Geologic map of the Kingman NW 7 ½' Quadrangle, Mohave County, Arizona

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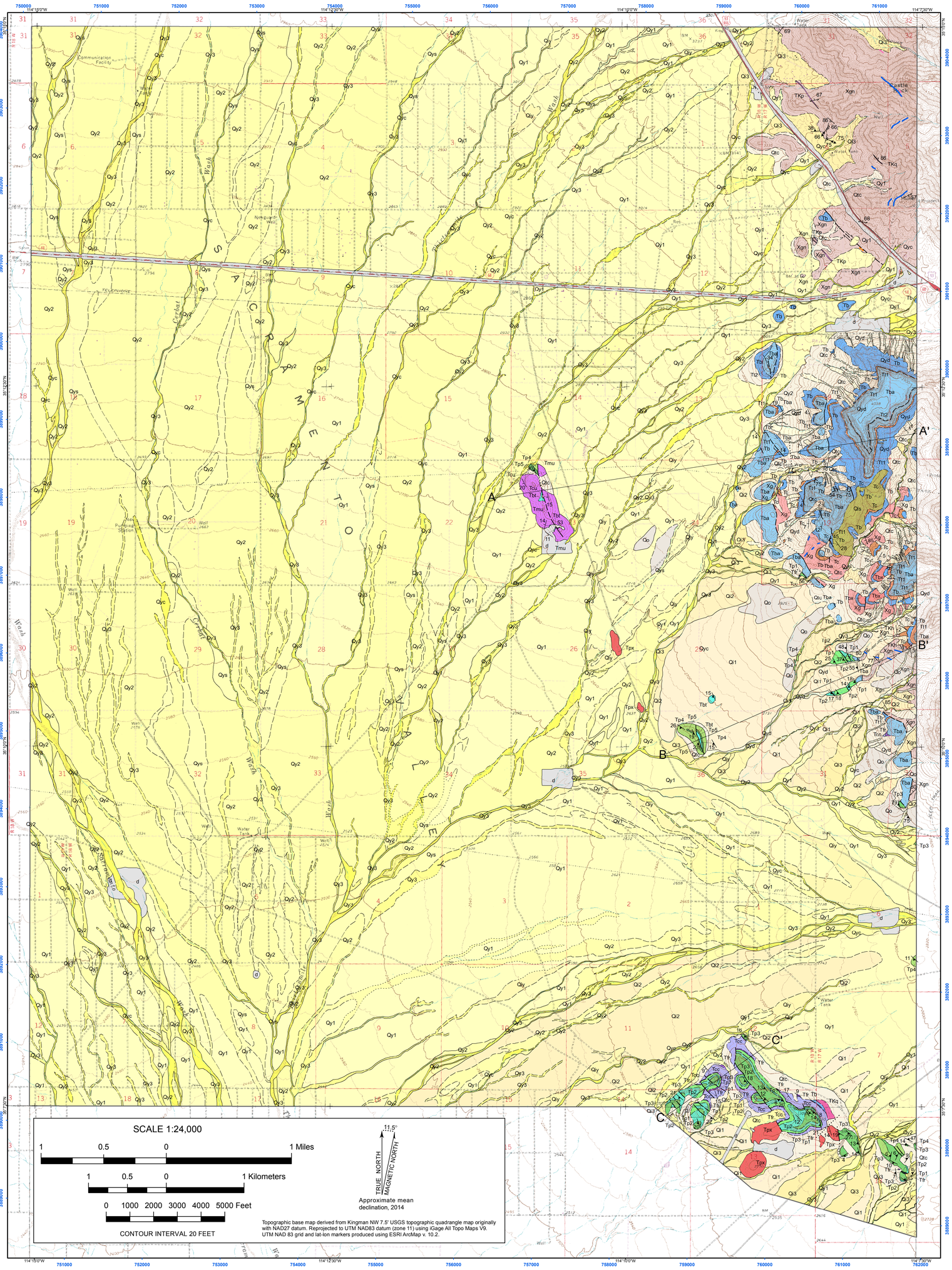
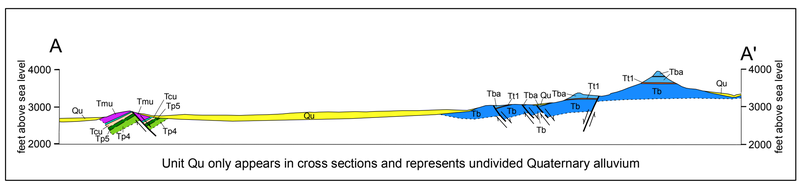
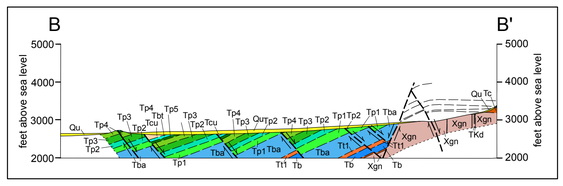
Arizona Geological Survey

