurrences are more abundant near the top of the unit where quartz sand beds are up to several tens of cm to 1/2 m in thickness. The Devonian Sevy Dolomite is also noted for its lack of fossils. These features are diagnostic of the Devonian Sevy Dolomite.

Although there is no complete section of the Devonian Sevy Dolomite in the Minerva Canyon quadrangle, its lower and upper contacts were studied at separate locations. Its gradational contact with the underlying Ordovician-Silurian undifferentiated dolomite section can be seen just east of hill 8395T in the southeast portion of Johns Wash. The dark, coarse-grained, cherty, dolomitic beds of the Ordovician-Silurian become less common as the contact with the overlying Devonian Sevy Dolomite is approached. Where the Devonian Sevy Dolomite is best exposed, its upper contact with the overlying Devonian Simonson Dolomite can be clearly seen. The transition is marked by an obvious change from the light grey, fine grained texture of the Devonian Sevy Dolomite to interbedded dark brown layers and the sugary texture characteristic of the Devonian Simonson Dolomite. In some places the transition appears to be an unconformity or disconformity where large cracks or fissures in the underlying Devonian Sevy Dolomite are filled with layered sandy to conglomeratic dolomite that is similar in lithology to the overlying Devonian Simonson Dolomite.

In the Minerva Canyon quadrangle the Devonian Sevy Dolomite has a minimum thickness of 213 m Whitebread (1969) cites an estimated thickness of 244 m for this unit in the old Wheeler Peak and Garrison 15" quadrangle. (OF93).

OSfl - Fish Haven and Laketown Dolomites, undifferentiated (Ordovician-Silurian)

The Ordovician and Silurian Fish Haven and Laketown Dolomites, undifferentiated, are best exposed between Johns Wash and Decathon Canyon in the east-central section of the Minerva Canyon Quadrangle. Our measurement of 230-270 m there differs substantially from Whitebread's (1969) measurement of 433 m (taken on the south of Silver Chief Canyon on the western side of the Minerva Canyon Quadrangle). The Ordovician and Silurian Fish Haven and Laketown Dolomites (undifferentiated in the map area) are best exposed to the south of Silver Chief Canyon on the western side of the Minerva Canyon Quadrangle. The Ordovician and Silurian Fish Haven and Laketown Dolomites (undifferentiated in the map area) are resistant, ledge- and cliff-forming dolomites ranging in color from dark brown to light grey. Parts of the section are chert-rich and form the more resistant ledges and cliffs within the unit. Above its contact with the underlying Eureka, the unit is well-bedded and finer-grained, but most of the lower section consists of a medium grained, sugary textured, dark brown dolomite. Higher in section, the dark brown dolomite is interbedded with layers of fine grained, light grey dolomite. Layers of dark brown, coral-rich dolomite are very common and are diagnostic of the unit. Also present in these dark brown layers are very large brachiopods, 10-13 cm in diameter. he interbedded dark brown dolomite weathers to well-rounded, mottled brown and grey outcrops, and the better bedded, finer grained light grey dolomite has blocky character when weathered. Bedding throughout the unit is often poorly developed or difficult to discern in the coarser grained, sugary-textured dolomite, but in the finer-grained light grey dolomite, bedding ranges from 10-20 cm in thickness. Chert is locally abundant and ranges from thin, discontinuous stringers (0.5-3 cm thick) roughly parallel to bedding to single layers of chert 1-2 m thick. The Fish Haven and Laketown Dolomite is fossiliferous, with abundant branching coral, *Halycites* (chain coral), crinoid stems, and brachiopods present throughout the section but are often difficult to see in the coarser-grained, sugary brown dolomite. The contact with the overlying Sevy Dolomite is gradational, with beds of lighter grey dolomite common in the upper section of the Fish Haven and Laketown unit becoming more abundant closer to the contact. The contact is mapped above the highest conspicuous layer of dark brown dolomite at the color change from dark to light dolomite. (OF93).

Oe - Eureka Quartzite (Ordovician)

The Ordovician Eureka Quartzite is a white, cliff-forming, thick-bedded quartzite which is exposed in several places in the Minerva Canyon quadrangle. The best intact section of Eureka Quartzite is present in the east-central part of the Minerva Canyon quadrangle, where it underlies Granite Peak. The Ordovician Eureka Quartzite represents a distinctive stratigraphic marker, occurring as it does between the yellow-weathering slope-forming, grey Ordovician Lehman Limestone of the Pogonip Group below and the dark colored undifferentiated dolomites of the Ordovician Silurian above. In this portion of the Minerva Canyon quadrangle, the Ordovician Eureka Quartzite is about 100 m thick. Whitebread (1969) measured a 134 m section of the Ordovician Eureka Quartzite 2 miles south of Chokecherry Canyon in the old Wheeler Peak and Garrison 15" quadrangles. The basal contact of the Ordovician Eureka Quartzite is seen as a gradational increase in quartz sand content in the upper beds of the Ordovician Lehman Limestone. This contact is exposed a mile north from where Murphy Wash intersects Johns Wash and half a mile from the road in Johns Wash. The upper contact of the Ordovician Eureka Quartzite can also been seen near this location and is evidenced by a small transition zone where Ordovician Eureka quartz grains gradually diminish in quantity in the overlying Ordovician-Silurian undifferentiated Dolomites.

The Ordovician Eureka Quartzite weathers to a rust color and is usually highly jointed and fractured. Because of its resistance to erosion, quartzite rubble and large blocks are common downslope of its exposures. Bedding is generally difficult to discern because of its purity and the presence of joint and fracture planes, except near the top of the unit where increasing carbonate content accentuates bedding

within the unit. The Ordovician Eureka Quartzite is an orthoquartzite composed of well rounded and well sorted, fine to medium grained quartz. The unit is distinctively lacking in fossils, although vertical burrows can locally be seen. (OF93).

