PLATE 1

SURFICIAL GEOLOGIC MAP OF SOUTHWESTERN PORTION OF JOHNSON VALLEY

A Project for the California Department of Fish and Wildlife
By the California Geological Survey

By: Jeremy T. Lancaster CEG

Project Background

Solar, wind, and geothermal renewable energy projects in California have increased with the passing of federal and state initiatives. In response to potential increased land use from these activities, the California Department of Fish and Wildlife (CDFW) and the State and Federal Renewable Energy Action Team agencies are identifying areas of higher biological value for inclusion into a Habitat Conservation Plan / Natural Community Conservation Plan. This plan is designated as the Desert Renewable Energy Conservation Plan (DRECP). As part of the DRECP process, Johnson Valley, located in San Bernardino County, 32 miles east of Victorville, California, has been designated as a development focus area (DFA) for renewable energy.

Prior to changes in land use, it is important to understand the relationship between surficial processes and ecosystem patterns. A collaborative study between CDFW ecologists and California Geological Survey (CGS) geologists was conducted to provide insight into the spatial and temporal history of landform development, soil substrate, and the distribution of ecological values. This project was designed to highlight the relationships between Quaternary geomorphic landforms and processes with the areal distribution of vegetation alliances in the study area. The general approach uses a regional geomorphic hierarchy that relates common landform terminology with surficial geologic nomenclature, defines soil properties (pedogenic development and texture) within each surficial unit to provide a better understanding of the relationship between surficial processes and ecological function. This surficial geologic map provides the basic geologic data for the collaborative project. The project report emphasizes complex interactions between vegetation and geomorphic processes by providing observational and analytical results based on geographic comparison of this surficial geologic map and the CDFW vegetation map (See project report, Lancaster et al, 2014). Surficial geologic mapping was conducted for a 69 km^2 (17,158 acres) area located in southwestern part of Johnson Valley within portions of the Old Woman Springs, Melville Lake, Rattlesnake Canyon, and Bighorn Mountains 7.5 minute quadrangles. This mapping area coincides with the southwest portion of the Johnson Valley DFA and is bounded by the San Bernardino Mountains to the south and a broad basin to the north. The study area includes streams that issue from Rattlesnake Canyon, the largest tributary upland watershed to this internally draining basin.

Geology

The surrounding mountains are underlain by diverse array of crystalline bedrock lithologies. Precambrian gneiss and schist and Paleozoic quartzite, gneissic quartzite and limestone form the predominant outcrop lithology within the San Bernardino Mountains (Dibblee and Minch, 2008). The western portion of the Bighorn Mountains are also underlain by Precambrian gneiss and schist, transitioning to Mesozoic granodiorite and quartz monzonite to the east of One Hole Spring. The unnamed northwest trending ridges that border Old Woman Springs are underlain by Precambrian gneiss, Mesozoic quartz monzonite and granodiorite that are capped by basalt of Tertiary age.