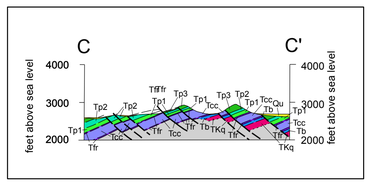
Digital Geologic Map 114 (DGM-114), version 1.0

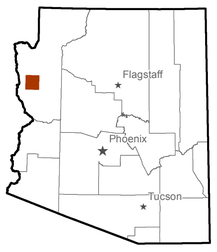
November 2015



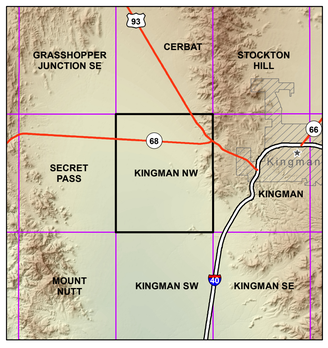


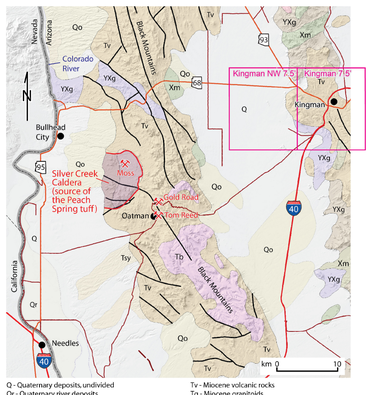




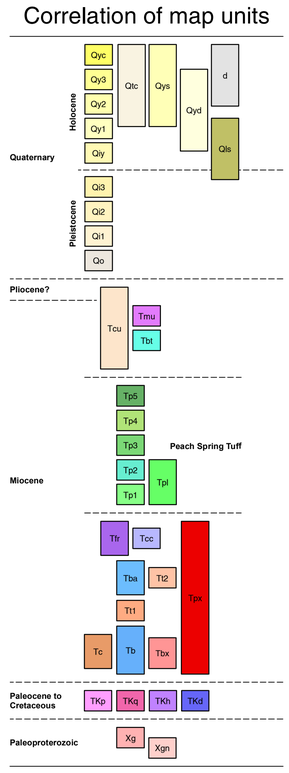


Location of map area





Correlation of map units



Contacts and faults

- Contact, accurate
- Contact, approximate
- Contact, obscured by anthropogenic modification
- Fault, accurate
- Fault, approximate
- Fault, concealed

Dikes

- Felsic dike
- Intermediate dike
- Mafic dike

Structure symbols

- Bedding, inclined
- Bedding, horizontal
- Igneous flow foliation, inclined
- Eutaxitic foliation, inclined
- Foliation and compositional layering, inclined
- Tectonic foliation, inclined
- Mylonitic foliation, inclined
- Strike and dip of minor fault
- Dip of fault or contact
- Stretching lineation, top to up-plunge direction

Other features

- Cross-section location

Introduction

The Kingman 7 ½' Quadrangle encompasses much of the city of Kingman in Mohave County, northwestern Arizona. Geologic mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992, and was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP assistance award # G13AC00374. Bedrock geologic mapping was conducted by Charles Ferguson and surficial geologic mapping was conducted by Joseph Cook. Mapping was compiled digitally using ESRI ArcGIS software.

Disclaimer: Geologic contacts are drawn to depict how they would appear on a landscape portrayed by the 1967 topographic base used for this map (which is the most recently available from the USGS). Contacts in areas where the topography has changed significantly (chiefly in the big road cuts along Interstate 40) are shown as they would have appeared before the change. In other areas, where the topography has not changed but is not particularly accurate, contacts were adjusted to match the "false" topography.