Op - Pogonip Group, undifferentiated (Ordovician)

A complete, well-exposed section of the Ordovician Pogonip Group is found at the southern end of Highland Ridge in the central part of the Minerva Canyon Quadrangle. In our mapping, we have followed the subdivisions of the Pogonip Group of Hintze (1951) into the Fillmore Limestone, Wahwah Limestone, Juab Limestone, Kanosh Shale, and Lehman Formation. Where these subdivisions were not possible, we have mapped them as Ordovician Pogonip Group, undifferentiated. By utilizing these subdivisions, we were able to map in more detail the complex faulting that occurs on the eastern slope of Decathon Canyon. Previously, Whitebread (1969) grouped the Wahwah, Juab, and Fillmore Limestones, and the Kanosh Shale and Lehman Formation of the Pogonip in this region. Total thickness of the Pogonip Group is approximately 530-730 m as measured from cross-sections in the Highland Ridge and Granite Peak area of the Minerva Canyon quadrangle. (OF93).

Includes the following units: Opl - Lehman Formation, Opk - Kanosh Shale, Opj - Juab Limestone, Opw - Wahwah Limestone, Opf - Fillmore Limestone, and Oph - House Limestone

** Oph (House Limestone) was not included as a member of the Pogonip Group on the source publication.

Opl - Lehman Formation (Ordovician)

The Ordovician Lehman Limestone is a medium grey, slope- to ledge-forming, well bedded, fine to medium grained limestone and silty limestone. The silty partings weather orangish yellow or reddish-pink. Bioturbation or burrowing is common, giving the beds a mottled appearance. Beds range from 2 to 10 cm thick and locally contain abundant layers of gastropods and ostracods. Unit thickness measured on the southwest flank of Granite Peak is approximately 300 m; to the south on Highland Ridge, it is approximately 100 m. This variation could be due to gentle folding and minor faulting that could not be documented given the generally poor exposure and the scale of our mapping. (OF93).

Opk - Kanosh Shale (Ordovician)

The Ordovician Kanosh Shale is a yellowish brown to olive grey, non-resistant, slope-forming, fissile shale. The Kanosh contains resistant beds of distinctive brown-weathering, highly fossiliferous grey limestone. Ostracods, trilobite spines, turitella, and phosphatic brachiopods are in abundance. The Kanosh exists almost entirely as float; the resistant limestone beds within it outcrop only on the ridge line to the north of the Mustang Spring in the Minerva Canyon quadrangle. Thickness varies because the unit apparently serves as a zone of movement or faulting between more resistant limestones above and beneath. The section on the southern end of Highland Ridge has a thickness of 110 m, but because exposure is rare, faulting and/ or folding could compromise this estimate. (OF93).

Opj - Juab Limestone (Ordovician)

The Ordovician Juab Limestone is a medium grey to medium dark grey, ledge forming, extremely well bedded, fine grained limestone to coarse grained clastic limestone with silty partings. The lower boundary of the unit with the underlying Wahwah Limestone is defined by the first appearance of less resistant, reddish, silty limestone with prevalent flat pebble conglomerate. Beds are 2 to 4 cm thick and coated by silt which weathers a distinctive reddish orange. Towards the top of the unit, beds become

more resistant and alternate at approximately 4 cm intervals between chert rich and fossiliferous limestone. Fossils include gastropods, ostracods, and trilobite debris. Thickness is approximately 230 m. (OF93).

Opw - Wahwah Limestone (Ordovician)

The Ordovician Wahwah Limestone is a medium grey, slope- to ledge-forming, well bedded, fine to medium grained limestone and shaley to silty limestone. It is distinguished from the underlying Fillmore Limestone by its higher limestone content, more resistant nature, and the lighter yellow to grey color of its region of exposure compared to the darker float of the underlying Fillmore. Limestone beds range from 2 to 30 cm thick and are commonly mottled yellow and grey. Ichnofossils are the only paleontological feature; they are primarily disorganized, simple burrows that range in width from .5 to 1.5 cm thick. In contrast to the underlying Fillmore, little or no flat pebble conglomerate occurs in the unit. Thickness is approximately 90 m. (OF93).

Opf - Fillmore Limestone (Ordovician)

The Ordovician Fillmore Limestone is exposed extensively along Highland Ridge and also in the southwestern portion of the study area. A complete section of 380 m was measured at the southern end of Highland Ridge. The Fillmore Limestone is a light grey, slope- to ledge-forming, limestone and shaley limestone which is notable at a distance for a pale orange to yellowish-orange color imparted by the weathering of silty olive grey layers. This coloration and a break in slope separates the Fillmore from the cliff forming, occasionally reddish, Notch Peak Limestone at all scales. The Fillmore is well bedded, fine grained to coarsely clastic, and is commonly shot by calcite veins. Beds range from 12 to 40 cm in thickness and crop out at approximately 6 m intervals and are separated by shale intervals. Limestone beds become increasingly resistant towards the top of the unit. The Fillmore is distinguished stratigraphically by abundant flat pebble conglomerate which is present throughout the unit. (OF93).

Oph - House Limestone (Ordovician)

House Limestone. No additional information was provided on source map. (Miller e. al., 2007).