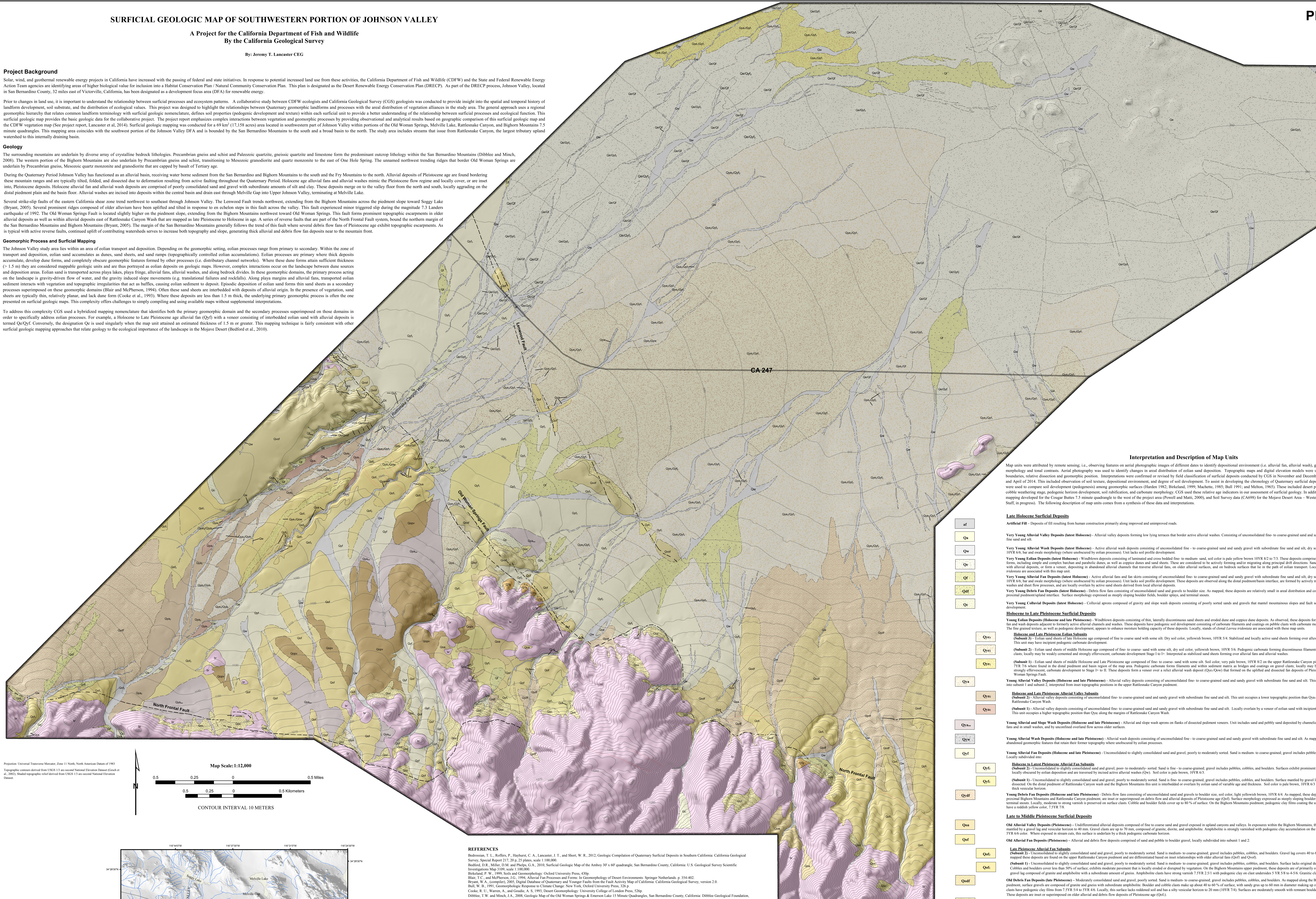
During the Quaternary Period Johnson Valley has functioned as an alluvial basin, receiving water borne sediment from the San Bernardino and Bighorn Mountains to the south and the Fry Mountains to the north. Alluvial deposits of Pleistocene age are found bordering these mountain ranges and are typically tilted, folded, and dissected due to deformation resulting from active faulting throughout the Quaternary Period. Holocene age alluvial fans and alluvial washes mimic the Pleistocene flow regime and locally cover, or are inset into, Pleistocene deposits. Holocene alluvial fan and alluvial wash deposits are comprised of poorly consolidated sand and gravel with subordinate amounts of silt and clay. These deposits merge on to the valley floor from the north and south, locally aggrading on the distal piedmont plain and the basin floor. Alluvial washes are incised into deposits within the central basin and drain east through Melville Gap into Upper Johnson Valley, terminating at Melville Lake.