Surficial geology

The map area encompasses a drainage divide that separates the Colorado River catchment from the Red Lake playa catchment. Valleys consist of gently sloping piedmonts covered by alluvial fan and terrace deposits, and nearly flat valley floors occupied by ephemeral washes, floodplains, and low terraces.

Surficial geologic units were mapped using field observations, stereo aerial photographs, digital orthophotographs and/or georeferenced satellite imagery, and digital elevation models (DEMs). Relative ages of alluvial deposits were estimated using characteristics of clast weathering, soil development, carbonate accumulation, and position in the landscape (Gile and others, 1981; Machette, 1985; Bull, 1991; Birkland, 1999). Soil development and carbonate accumulation begin once a deposit is isolated from active alluvial processes. As a result, the degree of soil development and carbonate accumulation are one of the criteria used to identify the approximate ages of surficial units.

Younger alluvial deposits have little to no soil development, retaining the original grey or brown color of the alluvial sediment, and no carbonate accumulation. Clasts in these deposits have no weathering rinds or surface patinas and thus appear brighter and fresher than older clasts. Young alluvial surfaces often retain original depositional characteristics such as bars and swales. Conversely, older alluvial deposits have better developed soils that appear orange or red in color, with soil horizons reflecting clay and carbonate accumulations. Clasts in older alluvial deposits often exhibit darkened weathering rinds or rock varnish, and thus appear darker on the ground and in aerial photographs. Preserved alluvial surfaces may be smooth and flat (Qi3), becoming more rounded and coarser with age (Qi2). The oldest alluvial surfaces (Qo and QTa) are often eroded, rounded ridges with no soils preserved and the carbonate horizon exposed.

Debris flow deposits are present on steep slopes of the mountain front and along proximal channels and terraces. Other proximal alluvial deposits exhibit strong carbonate accumulation and are very resistant to erosion resulting in deeply incised, narrow channels near the mountain front. Isolated exposures of well-cemented older alluvium are present along channels and within younger, unconsolidated alluvium throughout the mapping area, indicating burial of older alluvium is relatively shallow. Holocene alluvium along modern washes and arroyos is low relief and relatively unincised. As a result, channel migration, sheet flooding, distributary flow, and overbank deposition are common. Many young terraces along established channels and washes are prone to flooding, undercutting, and erosion during flow events.

Bedrock geology

Geology of the Kingman area is dominated by a sequence of Miocene volcanic rocks that fill a broad northeast-directed paleovalley (Beard and Faulds, 2011) that can be traced from the southernmost Black Mountains southwest of Kingman through Kingman and Peach Springs, Arizona to the southern rim of the Grand Canyon. The older volcanics consist of mafic lavas with interbeds of sandstone, conglomerate, and thin, (<3m thick) nonwelded, felsic ash-fall tuffs. The conglomerates are dominated by Proterozoic granitic clasts derived from the walls of the valley, but in one area near Gross Spring (section 9T21N, R17W), rounded clasts of dacitic lava most likely derived from the Black Mountains to the southwest are present. Dacitic lavas of this age are also present to the east of Kingman. Sparse northeasterly paleocurrents at this locality provide evidence that the paleovalley probably flowed to the northeast.

Younger Miocene rocks that fill the paleovalley consist of three ignimbrites dominated by the Peach Spring Tuff (Young and Brennan, 1974; Glazner et al., 1986) which forms the prominent cliffs in the Kingman area. The ledges and cliffs correspond to mappable zones in the Peach Spring Tuff that we expand from the two (upper and lower) originally mapped by Buesch and Valentine (1986) to five. All five zones are demonstrably part of a single cooling unit, and clearly distinct from the underlying Cook Canyon, and overlying Bonnelli tuffs. The Cook Canyon Tuff fills a smaller, similarly oriented paleovalley inset into the broader main valley.

Structurally, Tertiary strata of the Cerbat-Hualapai Mts change from flat-lying along the crest of the range into predominately southwest-tilted in the Sacramento Valley to the west. The change occurs through a west-vergent anticlinorium associated with down-to-the-east normal faults that are cut by down-to-the-west (basin) normal faults.

Along the crest of the range, dip-slip faulting is minimal, and faults, like the one that cuts through the town of Kingman, are predominantly strike-slip with as much as 2km of dextral displacement. Strike-slip motion is indicated by numerous kinematic indicators along the fault and its related strands. Flower structures occur along strands of the fault in the SW ¼ of section 23, T21N, R17W. Dextral motion is also indicated by offset across the fault of the northwestern edge of a paleovalley filled with the Cook Canyon Tuff.