** Oph (House Limestone) was not included as a member of the Pogonip Group on the source publication.

OCn - Notch Peak Limestone (Ordovician-Cambrian)

Whitebread (1969) divided a thick, cliff-forming, cherty limestone in the Minerva Canyon and Wheeler Peak Quadrangles into the Upper Cambrian Notch Peak Limestone and the Lower Ordovician House limestone. In this study, we have combined the two units into the Upper Cambrian-Lower Ordovician Notch Peak Limestone following the suggestion of Hintze (1980). Throughout East-Central Nevada, the Cambrian-Ordovician boundary typically occurs near the top of this thick (790-870 m (Whitebread, 1969)) cherty, cliff-forming limestone, and it is not an easily mappable rock contact. Although previous workers (e.g. Fritz, 1968; Woodward, 1969?; and Young, 1960) all attempted to map this time-stratigraphic boundary, it has proved impractical. The first easily mappable rock-stratigraphic boundary or contact occurs at the sharp break in slope between the relatively pure grey cliff- to ledge-forming Notch Peak Limestone (our usage) to the non-resistant, typically yellow to reddish brown, slope-forming Fillmore Limestone of the Pogonip Group which is characterized by abundant flat-pebble conglomerate and little or no chert.

The Ordovician-Cambrian Notch Peak Limestone is best exposed on a north-south trending ridge in the

Minerva Canyon Quadrangle. A partial section of 770 m was measured on this ridge. The Ordovician-Cambrian Notch Peak Limestone is a resistant, medium-grey to dark grey, cliff-forming limestone. The limestone is in general a very fine to fine grained limestone, and chert nodules and stringers subparallel to bedding are its most characteristic feature. Chert nodules (2.5-7.5 cm thick) parallel to bedding are very common lower in section, with individual chert layers ranging up to 30 cm in thickness. There are medium-dark grey, nonfossiliferous, massive sections common in the middle of the Notch Peak that weather in a blocky manner. The float from the massive and chert-rich sections is commonly made up of equant cobbles with sharp fracture surfaces. Scattered, localized dolomitization has occurred in the massive sections of the Notch Peak unit. Well-bedded limestone sections (bedding 2.5-30 cm thick) defined by tan or pink silty interbeds (5-15 mm thick) are common higher in section. Platy fracture is common in these well-bedded sections, with evidence for bioturbation or burrowing evident along exposed, silty parting surfaces. Although chert is common in the Notch Peak limestone, it seldom occurs where there is silty interbedding. Sections of the unit containing chert have bedding thicknesses ranging from 15 cm to 1.2 m thick. Gastropods, trilobite debris, inarticulate brachiopods, stromatolites, and fossil hash are common higher in the section. The contact with the overlying Fillmore Limestone occurs at the sharp break in slope from the cliff- to ledge-forming Notch Peak Limestone to the slope-forming Fillmore Limestone. (OF93).

Ccs - Corset Spring Shale (Cambrian)

The Cambrian Corset Spring Shale is exposed along Johns Wash and in relation to the Gateway Fault. A complete section of 26 m was measured at the head of Johns Wash and is in agreement with a previous measurement by Whitebread (1969). The corset Spring Shale is a light olive grey to brown, fissile shale which weathers to very gentle slopes. This typically forms a bench above the underlying Johns Wash Limestone which is the only indication of its presence from afar. Closer examination is not initially more enlightening as the Corset Spring weathers to a characteristic splintery float resembling wood chips. This float is typically the only means by which the shale may be mapped.

Where better exposed, distinctive units may be seen within the Corset Spring Shale. According to Whitebread (1969), the upper portion of the formation is characterized by units of shale interbedded with limestone units. The shale is fissile and occurs in layers approximately 2 mm thick, and contain scattered discoidal nodules of medium-grey aphanitic limestone 3-8 cm in diameter. The limestone units in the upper portion of the Corset Spring are described by Whitebread as medium-grey, and coarsely clastic with beds 6-16 cm thick. The bedding planes are uneven and punctuated by layers of trilobite and echinoderm fragments.

The middle units of the Corset Spring Shale are, according to Whitebread, entirely light-olive-grey shales. These contain lenses of coarsely bioclastic limestone which average .8-3 cm thick and are between 9 and 72 cm long. Also in the middle units Whitebread describes a single 18 cm bed of intraformational conglomerate with rounded flat limestone pebbles in a clastic limestone matrix.

The lower portion of the Corset Spring Shale, by Whitebread's description, is once again interbedded units of limestone and shale. The shale has no peculiar characteristics in this portion of the section. The limestone units are described as being medium-grey to dark-grey and weathering light-grey. the bedding is uneven and between 1.5 and 6 cm thick. The limestone are locally nodular due to coalescence of grayish-orange-weathering shaly partings, and some beds are crowded with trilobite fragments. (OF93).

Cjw - Johns Wash Limestone (Cambrian)

The Cambrian Johns Wash Limestone is exposed in Johns Wash and in relation to the Gateway Fault. A complete section of 86 m was measured at the head of Johns Wash which agrees with a previous

measurement by Whitebread (1969). The Johns Wash Limestone is a medium grey to light grey, ledge to cliff-forming limestone that is easily distinguishable from the underlying, non-resistant Lincoln Peak, and even less resistant, overlying Corset Springs Shale. However, when present in a complete stratigraphic section it is easily confused at a distance with the Notch Peak Limestone (which overlies the Corset Spring) as the formations appear as one continuous set of cliffs. Upon closer inspection one may see that the Johns Wash Limestone is thin bedded to massive, and medium to coarse grained. The limestone is interbedded with wavy, yellowish-brown calc-arenite layers and clastic carbonate. The Johns Wash Limestone locally contains abundant cross bedded oolitic limestone beds .5 - 1 m thick. Other thick bedded to massive parts of the section are characterized by fenestral fabric, especially near the top of the section. Together with its more resistant cliff-forming nature and light color, the cross-bedding and fenestral fabric found in the Johns Wash Limestone is distinctive. (OF93).