Several strike-slip faults of the eastern California shear zone trend northwest to southeast through Johnson Valley. The Lenwood Fault trends northwest, extending from the Bighorn Mountains across the piedmont slope toward Soggy Lake (Bryant, 2005). Several prominent ridges composed of older alluvium have been uplifted and tilted in response to en echelon steps in this fault across the valley. This fault experienced minor triggered slip during the magnitude 7.3 Landers earthquake of 1992. The Old Woman Springs Fault is located slightly higher on the piedmont slope, extending from the Bighorn Mountains northwest toward Old Woman Springs. This fault forms prominent topographic escarpments in older alluvial deposits as well as within alluvial deposits east of Rattlesnake Canyon Wash that are mapped as late Pleistocene to Holocene in age. A series of reverse faults that are part of the North Frontal Fault system, bound the northern margin of the San Bernardino Mountains and Bighorn Mountains (Bryant, 2005). The margin of the San Bernardino Mountains generally follows the trend of this fault where several debris flow fans of Pleistocene age exhibit topographic escarpments. As is typical with active reverse faults, continued uplift of contributing watersheds serves to increase both topography and slope, generating thick alluvial and debris flow fan deposits near to the mountain front.

Geomorphic Process and Surficial Mapping

The Johnson Valley study area lies within an area of eolian transport and deposition. Depending on the geomorphic setting, eolian processes range from primary to secondary. Within the zone of transport and deposition, eolian sand accumulates as dunes, sand sheets, and sand ramps (topographically controlled eolian accumulations). Eolian processes are primary where thick deposits accumulate, develop dune forms, and completely obscure geomorphic features formed by other processes (i.e. distributary channel networks). Where these dune forms attain sufficient thickness (> 1.5 m) they are considered mappable geologic units and are thus portrayed as eolian deposits on geologic maps. However, complex interactions occur on the landscape between dune sources and deposition areas. Eolian sand is transported across playa lakes, playa fringe, alluvial fans, alluvial washes, and along bedrock divides. In these geomorphic domains, the primary process acting on the landscape is gravity-driven flow of water, and the gravity induced slope movements (e.g. translational failures and rockfalls). Along playa margins and alluvial fans, transported eolian sediment interacts with vegetation and topographic irregularities that act as baffles, causing eolian sediment to deposit. Episodic deposition of eolian sand forms thin sand sheets as a secondary processes superimposed on these geomorphic domains (Blair and McPherson, 1994). Often these sand sheets are interbedded with deposits of alluvial origin. In the presence of vegetation, sand sheets are typically thin, relatively planar, and lack dune form (Cooke et al., 1993). Where these deposits are less than 1.5 m thick, the underlying primary geomorphic process is often the one presented on surficial geologic maps. This complexity offers challenges to simply compiling and using available maps without supplemental interpretations.

To address this complexity CGS used a hybridized mapping nomenclature that identifies both the primary geomorphic domain and the secondary processes superimposed on those domains in order to specifically address eolian processes. For example, a Holocene to Late Pleistocene age alluvial fan (Qyf) with a veneer consisting of interbedded eolian sand with alluvial deposits is termed Qe/Qyf. Conversely, the designation Qe is used singularly when the map unit attained an estimated thickness of 1.5 m or greater. This mapping technique is fairly consistent with other surficial geologic mapping approaches that relate geology to the ecological importance of the landscape in the Mojave Desert (Bedford et al., 2010).



Projection: Universal Transverse Mercator, Zone 11 North, North American Datum of 1983