In the crystalline basement rocks, there are several persistent, moderately north-dipping, top-to-the south mylonite zones. The mylonites predate deposition of the Mid-Tertiary strata, but it is not known how they relate to the emplacement of Laramide porphyritic rocks.

The McConnico district in the southwest corner of the Kingman map area, and southeast corner of the Kingman NW map area, which produced 3600 oz. of gold and 1800 oz. of silver from 23,000 tons of ore (Keith et al. 1983), is associated with an extensive belt of Laramide porphyry dikes and intrusions, but in one area (section 33, T21N, R17W) alteration is also associated with a feeder dike for a flow of the Miocene biotite-phyric xenolithic mafic lava (Tbb). Most of the Laramide dikes strike northwesterly, but at McConnico a suite of dikes strike west-southwest, in apparent alignment with a newly recognized Laramide quartz porphyry intrusion (TKq) that crops out along the eastern foot of a range of hills in the southeast corner of the Kingman NW map area.

Sparse, horizontally-emplaced gabbroic dikes of probable Middle Proterozoic age, based on our correlation of these intrusions with a wide ranging suite of horizontal diabase dikes in the region (Howard, 1991), are spatially associated with the Holy Moses Mine along the south-central edge of the Kingman map area.

The contact between the granitic gneiss (Xgn) and the megacrystic granite (Xg) is gradational and metasomatic. Small bodies of K-feldspar megacrystic pegmatite similar to the Kingman feldspar deposit just to the north of the Kingman map area, are present in the megacrystic granite in the se ¼ of section 33, T21N, R17W.

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Citation for this map:

Ferguson, C.A., and Cook, J.P., 2014, Geologic map of the Kingman 7 ½' Quadrangle, Mohave County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-113, scale 1:24,000.

This geologic map was funded in part by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G13AC00374 (2013). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Map Unit Descriptions

other units

d — **Disturbed ground** - Heavily disturbed ground due to mining, extensive excavation, construction of earth dams, and highways.

Qtc — **Quaternary hillslope talus and colluvium** - Unconsolidated to weakly consolidated very poorly sorted angular rock debris deposited on and at the base of bedrock slopes and mantling highly eroded bedrock hills.

Qls — **Landslide** - Landslide masses composed chiefly of mafic lava derived from the colllapse of steep slopes.

Piedmont Alluvium

Qyd — **Holocene debris flow deposits** - Snouts, levees, scoured debris flow channels, and debris flow-dominated fans. Qyd deposits are located on or at the base of steep bedrock slopes along the Hualapai Mountains and along some channels within and near the mountain front. Unit Qyd also includes areas of erosion (debris flow scars) on hillslopes that are spatially associated with debris flow deposits. Coarse cobble and boulder lag forms linear levees bordering steep hillslope channels or elongate lobes representing debris flow snouts. Older Qyd deposits are predominantly composed of darkly varnished coarse cobble to boulder lag while younger deposits are less darkly varnished to unvarnished and retain a greater portion of finer grained (silty to pebbly) matrix between larger clasts.

Qys — **Low energy sheetflood deposits** - Qys deposits consist of unconsolidated very fine silty to sandy alluvium deposited in the distal fan environment and adjacent to unincised flood prone alluvial fan channels. Vegetation on Qys deposits consists of small bunch grass and desert shrubs. Qys deposits exhibit low relief bar and swale microtopography and may exhibit distributary flow in unincised reaches. Qys deposits are similar in elevation and distribution to Qy3 deposits but are broader and do not exhibit clear channelized flow.

Qyc — **Active channel and arroyo deposits** - Qyc deposits are composed of unconsolidated, very poorly sorted sandy to cobbly ephemeral piedmont channel sediments. Large boulders and cobbles are common in poorly sorted Qyc alluvium near the mountain front while distal Qyc alluvium is composed primarily of well-sorted sand with rare cobbles. Channels may exhibit bar and swale microtopography with bars composed of coarser sediments. Qyc deposits range from unvegetated in active channels to well-vegetated with small shrubs, catclaw acacia, creosote, and desert broom on in-channel bars. No soil development is present in Qyc alluvium although varnished and CaCO3-coated clasts reworked from adjacent older deposits may be present. Qyc deposits commonly become submerged during moderate to extreme flow conditions and can be subject to deep, high velocity flow and lateral bank erosion. Channels are generally incised 0.5 to 1.5m below adjacent Holocene alluvium and may be incised into adjacent Pleistocene alluvium by 5m or more.