Clp - Lincoln Peak Formation (Cambrian)

The Cambrian Lincoln Peak Formation is exposed along Johns Wash, and extensively in relation to the decollement. The best exposure is along the east side of Lincoln Peak at which a partial thickness of 630 m was measured. Whitebread (1969) estimates 1,200-1,370 m. The Lincoln Peak is a non-resistant limestone and shale which generally weathers to gentle slopes of brownish orange covered by dense vegetation. The coloration and low angle of slope distinguish the Lincoln Peak from the more resistant, underlying E Member of the Pole Canyon Limestone and may be easily seen on air photos. The contact is similarly notable between the Lincoln Peak and the overlying Johns Wash Limestone. However, in the study area, at least one contact involving the formation is always fault bound in either the upper or lower portions of the section. In general, the formation consists of a light to medium bluish grey, fine grained, thin bedded limestone with silty partings, silty limestone, or calcareous siltstone, each interbedded with shale. Overall, bedding ranges from 3 to 30 cm thick and is punctuated by rare beds of chert or trilobite hash rich horizons. Where the limestone layers are thickest, the shale occurs as wavy interbeds and partings. The basal portion of the section is commonly interbedded with a fissile shale or calcareous shale bedded at 1 to 3 cm intervals and locally characterized by a reddish-purple color. (OF93).

Clpmb - Lincoln Peak Formation, conglomerate marker bed (Middle Cambrian)

Marker beds within Clp (Lincoln Peak Formation). No additional information was provided on source map. (Miller e. al., 2007).

Cpc - Pole Canyon Limestone, undifferentiated (Middle Cambrian)

The Middle Cambrian Pole Canyon Limestone, as described by Whitebread (1969) during previous mapping of the Minerva Canyon and Wheeler Peak Quadrangles, consists of five distinct subunits (A,B, C,D, and E) mappable at 1:24,000 scale. These five subunits were further divided and described in a section measured by Whitebread (1969). In summary, the A,C, and E members are generally darker, consisting of medium-dark- to dark grey, slope-forming limestones with abundant silty interbeds, whereas the B and D members are mostly light grey to white, cliff-forming limestones. However, these color distinctions are not always continuous along strike. The unit as a whole forms prominent grey and white cliffs which underlie and are spectacularly exposed beneath Mount Washington. It dips gently southward towards the valley floor to the west and is also well-exposed in the upper reaches of Big Wash drainage to the east of Mount Washington. The units are particularly well-displayed as they cross the high ridge line of the southern Snake Range and can be viewed looking south from Wheeler Peak and Baker Peak. The complete section is best exposed east of the fork in Lincoln Canyon in the southern section of the Wheeler Peak Quadrangle and in the cliffs east of Mount Washington. The Pole Canyon was measured in Lincoln Canyon and has a total thickness of 557 m.

Includes the following sub units: Cpcmb - Pole Canyon Limestone, undifferentiated, conglomerate marker bed, Cpce - Pole Canyon Limestone, e member, Cpcd - Pole Canyon Limestone, d member, Cpcc - Pole Canyon Limestone, c member, Cpcb - Pole Canyon Limestone, b member, and Cpca - Pole Canyon Limestone, a member. (OF93).

Cpcmb - Pole Canyon Limestone, undifferentiated, conglomerate marker bed (Middle Cambrian)

Markers beds with Cpc (Pole Canyon Limestone) units. (OF93).

Cpce - Pole Canyon Limestone, e member (Middle Cambrian)

The E member of the Pole Canyon Limestone is well-exposed and was measured on the south side of Swallow Canyon in the Wheeler Peak Quadrangle. The unit was measured there by Whitebread (1969), where the total thickness is 109 m.

The E member of the Pole Canyon Limestone consists of two types of limestone: a fine grained, platey and silty slope-forming limestone and a very fine to fine grained, cliff-forming limestone. The lower 23 - 33 m of the E member crops out as a dark grey slope-former with tan or pink silt abundant along partings. Near the lower contact, the E member is well-bedded, and platy fracture is common. The bedding planes are mottled, with tan or pink silt along the partings. The mottled appearance of the silt beds is the result of bioturbation or burrowing. Fenestral fabric is common in the E member limestone. Higher in the section is a massive, medium grey cliff-former. Lenses of oolitic limestone are common in the massive member, and lenses of rip up clasts are present. Small *Girvinella* (5-10 mm in diameter) are also present in the massive section of the E member. The upper section of the E member is a poorly-exposed, dark grey slope-former. (OF93).

Cpcd - Pole Canyon Limestone, d member (Middle Cambrian)

The D member of the Pole Canyon Limestone is well-exposed on the east fork of Lincoln Canyon in the Wheeler Peak Quadrangle. Our measurement of 100 m differs substantially from Whitebread's (1969) measurement of 59 m. The D member of the Pole Canyon Limestone is a resistant, massive, cliff-forming limestone. The limestone is very fine to fine grained, medium to light grey (with a bluish tint). In terms of its color and bedding characteristics, the D member is the most variable of the five Pole Canyon subunits. There are localized sections of darker grey limestone within the unit, and in those sections, tan colored, silty interbeds are common. The silty interbeds (2.5 - 3.75 cm apart) are parallel to bedding and 1-3 mm in thickness. The silt has a mottled appearance in outcrop and is a result of bioturbation or burrowing. The D member contains abundant oolitic limestone throughout the section. The D member contains tiny flecks and blebs of lighter colored limestone (1-2 mm in diameter) which are diagnostic of the D member. Fenestral fabric is also common in the D member. The contact with the overlying E member is marked by a change in slope and by the last appearance of light colored beds. (OF93).