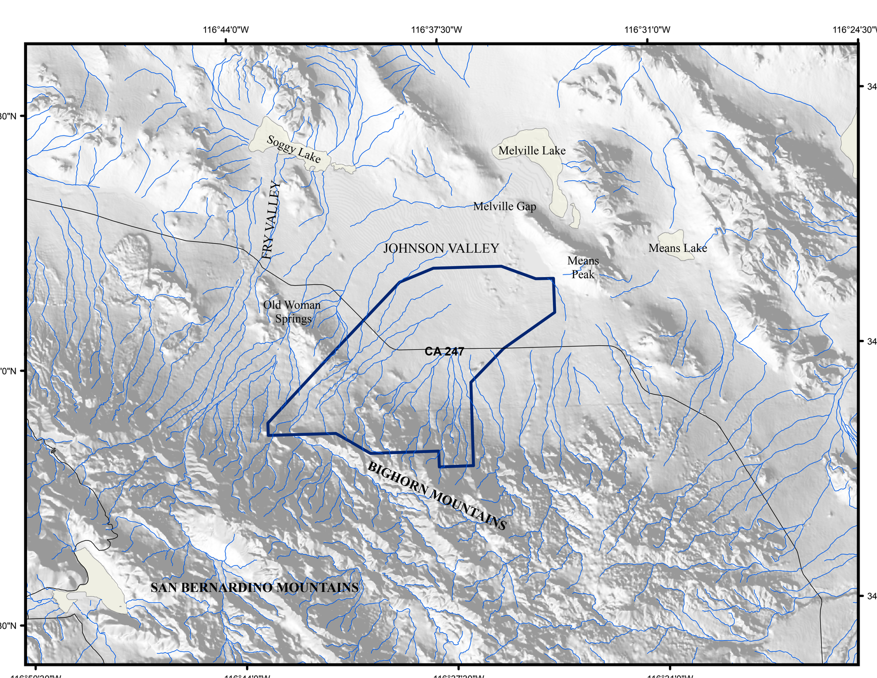
Topographic contours derived from USGS 1/3 arc-second National Elevation Dataset (Gesch et al., 2002); Shaded topographic relief derived from USGS 1/3 arc-second National Elevation Dataset.

Map Scale: 1:12,000

0.5 — 0.25 — 0 — 0.5 Miles

0.5 — 0.25 — 0 — 0.5 Kilometers

CONTOUR INTERVAL 10 METERS



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Imagery Used

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Google Earth, 2005, Digital Globe Imagery, accessed via Google Earth (v. 7.1.2.2041) on January 5, 2014

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U.S. Department of Agriculture, Farm Service Agency-Aerial Photography Field Office, National Agriculture Imagery Program (NAIP), 2005, 1-meter resolution.

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U.S. Department of Agriculture, 2009, accessed via Google Earth (v. 7.1.2.2041) on January 5, 2014U.S. Geological Survey, 1989, accessed via Google Earth (v. 7.1.2.2041) on January 15, 2014

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Interpretation and Description of Map Units

Map units were attributed by remote sensing; i.e., observing features on aerial photographic images of different dates to identify depositional environment (i.e. alluvial fan, alluvial wash), geomorphic position, surface morphology and tonal contrasts. Aerial photography was used to identify changes in areal distribution of eolian sand deposition. Topographic maps and digital elevation models were used to identify topographic boundaries, relative dissection and geomorphic position. Interpretations were confirmed or revised by field classification of surficial deposits conducted by CGS in November and December of 2013, and in February and April of 2014. This included observation of soil texture, depositional environment, and degree of soil development. To assist in developing the chronology of Quaternary surficial deposits, observable soil factors were used to compare soil development (pedogenesis) among geomorphic surfaces (Harden 1982; Birkeland, 1999; Machette, 1985; Bull 1991; and Melton, 1965). These included desert pavement and desert varnish, cobble weathering stage, pedogenic horizon development, soil rubification, and carbonate morphology. CGS used these relative age indicators in our assessment of surficial geology. In addition, CGS reviewed surficial mapping developed for the Cougar Buttes 7.5 minute quadrangle to the west of the project area (Powell and Matti, 2000), and Soil Survey data (CA698) for the Mojave Desert Area – Western Central Part (Soil Survey Staff, in progress). The following description of map units comes from a synthesis of these data and interpretations.

Late Holocene Surficial Deposits

af — **Artificial Fill** – Deposits of fill resulting from human construction primarily along improved and unimproved roads.

Qa — **Very Young Alluvial Valley Deposits (latest Holocene)** - Alluvial valley deposits forming low lying terraces that border active alluvial washes. Consisting of unconsolidated fine- to coarse-grained sand and sandy gravel with subordinate fine sand and silt.

Qw — **Very Young Alluvial Wash Deposits (latest Holocene)** - Active alluvial wash deposits consisting of unconsolidated fine - to coarse-grained sand and sandy gravel with subordinate fine sand and silt, dry soil color is brownish yellow, 10YR 6/6; bar and swale morphology (where unobscured by eolian processes). Unit lacks soil profile development.