Qy3 — **Secondary channel alluvium, low terraces, and in-channel bars** - Recently active piedmont alluvium located primarily along or within active drainages including floodplain, low-lying terrace, less active tributary drainages to Qyc channels, and distal reaches of active fan channels that have aggraded and transitioned to distributary flow and infiltration. Qy3 deposits are composed of unconsolidated to very weakly consolidated unvarnished sandy alluvium with a discontinuous pebbly cover. Qy3 drainages are often wider, lower energy, and more heavily vegetated than the Qyc channels they drain into. Vegetation consists of large creosote, brittlebush, goldeneye, and other small desert shrubs. These deposits may exhibit low-relief bar and swale microtopography and are susceptible to inundation during moderate to extreme flow conditions when channel flow exceeds capacity. Qy3 deposits are generally unincised but may exhibit small rill networks adjacent to Qyc deposits. Soil development is generally absent or incipient on Qy3 deposits which exhibit pale buff to light brown (7.5 - 10 YR 5/4) surface coloration although local color variations exist depending on parent material. Qy3 terraces are located 0.5-1m below Qy2 deposits and 3-5m below Pleistocene alluvium close to the mountain front.

Qy2 — **Broad, low relief alluvial fan and terrace deposits** - Qy2 deposits consist of piedmont terrace deposits located primarily along the flanks of incised drainages, isolated intrachannel remnants, and low-relief terraces inset into older alluvium. These deposits consist of predominantly fine grained unconsolidated to weakly consolidated poorly to moderately well-sorted sediments with sub-rounded to sub-angular cobble and boulder-dominated bars. Where inset into older alluvium, Qy2 deposits are planar with remnant bar and swale microtopography. Soil development on Qy2 deposits is minor, characterized by incipient stage I-II calcium carbonate accumulation in the form of small filaments and medium brown (7.5 YR 5/6) surface coloration with locally redder deposits where derived from granitic parent material. In some locations thin Qy2 deposits overlie older Pleistocene deposits. In these locations well-varnished boulders protrude through unvarnished, younger, sandy Qy2 alluvium and vegetation may be more similar to populations observed on Pleistocene deposits. Vegetation on Qy2 surfaces consists of numerous medium creosote, yucca, small shrubs, weeds, grasses, and cactus. These surfaces are subject to inundation during moderate to extreme flow conditions when channel flow exceeds capacity or due to channel migration on low-relief portions of broad distal fan deposits. Planar Qy2 terraces are typically elevated from 0.5 - 1.5m above younger alluvium and active channels with less relief relative to other surfaces closer to the center of Golden Valley far from the mountain front.

Qy1 — **Inactive alluvial fan remnants, terraces, and bars** - Qy1 deposits consist of planar terraces along larger fan drainages inset into older alluvium. They stand up to 1-2 m higher in the landscape than Qy2 deposits, are not part of the modern drainage system except possibly under flood conditions, and partially overlie Pleistocene deposits in some areas, especially near the mountain front. Qy1 deposits are composed of sandy to pebbly swales with coarser unvarnished to moderately varnished cobble to small boulder bars. Bar and swale microtopography is somewhat muted by incipient pavement formation. Pebbles and cobbles exposed in cross section exhibit stage I-II calcium carbonate accumulation with some clasts exhibiting thicker CaCO3 rinds on the undersides. Many areas of Qy1 deposits appear lighter on aerial photos due to the abundance of overturned CaCO3-coated clasts and carbonate flakes on the surface. Larger clasts are surrounded by a medium brown matrix of fine sand to silt. Surface color ranges from 5-7.5 YR 5/4-5/6 depending on location in the piedmont and dominant parent material. Vegetation on Qy1 deposits is similar to that found on Qy2 deposits; medium creosote, yucca, catclaw, small shrubs, weeds, and grasses. Elevation difference between Qy1 and Qy2 deposits decreases with distance from the mountain front.