Cpcc - Pole Canyon Limestone, c member (Middle Cambrian)

The C member of the Pole Canyon Limestone was measured on the north side of Swallow Canyon in the Wheeler Peak Quadrangle. Our measurement of 45 m differs slightly from Whitebread's (1969) measurement of 52 m. The C member of the Pole Canyon Limestone is a less resistant slope-former of dark grey limestone which occurs between and separates the two cliff forming B and D units. The unit consists of fine to medium grained limestone with small lenses of dolomite (2-3 cm thick). The C member contains abundant red-pink silt interbeds (1-3 mm thick) which are commonly discontinuous along strike. These silt interbeds (diagnostic of the C member) are roughly parallel to bedding and have

undulatory stringers of silt connecting silty blebs. The silt has a mottled appearance, which is the result of bioturbation or burrowing. Lenses of darker oolitic limestone are locally abundant in the middle of the C member section. Near its upper and lower contacts, the C member is very well-bedded (2.5 - 3.75 cm thick) and platy fracture is common, with bedding well-defined by silty partings. Fenestral fabric is common in the C member limestone. The upper contact of the C member is marked by an abrupt change in slope at the base of the cliffs of the overlying D member. (OF93).

Cpcb - Pole Canyon Limestone, b member (Middle Cambrian)

The B member of the Pole Canyon Limestone is well-exposed east of the fork in Lincoln Canyon in the Wheeler Peak Quadrangle. The unit was measured there by Whitebread (1969), where the total thickness is 200 m. The B member of the Pole Canyon Limestone is a massive, resistant, cliff-forming limestone distinctive for its light color compared to the A member below. The prominent white cliffs of the B member are easily visible on air photos as white swatches. The lower 30 - 70 m of the B member consists of homogeneous, light grey, and very fine to fine grained limestone. In this section, the B member contains abundant tan silt in mottled stringers and blebs strung out sub-parallel to bedding, a result of extensive bioturbation or burrowing. The upper 135 - 150 m of the B member consists of alternating medium dark and light grey limestone beds 1.5 - 17 m thick. The darker limestone layers are fine grained and commonly have lighter colored limestone blebs (2-3 mm thick) strung out parallel to bedding planes, which is diagnostic of the B member limestone. Fenestral fabric is common in the B member limestone. The contact with the overlying C member is marked by an abrupt change in slope and the last appearance of light beds. (OF93).

Cpca - Pole Canyon Limestone, a member (Middle Cambrian)

The A member of the Pole Canyon Limestone is well-exposed near the head of the north fork of Big Wash in the Wheeler Peak Quadrangle. The unit was measured there by Whitebread (1969), where the total thickness is 137 m. The A member of the Pole Canyon Limestone generally consists of a dark grey, slope-forming limestone, but more massive, resistant parts of the section are common as well. The unit contains abundant tan or pink silty interbeds which are commonly bioturbated or burrowed, giving the silt beds a mottled appearance. Limestone in the A member is fine to medium grained and contains lenses of oolitic limestone. There is a section of more resistant, cliff-forming limestone 7+ m in thickness in the middle of the A member (designated as subunit 2 of the A member by Whitebread (1969)). This cliff-forming section contains a 1-2 m layer of light grey limestone, and above the cliff is a section of yellowish-brown siltstone and calcareous quartzite 1.5 - 3.5 m thick (described as subunit 3 of the A member by Whitebread (1969)). *Girvinella* 1.25 - 2.5 cm in diameter are very abundant throughout the A member and are a diagnostic feature of the unit. The member is in general thin-bedded (bedding 1.25 - 3.5 cm thick) with abundant pink silt layers (1-3 mm thick) parallel to bedding along parting surfaces. Fenestral fabric is common in the A member limestone. The A-B contact is gradational, with the upper meter of dark grey A unit limestone grading into the lighter grey B unit limestone. The contact is the first appearance of the lighter grey limestone. (OF93).

Cpi - Pioche Shale (Lower Cambrian)

The Early Cambrian Pioche Shale forms an important lithologic transition between dominantly clastic Early Cambrian and older strata and the overlying Middle Cambrian carbonate section. Intact and little metamorphosed sections are widely exposed in the Wheeler Peak quadrangle and superb exposures of the unit occur in the Mt. Wheeler Peak Mine district on the western flank of the range. Thickness of 96, 90, and 90 m were measured to the east and west of Mount Washington. The Pioche Shale consists of dark siltstone, quartzose, sandy siltstone and calcareous quartzite and shale that is greenish grey to khaki-colored and is mostly thin bedded. True shale is less common in the section in the Southern Snake Range. Sedimentary features characteristic of the Pioche Shale include abundant grazing trace

fossils, ripples, mud cracks, and burrows. The Pioche is transitional with the underlying Prospect Mountain Quartzite and contains thin dark-colored quartzite beds in its lower part interbedded with olive-brown to rust-brown siltstone. Abundant detrital mica is present but is particularly common at the basal section. The middle part of the section consists of siltstone, khaki shale and reddish sandstone. Calcareous horizons occur intermittently throughout the unit. Several thick (meters to tens of meters) layers of micaceous quartzite occur near the top of the section, and the amount of limestone with respect to shale increases upward toward the base of the massive overlying limestone of the Pole Canyon Formation. The upper contact with the Pole Canyon Limestone is particularly well exposed in snow avalanche chutes on the northeastern face of Mount Washington. At this location, several centimeters to tens of centimeters of thick dark grey, conspicuously orange weathering siltstone layers and lamina are interbedded with grey limestone in equal proportions and mark the transition to the overlying dark grey limestone of the Pole Canyon Formation. In the map area, the Pioche Shale is largely unmetamorphosed except in the vicinity of the Snake Creek-William Creek pluton in the Snake Creek Drainage and on the ridge line between Pyramid Peak and Mt. Washington. At these locations, it is metamorphosed to biotite-, muscovite- and andalusite- bearing psammite, schist and calc-silicate (garnet, epidote, and diopside) bearing rocks. (OF93).