Qe — **Very Young Eolian Deposits (latest Holocene)** - Windblown deposits consisting of laminated and cross bedded fine- to medium- sand, soil color is pale yellow brown 10YR 8/2 to 7/3. These deposits comprise a wide range of geomorphic forms, including simple and complex barchan and parabolic dunes, as well as coppice dunes and sand sheets. These are considered to be actively forming and/or migrating along principal drift directions. Sand sheets are also interbedded with alluvial deposits, or form a veneer, depositing in abandoned alluvial channels that traverse alluvial fans, on older alluvial surfaces, and on bedrock surfaces that lie in the path of eolian transport. Locally, stands of clonal *Larrea tridentata* are associated with this map unit.

Qf — **Very Young Alluvial Fan Deposits (latest Holocene)** - Active alluvial fans and fan skirts consisting of unconsolidated fine- to coarse-grained sand and sandy gravel with subordinate fine sand and silt, dry soil color is brownish yellow, 10YR 6/6; bar and swale morphology (where unobscured by eolian processes). Unit lacks soil profile development. These deposits are observed along the distal piedmont/basin interface, are formed by actively migrating distributary alluvial washes and sheet flow processes, and are locally overlain by active sand sheets derived from local alluvial deposits.

Qdf — **Very Young Debris Fan Deposits (latest Holocene)** - Debris flow fans consisting of unconsolidated sand and gravels to boulder size. As mapped, these deposits are relatively small in areal distribution and confined to locations along the proximal piedmont/upland interface. Surface morphology expressed as steeply sloping boulder fields, boulder splays, and terminal snouts.

Qc — **Very Young Colluvial Deposits (latest Holocene)** - Colluvial aprons composed of gravity and slope wash deposits consisting of poorly sorted sands and gravels that mantel mountainous slopes and fault scarps. Unit lacks soil profile development.

Holocene to Late Pleistocene Surficial Deposits

Young Eolian Deposits (Holocene and late Pleistocene) - Windblown deposits consisting of thin, laterally discontinuous sand sheets and eroded dune and coppice dune deposits. As observed, these deposits formed on abandoned alluvial fan and wash deposits adjacent to formerly active alluvial channels and washes. These deposits have pedogenic soil development consisting of carbonate filaments and coatings on pebble clasts with carbonate morphology up to Stage II. The fine grained texture, as well as pedogenic development, appears to enhance moisture holding capacity of these deposits. Locally, stands of clonal *Larrea tridentata* are associated with these map units.

Holocene and Late Pleistocene Eolian Subunits

Qye$_3$ — **(Subunit 3)** – Eolian sand sheets of late Holocene age composed of fine to coarse sand with some silt. Dry soil color, yellowish brown, 10YR 5/4. Stabilized and locally active sand sheets forming over alluvial fans and alluvial washes. This unit may have incipient pedogenic carbonate development.

Qye$_2$ — **(Subunit 2)** - Eolian sand sheets of middle Holocene age composed of fine- to coarse- sand with some silt, dry soil color, yellowish brown, 10YR 5/6. Pedogenic carbonate forming discontinuous filaments and thin coatings on gravel clasts; locally may be weakly cemented and strongly effervescent, carbonate development Stage I to I+. Interpreted as stabilized sand sheets forming over alluvial fans and alluvial washes.

Qye$_1$ — **(Subunit 1)** - Eolian sand sheets of middle Holocene and Late Pleistocene age composed of fine- to coarse- sand with some silt. Soil color, very pale brown, 10YR 8/2 on the upper Rattlesnake Canyon piedmont, and reddish yellow, 7YR 7/6 where found in the distal piedmont and basin region of the map area. Pedogenic carbonate forms filaments and within sediment matrix as bridges and coatings on gravel clasts; locally may be moderately cemented and strongly effervescent, carbonate development to Stage I+ to II. These deposits form a veneer over a relict alluvial wash deposit (Qye$_1$/Qow) that formed on the uplifted and dissected fan deposits of Pleistocene age, south of the Old Woman Springs Fault.