Qiy — **Partially buried Pleistocene alluvial fan deposits** - Qiy deposits represent areas in the piedmont where patterns of alluvial fan erosion and deposition have resulted in minor to discontinuous burial of older alluvium by younger deposits. Qiy deposits are characterized by intermittent exposure of older, CaCO3-rich piedmont alluvium beneath unconsolidated Holocene deposits. The distribution of Qiy exposures is predominantly along eroded edges and broad swales within the overlying younger alluvial unit. Qiy deposits are often located in close proximity to higher-standing Pleistocene fan deposits.

Qi3 — **Intermediate alluvial fan and terrace deposits** - Qi3 deposits mark the mountain front are located at higher elevations in the landscape than Holocene alluvium but are partially buried by younger deposits farther from the mountain front where relief between Pleistocene and Holocene deposits is reduced or absent. Wide terraces are planar where preserved and exhibit remnant bar and swale microtopography which has been overprinted and smoothed by pavement formation, inflation, and churning by vegetation. Very coarse, medium to well-varnished boulder dominated bars are partially buried by moderate pavement development in surrounding swales. Clast cover is composed of vesicular basalt, mixed volcanics, and granitoids. Basalt clasts are the most varnished lithology and Qi3 surface color varies depending on lithology dominance. Vegetation on Qi3 surfaces consists of small shrubs, creosote, catclaw acacia, yucca, cholla, and ocotillo. Many Qi3 surfaces appear whitish on aerial photos due to abundant overturned CaCO3-coated clasts and carbonate flakes on the surface. Surface soil color is medium brown 5-7.5 YR 5/4.

Qi2 — **Older intermediate alluvial fan and terrace deposits** - Qi2 deposits in the southwest portion of the Kingman quad and southeast portion of the Kingman NW quad are relatively thin (6m or less) alluvial remnants deposited atop a weathered grusy bedrock pediment. Clast lithology includes basalt, mixed volcanics, and granitoids. These deposits exhibit darker, more well-developed varnish than nearby Qi3 deposits especially where basalt clasts are abundant. Granitoid clasts weather to individual grains rather than becoming varnished, resulting in an alternating light and dark surface. Some large, long-standing stationary basalt boulders within Qi2 deposits exhibit thick shiny rock varnish. Qi2 deposits also exhibit a more mature, interlocking pavement and more advanced (stage II-III) calcium carbonate accumulation than Qi3 deposits. Qi2 remnants are broadly rounded. The flanks of preserved Pleistocene surfaces are covered by abundant feldspar and quartz grains with intermittent exposure of in situ granite. CaCO3 flakes litter eroded crest and flanks of surface. Pavement has been destroyed by veg churning and disturbance of underlying soil carbonate. Vegetation on Qi2 surfaces consists of small shrubs, creosote, yucca, ocotillo, and crucifixion thorn.

Qi1 — **Older, higher standing intermediate alluvial fan deposits** - Qi1 deposits are relict alluvial fan remnants located close to the mountain front that stand higher in the landscape than Qi2 and younger deposits. Qi1 deposits may be deposited atop eroded bedrock pediment or older, well-cemented alluvium including Qo deposits and basin-filling alluvium. Exposed, partially buried clasts are well-varnished except where exfoliation weathering has chipped away the surface of long-exposed clasts. Despite the presence of well varnished clasts present at the surface in basalt-dominated deposits, Qi1 surfaces appear white on aerial photos due to an abundance of CaCO3 rinds, flakes, and overturned clasts littering the surface. The presence of such quantity of soil carbonate at the surface indicates Qi1 deposits are sufficiently long standing to have developed significant soil carbonate and subsequently become churned by vegetation and bioturbation in order to expose carbonate litter at the surface. This same process has also affected the quality of pavement on these deposits. In some locations a second round of pavement formation composed primarily of broken carbonate shards is ongoing. Undisturbed desert pavement is discontinuous or absent over much of the surface except in pebble dominated swales. Qi1 deposits are broadly rounded and exhibit deeply incised mature tributary drainage networks. Where exposed in channel walls, these deposits exhibit well developed (stage III-IV) calcium carbonate accumulation. Channel walls may be undercut and exhibit a coarsely sculpted appearance due to the level of cementation exposed by incision. Vegetation on Qi~1 deposits is similar to that found on Qi2 deposits although yucca and ocotillo are more abundant.