CZpm - Prospect Mountain Quartzite (Lower Cambrian-Late Proterozoic)

The thick (1.5 km), resistant Early Cambrian Prospect Mountain Quartzite underlies a significant portion of the Wheeler Peak quadrangle, forming the jagged and rugged, glaciated crest of the range north of Pyramid Peak to Wheeler Peak. The Prospect Mountain Quartzite dips gently south and is well exposed in steep glacial cirques, cirque walls, and cliffs of the Southern Snake Range. The best exposure of the gradational upper contact of the Prospect Mountain Quartzite with the Pioche Shale is located on the ridge between Box and Dry Canyons north of Mt. Wheeler Mine. The top of the unit contains three or four thick layers of slope forming dark siltstone and silty shale that frequently give the top of the Prospect Mountain Quartzite a terraced appearance. A good frontal view of the main part of the unit can be seen in the cirque walls above the small glacier just to the north of Wheeler Peak. Here, the lower third to half of the formation consists of thickly bedded (.3-1.5 m) lighter colored, coarse grained quartzite, gritty to conglomeratic quartzose to feldspathic quartzite, while the upper part of the formation is somewhat thinner bedded and contains more horizons of dark silty quartzite and siltstone. In general, the Prospect Mountain Quartzite forms cliffs and talus slopes that weather rust-brown, tan, or purple. Whitebread (1969) estimates the thickness of the Prospect Mountain Quartzite as 1520 m. Due to the intruding Jurassic granite, only a partial thickness of 1250 m was measured along the ridge line south from Stella Lake in the Windy Peak quadrangle. Bedding thicknesses in the Prospect Mountain Quartzite are generally quite consistent, and the .3-1 m thick beds are ubiquitously cross-bedded, where cross-bedding is defined by dark laminations. Occasionally, soft sediment slumping of crossbeds is evident. In hand specimen, the quartzite is white to gray, well-sorted, medium to course-grained, and generally consists of 90-95% quartz, 5% feldspar, except for the more feldspathic horizons which can contain up to 25% feldspar. At the base, fine grained green intervals and purple siltstone intervals typical of the underlying Osceola Argillite are overlain by medium to coarse grained, crossbedded quartzite, gritty to conglomeratic quartzite and feldspathic quartzite. The Prospect Mountain Quartzite is distinguished from similar quartzite units in the underlying McCoy Creek Group by its general lack of pebble conglomerates (thin horizons are, however, occasionally present) and only rare pelitic intervals, by the abundance of cross-beds, and by the more regular bedding and total thickness of the unit as a whole. (OF93). Cpm (Early Cambrian Prospect Mountain Quartzite) on source map.

Zm- McCoy Creek Group, undifferentiated (Late Proterozoic)

Only the upper two units of the McCoy Creek Group, the McCoy Creek Group Quartzite 1 (the Shingle Creek Quartzite of Misch and Hazard, 1962) and the Osceola Argillite, are exposed in the Wheeler Peak quadrangle, but just to the north, in the Windy Peak quadrangle, the McCoy Creek Group consists

of a series of variably metamorphosed alternating quartzite and pelitic units. On the north-facing slopes leading up towards Wheeler Peak, the McCoy Creek Group forms an intact, gently dipping, apparently conformable section about 1100 m thick that has been subdivided into five units. Previous description of these units can be found in Misch and Hazzard (1962) and Miller and others (1992). Our unit nomenclature differs somewhat from that of Misch and Hazzard (1962); these differences are discussed in the unit descriptions below. The McCoy Creek Group has been assigned a Late Precambrian age based on its position beneath the Prospect Mountain Quartzite which is generally assigned to the Early Cambrian (Hose and Blake, 1976). Hose and Blake (1976) described the depositional environment of the entire McCoy Creek Group as having oscillated from near shore to offshore marine environments. (OF93). pCMc (Precambrian McCoy Creek Group) on source map.

Includes the following sub units: Zmoa- Osceola Argillite of the McCoy Creek Group, Zmsc - McCoy Creek Group, Shingle Creek Shale, and Zmq - McCoy Creek Group, quartzite

Zmoa- Osceola Argillite of the McCoy Creek Group (Late Proterozoic)