Qya — **Young Alluvial Valley Deposits (Holocene and late Pleistocene)** - Alluvial valley deposits consisting of unconsolidated fine- to coarse-grained sand and sandy gravel with subordinate fine sand and silt. This unit is locally differentiated into subunit 1 and subunit 2, interpreted from inset topographic positions in the upper Rattlesnake Canyon piedmont.

Holocene and Late Pleistocene Alluvial Valley Subunits

Qya$_2$ — **(Subunit 2)** - Alluvial valley deposits consisting of unconsolidated fine- to coarse-grained sand and sandy gravel with subordinate fine sand and silt. This unit occupies a lower topographic position than Qya$_1$ along the margins of Rattlesnake Canyon Wash.

Qya$_1$ — **(Subunit 1)** - Alluvial valley deposits consisting of unconsolidated fine- to coarse-grained sand and sandy gravel with subordinate fine sand and silt. Locally overlain by a veneer of eolian sand with incipient pedogenic development. This unit occupies a higher topographic position than Qya$_2$ along the margins of Rattlesnake Canyon Wash.

Qya$_{sw}$ — **Young Alluvial and Slope Wash Deposits (Holocene and late Pleistocene)** - Alluvial and slope wash aprons on flanks of dissected pediment veneers. Unit includes sand and pebbly sand deposited by channelized flow on small alluvial fans and in small washes, and by unconfined overland flow across older surfaces.

Qyw — **Young Alluvial Wash Deposits (Holocene and late Pleistocene)** - Alluvial wash deposits consisting of unconsolidated fine - to coarse-grained sand and sandy gravel with subordinate fine sand and silt. As mapped these deposits are abandoned geomorphic features that retain their former topography where unobscured by eolian processes.

Qyf — **Young Alluvial Fan Deposits (Holocene and late Pleistocene)** - Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Locally subdivided into:

Holocene to Latest Pleistocene Alluvial Fan Subunits

Qyf$_2$ — **(Subunit 2)** - Unconsolidated to slightly consolidated sand and gravel, poor- to moderately- sorted. Sand is fine - to coarse-grained; gravel includes pebbles, cobbles, and boulders. Surfaces exhibit prominent bar and swale morphology, locally obscured by eolian deposition and are traversed by incised active alluvial washes (Qw). Soil color is pale brown, 10YR 6/3.

Qyf$_1$ — **(Subunit 1)** - Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is fine- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Surface mantled by gravel lag to 60 mm, and is slightly dissected. On the distal piedmont of Rattlesnake Canyon wash and the Bighorn Mountains this unit is interbedded or overlain by eolian sand of variable age and thickness. Soil color is pale brown, 10YR 6/3 and has a faint 10-20 mm thick vesicular horizon.

Qydf — **Young Debris Fan Deposits (Holocene and late Pleistocene)** - Debris flow fans consisting of unconsolidated sand and gravels to boulder size, soil color, light yellowish brown, 10YR 6/4. As mapped, these deposits are observed along the proximal Bighorn Mountains and Rattlesnake Canyon piedmont, are inset or superimposed on debris flow and alluvial deposits of Pleistocene age (Qof). Surface morphology expressed as steeply sloping boulder fields, boulder splays and terminal snouts. Locally, moderate to strong varnish is preserved on surface clasts. Cobble and boulder fields cover up to 80 % of surface. On the Bighorn Mountains piedmont, pedogenic clay films coating the underside of gneissic clasts have a reddish yellow color, 7.5YR 7/8.

Late to Middle Pleistocene Surficial Deposits

Qoa — **Old Alluvial Valley Deposits (Pleistocene)** – Undifferentiated alluvial deposits composed of fine to coarse sand and gravel exposed in upland canyons and valleys. In exposures within the Bighorn Mountains, the surface of this unit is mantled by a gravel lag and vesicular horizon to 40 mm. Gravel clasts are up to 70 mm, composed of granite, diorite, and amphibolite. Amphibolite is strongly varnished with pedogenic clay accumulation on the undersides of clasts having 5YR 6/6 color. Where exposed in stream cuts, this surface is underlain by a thick pedogenic carbonate horizon.