Qo — **High standing, deeply dissected and eroded alluvial fan remnants** - Weakly to moderately-consolidated sand, gravel, cobble and boulder deposits forming elevated strath terraces and saddles overlying bedrock approximately 100 to 180 ft (35-50 m) above the modern channels. Where surfaces are well-preserved, soil development is strong, with clay-rich reddish brown argillic horizons and moderate carbonate accumulation. Qo surfaces typically are fairly smooth except where eroded at their margins.

Miocene bedrock units

Tcu — **Younger Conglomerate and sandstone** - Conglomerate and sandstone younger than the Peach Spring Tuff is medium- to thick-bedded, and mostly clast-supported. Clasts range from pebbles to boulders and range from rounded to sub-angular. Clasts are dominated by Peach Spring Tuff and mafic lava. Thickness: 0-25 m.

Tmu — **upper mafic lava** - Light gray weathering mafic lava containing 1-3%, <2 mm iddingsite phenocrysts. This lava is present at only one locality: an isolated hogback shaped hill in the W1/2 of section 23, T21N, R18W where it overlies a thin sedimentary interval (Tcu) that overlies the uppermost, Warm Springs zone, of the Peach Spring Tuff (Tp5) at the north end of the hill, and tuff of the Bonnelli House (Tbt) at the south end of the hill. Thickness: 0-60 m.

Tbt — **tuff of Bonnelli House** - A pair of nonwelded to poorly welded, light gray, phenocryst-poor ignimbrites containing 1-5%, 1-5 mm sanidine phenocrysts. The ignimbrites contain <5% pumice, and <1% lithic lapilli. The lower ignimbrite is thinner (<3 m) and generally poorly to nonwelded. The upper ignimbrite, which at Kingman yields a sanidine Ar/Ar age of 17.72 +/- 0.01 Ma (Spencer et al., in preparation), is thicker (up to 10 m), more welded, and is slightly green in some areas. The greenish hue increases in rocks that contain 1-3% angular lithophysal cavities, many of which appear to be molds of weathered out lapilli. The cavities are commonly lined with black, finely crystalline minerals. Some of the cavities strongly resemble woody stems while others might be leaf and/or shell fragments. A 2-10 cm thick interval of very fine-grained, white ash-fall tuff separates the two ignimbrites. The unit is named for the Bonnelli House, an historic home near the courthouse in downtown old Kingman that is constructed mostly of dimension stone quarried from the ignimbrite. Thickness: 0-25 m.

Peach Spring Tuff

The Peach Spring Tuff is a large-volume, rhyolitic ignimbrite that erupted from a caldera 30 km to the west of Kingman 18.78 +/- 0.02 million years ago (Ferguson et al., 2013). Five mappable zones of the Peach Spring Tuff are recognized in the Kingman area (Tp1-5). Compositional variations based on phenocryst and pumice content are the basis for three of the zones, and the other two are defined by changes in degree of welding and vapor phase alteration. The ignimbrite contains phenocrysts of sanidine (up to 5 mm) > plagioclase (<3 mm), sparse biotite (<2 mm), minor sphene (titanite), amphibole, and traces of quartz, allanite/chevkinite, and pyroxene. The sanidine - plagioclase ratio ranges from 2:1 to 4:1. The presence of sphene (titanite) is often quoted as diagnostic criteria for identification of the ignimbrite, but it is not always visible in hand specimen. Phenocryst content increases upward from 2-35%. The increase from 2-20% occurs smoothly through the lower 4 zones, but the increase from 20 to 35% occurs rapidly across a 2-4 m thick interval concomitant with an abrupt increase in welding at the base of the uppermost zone (Tp5). The transition is also recognized near Warm Springs in the southern Black Mountains where the abrupt upward increase in phenocrysts is accompanied by a change in chemical composition from rhyolite below to trachyte above (Pamukcu et al., 2013). This transition is crucial because it provides an important link between the Peach Spring Tuff's mostly rhyolitic outflow sheet and the trachyitic intracaldera tuff at Silver Creek. The phenocryst-rich vitrophyre, known as the Warm Springs zone of the Peach Spring Tuff (Tp5), is present in the Kingman NW map area, but has not been identified in the Kingman map area.

Pumice content of the Peach Spring Tuff increases gradually upward. A fairly abrupt upward increase occurs across an approximately 2-4 m thick interval that defines the boundary between zones Tp2-Tp3 which is also accompanied by a change from vertically jointed cliff below to horizontally jointed ledge above. The transition is easily mappable in the Kingman area, and was used by Buesch and Valentine (1986) as the contact between their upper and lower map units of the Peach Spring Tuff.