The Osceola Argillite of Misch and Hazzard(1962) in the Late Precambrian McCoy Creek Group is exposed in the northwestern corner of the Wheeler Peak quadrangle where it overlies older quartzite (pCmc1) of the McCoy Creek Group and underlies the Prospect Mountain Quartzite. Good exposures of the unit occur on the slopes north of Hub Mine and in the Pine Creek drainage. The unit is a gentle slope-former with occasional resistant silt on calcareous beds that form ledges from 1 to 10 m thick. According to Whitebread (1969), the Osceola is 180 to 230 m thick. A thickness of 190 m was derived from the area between Pine Creek and Ridge Creek. On the north slope of Bald Mountain in the Windy Peak quadrangle, the section was estimated to be about 200 m thick (Miller and others, 1992). The Osceola Argillite consists mostly of well-bedded to laminated slates and siltstone which are distinctively green to grey-blue, although locally, maroon colors are common (such as in the less metamorphosed Stella Lake region). Abundant sedimentary structures are present and include small-scale cross beds (maximum height 6 cm), ripple marks, fluid-escape structures, rip-up clasts and soft sediment folds and slumps. Quartz-rich sandy to gritty layers and lenses also occur in the formation and some of these exhibit cross-bedding and more rarely graded beds. Rare limestone interbeds occur near the base of the unit and calcareous muds occur throughout the sequence. The contact of the Osceola Argillite with the overlying Prospect Mountain Quartzite is gradational over approximately 10-15 m. The upper part of the Osceola contains interbeds of cross-bedded pure quartz sand. The bottom 10-15 m of the Prospect Mountain Quartzite contains many thin argillaceous intervals similar to lithologies present in the Osceola. The metamorphic grade and the degree of deformation within the Osceola Argillite varies from very little metamorphosed and deformed near Stella Lake to amphibolite facies (biotite, muscovite, staurolite, garnet, andalusite and sillimanite) adjacent to Jurassic plutons in the western part of the Wheeler Peak quadrangle and in the Windy Peak quadrangle to the north (Miller and others, 1988). Abundant metamorphic staurolite, muscovite and chlorite are present in the Wheeler Peak quadrangle. The staurolite and other aluminum silicate minerals are frequently entirely retrograded to white mica and chlorite in Wheeler Peak quadrangle. Where little deformed, the shale layers possess an incipient penetrative cleavage that dips east with respect to more gently-dipping bedding (Figure 8). This cleavage can be tracked into the contact aureoles of Jurassic plutons (Snake Creek-Williams Canyon Pluton in the Wheeler Peak quadrangle) where it is more intensely developed and can be shown to have formed synchronously with the intrusion of plutons (Miller and others, 1988). This east dipping cleavage is cut by a younger, west-dipping cleavage inferred to be Cretaceous in age which was seen locally in the Wheeler Peak quadrangle (Miller and others, 1988). (OF93). pCmo (Late Precambrian McCoy Creek Group Osceola Argillite) on source map.

Zmsc - McCoy Creek Group, Shingle Creek Shale (Late Proterozoic)

Shingle Creek Shale. No additional information was provided on source map. (Miller e. al., 2007).

Zmq - McCoy Creek Group, quartzite (Late Proterozoic)

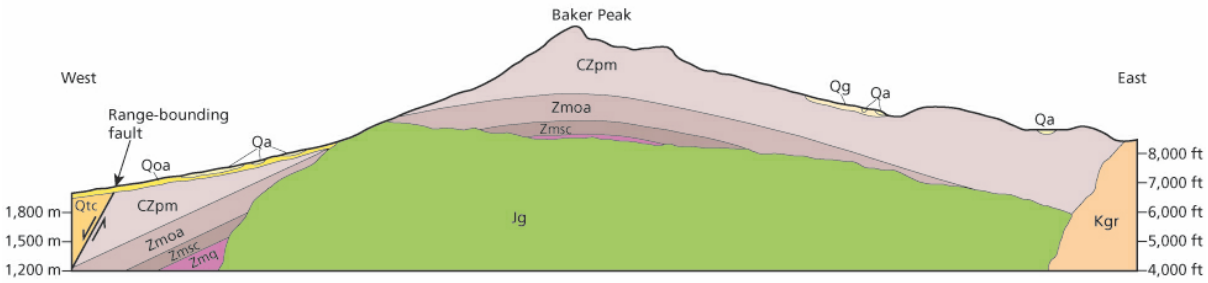
The quartzite of the Late Precambrian McCoy Creek Group Unit 1 varies considerably in thickness and grain size from north to south across the Windy Peak and Wheeler Peak quadrangles. According to Whitebread (1969), the unit is about 150 m thick. A full section is not present in the Wheeler Peak quadrangle - the lower part of the section being covered by alluvium. Unit one is primarily a ledgy cliff-former becoming a ledgy slope-former near the top 20 m of the unit. To the north, in the Windy Peak quadrangle, it is a thin conglomeratic quartzite, no more than 30 m thick, with clasts consisting mostly of rounded quartz pebbles 1-3 cm in diameter. To the south of Willard Creek, in the Wheeler Peak quadrangle, it is mostly a well-bedded quartzite with conglomerate beds of variable thickness occurring only locally in its upper part. The maximum partial thickness of the section measured in the Wheeler Peak quadrangle is 112 m. Misch and Hazzard (1962) named the unit the Shingle Creek Conglomeratic Quartzite (pCs) which was followed by Whitebread(1969), but since the unit is neither notably thin nor conglomeratic across the greater region of the Wheeler Peak quadrangle, we have designated it the McCoy Creek Group Unit 1 (pCm1.). (OF93). pCm1 (Late Precambrian McCoy Creek Group Unit 1 (quartzite)) on source map.

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Great Basin National Park, Nevada (GRBA) are presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (when viewing the digital format of this document).

***The GRI digital data initially contained geologic cross section lines A-A' and F-F' , however, neither had a cross section graphic provided with the source data. Repeated requests were made to acquire these graphics from the source map author, but the graphics were unfortunately never obtained. Both the cross section lines, as well as the text pertaining to each missing graphic, have been removed from the GRI GIS data and this document, respectively.*

Cross Section B-B'



Provided by Elizabeth Miller, Stanford University. (Miller et. al., 2007). Graphic updated by Trista Thornberry-Ehrlich (Colorado State University).