Qof — **Old Alluvial Fan Deposits (Pleistocene)** – Alluvial and debris flow deposits comprised of sand and pebble to boulder gravel, locally subdivided into subunit 1 and 2:

Late Pleistocene Alluvial Fan Subunits

Qof$_2$ — **(Subunit 2)** - Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Gravel lag covers 40 to 60 % of the surface. As mapped these deposits are found on the upper Rattlesnake Canyon piedmont and are differentiated based on inset relationships with older alluvial fans (Qof1 and Qvof).

Qof$_1$ — **(Subunit 1)** - Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Surface lacks original depositional topography. Cobbles and boulders cover less than 50% of surface; exhibits moderate pavement that is locally eroded or disrupted by vegetation. On the Bighorn Mountains upper piedmont, these deposits are of primarily of debris flow origin, with a gravel lag composed of granite and amphibolite with a subordinate amount of gneiss. Amphibolite clasts have strong varnish 7.5YR 2.5/1 with pedogenic clay on clast undersides 5 YR 5/8 to 4-5/6. Granitic clasts are strongly pitted.

Qodf — **Old Debris Fan Deposits (late Pleistocene)** – Moderately consolidated sand and gravel, poorly sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. As mapped along the Bighorn Mountains upper piedmont, surface gravels are composed of granite and gneiss with subordinate amphibolite. Boulder and cobble clasts make up about 40 to 60 % of surface, with sandy grus up to 60 mm in diameter making up swales. Bottom of gneissic clasts have pedogenic clay films from 7.5YR 5/4 to 5YR 4/6. Locally, this surface lacks reddened soil and has a silty vesicular horizon to 20 mm (10YR 7/4). Surfaces are moderately smooth with remnant boulder fields preserved locally. These deposits are inset or superimposed on older alluvial and debris flow deposits of Pleistocene age (Qof$_1$).

Qoc — **Old Colluvial Deposits (Pleistocene)** - Colluvial aprons composed of gravity and slope wash deposits consisting of poorly sorted sands and gravels, preserved on the flanks of steep mountain slopes and fault scarps. Locally, these deposits are cemented by carbonate soil development.

Qopv — **Old Pediment Veneer Deposits (Pleistocene)** – Pervasively chalky-cemented sand and pebbly sandstone; firm to hard; poorly sorted; cemented to well cemented. Calcification is consistent with a Stage IV to VI petrocalcic soils. Based on field relations in the map area, this unit is interpreted to form a veneer over a former (Pleistocene?) bedrock erosional surface.

Middle to Early Pleistocene Deposits

Qvof — **Very Old Debris Fan Deposits (Pleistocene)** – Moderate- to well- cemented fanglomerate; interbedded fluvial and debris flow deposits. Fluvial deposits are thin- to thick-bedded, poorly sorted pebble to cobble conglomerate that exhibit channels and cross-bedding. Debris flow deposits are massive and unsorted with angular pebble- to cobble-sized angular to subangular clasts. As mapped these deposits are exposed as fault-bound ridges associated with the Lenwood and Old Woman Springs faults. Over 30 m of this unit is exposed on the western margin of Rattlesnake Canyon Wash. Locally these deposits contain several well developed pedogenic Bt and calcic (k) horizons.

QTs — **Very Old Alluvial and Lacustrine Deposits (Pleistocene and Tertiary)** – Poor- to moderately- consolidated clay, silt, and sand, moderately sorted. Sand is medium- to coarse-grained. As mapped this unit is exposed along the fault-bound topographic break at the northern margin of the Bighorn Mountains.

Mesozoic and Older Bedrock

Br — **Bedrock Undifferentiated (Pliocene to Proterozoic)** – Undifferentiated crystalline bedrock composed of Precambrian gneiss, schist; Paleozoic quartzite, gneissic quartzite and limestone; Mesozoic granodiorite and quartz monzonite.

Symbol Explanation

Geologic Contact – Solid where location in accurate, long-dashed where location is approximate

Fault - Solid where location in accurate, long-dashed where location is approximate, dotted where location is concealed. Compiled by Bryant (2005)

Lineament – Vegetation, tonal, and topographic. Mapped by author as a part of this assessment.