Cross Section C-C'

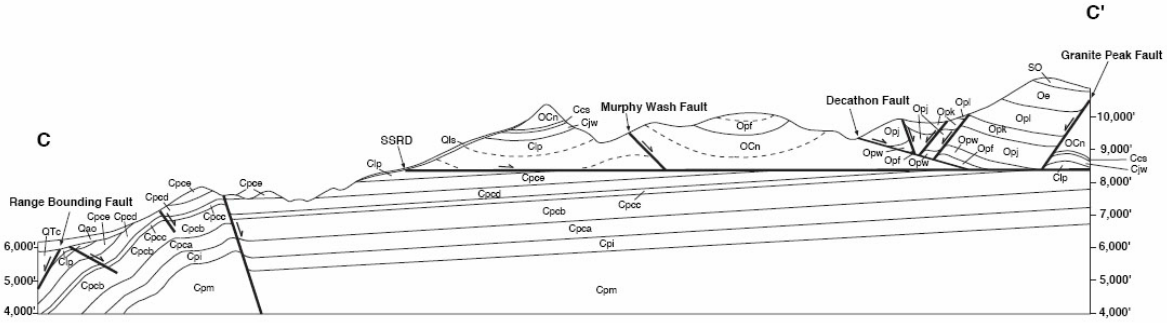
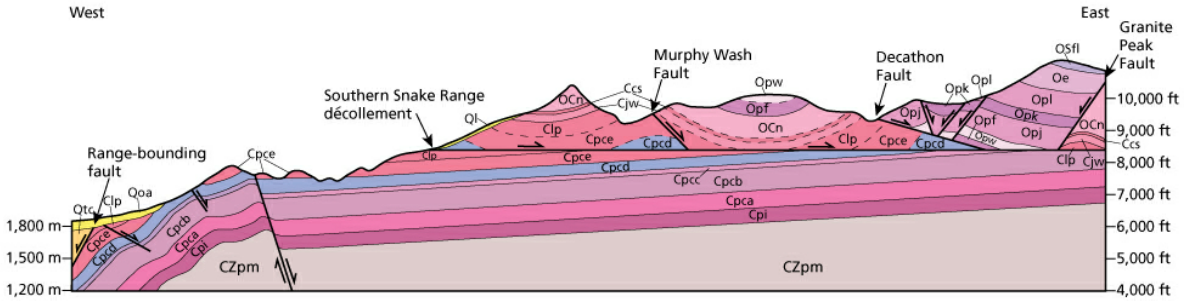


Figure 5

Provided by Elizabeth Miller, Stanford University. (Miller et. al., 2007).

Cross Section D-D'



Provided by Elizabeth Miller, Stanford University. (Miller et. al., 2007). Graphic updated by Trista Thornberry-Ehrlich (Colorado State University).

Cross Section E-E'

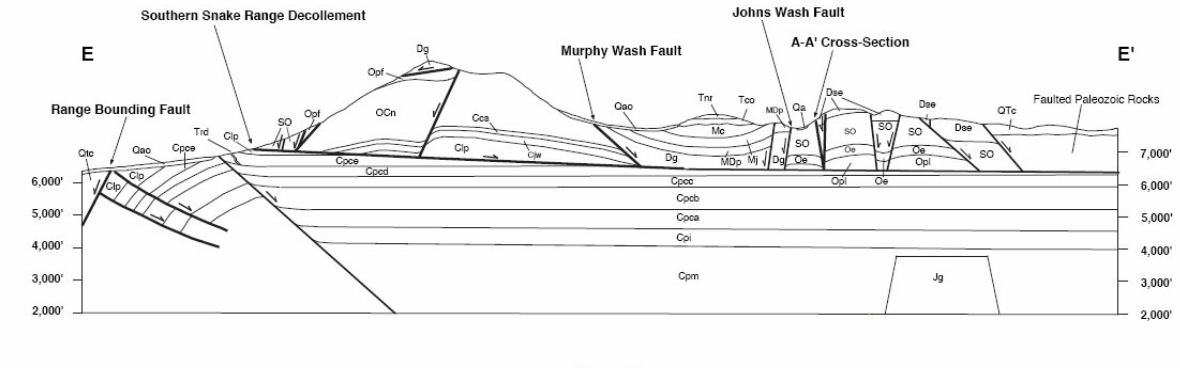


Figure 7

Provided by Elizabeth Miller, Stanford University. (Miller et. al., 2007).

Additional Source Map Information

Source Mapping Credits

The following citations were cited by Elizabeth Miller as mapping credits for the Miller, E.L, 1995, and the Stanford Geological Survey, 2007 digital data:

McGrew, A.J. and Miller, E.L., 1995, Geologic Map of Kious Spring and Garrison 7.5' Quadrangles, White Pine County, Nevada and Millard County, Utah, U.S. Geological Survey, Open-File Report OF-95-10, 1:24000 scale.

Whitebread, D.H., 1969, Geologic Map of the Wheeler Peak and Garrison Quadrangles, Nevada and Utah, U.S. Geological Survey, Miscellaneous Field Studies Map I-578, 1:48,000 scale

Arches 7.5' quadrangle modified after Whitebread (1969), and the Kious Spring 7.5' quadrangle after McGrew and Miller, 1992.

All other 7.5' quadrangles by Miller and the Stanford Geological Survey (Miller e. al., 2007).

Pre-GRI GIS compilation by Vyacheslav V. Akinin, Northeast Research Institute, Russian Academy of Sciences, Magadan, RU

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 Great Basin National Park, Nevada (GRBA) developed by Stephanie O'Meara and updated in 2014 by Derek Witt (Colorado State University) using source digital data developed by Vyacheslav V. Akinin (Northeast Research Institute, Russian Academy of Sciences) and others (Stanford University and the Stanford Geological Survey) from geologic mapping done by Elizabeth Miller (Stanford University and the Stanford Geological Survey) and others from 1993 to 1997. (see Source Maps).

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

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).