The Peach Spring Tuff can be divided into three cooling unit zonations that are present in nearly all regional welded ignimbrites: 1) lower nonwelded, 2) middle welded, and 3) upper vapor-phase altered poorly welded (Smith, 1961). A total of five zones are therefore recognized and mapped in the Kingman area. The transition from the lower nonwelded to middle welded zone is the upward change from our Holy Moses zone (Tp1) to the Sawmill Canyon zone (Tp2), and the transition from the welded middle zone upward into the vapor-phase altered poorly welded zone is the Slaughterhouse Canyon zone (Tp3) - Hilltop zone (Tp4) boundary. None of the cooling unit or phenocryst-pumice content transitions represent boundaries between separate flow-units. The transitions occur across intervals on the order of 5 cm to 3 m thick. The lower two cooling unit zones thin dramatically to the south, and are lumped together as one map unit (Tp1) in these areas. Also in the south, a black vitrophyre is commonly present just above the base of the ignimbrite at what would probably be the Tp1-2 boundary. The base of the ignimbrite is defined throughout most of the area by a 0-150 cm-thick surge deposit (Valentine et al., 1989) which we include as part of the Tp1 zone. Although considered an ash-fall tuff by some (Wilson and Self, 1990) we agree with Valentine et al. (1989; 1990) that this lowermost deposit is probably a surge.

Tp5 — **Warm Springs zone of the Peach Spring Tuff** - Phenocryst-rich (30-35% sanidine > plagioclase) densely welded ignimbrite with black vitric matrix and 10-20% fiamme. This zone abruptly, yet gradually overlies light-colored ignimbrite (Tp4). Thickness: up to 20 m.

Tp4 — **Hilltop zone of the Peach Spring Tuff** - Poorly welded, moderately phenocryst-rich (15-18% sanidine > plagioclase) ignimbrite with abundant, weakly compacted pumice (15-30%) and fairly abundant (5-10%) lithic lapilli. In some areas, lithic blocks up to 1m are present. The base of the zone is defined by an abrupt upward increase in pumice accompanied by a decrease in compaction (as defined by shape of the pumice fragments). The base of the zone corresponds to the upper part of a cliff, and the bulk of the zone forms rounded hill tops. The zone is named for the Hill Top Motel at the crest of old US route 66 in Kingman. Thickness: up to 35 m.

Tp3 — **Slaughterhouse Canyon zone of the Peach Spring Tuff** - The main welded zone of the Peach Spring Tuff is a reddish gray strongly welded ignimbrite containing 12-15% sanidine > plagioclase phenocrysts and 5-15% pumice, typically compacted with length to width ratios > 5:1. The base of the zone is defined by an abrupt upward increase of pumice from <<5% to 7-15%. The base of the zone corresponds to a prominent ledge defined by an upward change from vertical joints to horizontal joints. Pumice at the base of the zone are replaced by lithophysal cavities. Thickness: up to 60 m.

Tp2 — **Sawmill Canyon zone of the Peach Spring Tuff** - The lower part of the welded, interior zone of the Peach Spring Tuff is characterized by strong vertical jointing and very low <5% pumice content. Phenocryst content ranges between 5-12%, and lithics are sparse (<2%). The zone is a strong cliff-former. The base of the zone is typically very sharp and corresponds to a ledge developed along the top of the nonwelded Holy Moses zone (Tp1). Thickness: up to 40 m.

Tp1 — **Holy Moses zone of the Peach Spring Tuff (Miocene)** - The basal nonwelded zone of the Peach Spring Tuff is a cliff-former that contains 1-5% phenocrysts, 1-5% lithic lapilli, and <5% pumice. The base overlies a 50-150 cm thick laminated to thin-bedded medium- to coarse-ash grained surge deposit. Thickness: up to 50 m.

Tpl — **Combined lower zones of the Peach Spring Tuff** - The lower two zones of the Peach Spring Tuff. Thickness: 0-20 m.

Tpx — **Pyroxene mafic lava** - Mafic lava containing 3-15%, 2-10 mm pyroxene phenocrysts and pyroxene-olivine aggregates that are probably ultramafic xenoliths, plus 1-5%, <3 mm olivine / iddingsite. Rare 2-15 mm xenoliths of quartz-feldspar granitic aggregates are also present. This lava occurs in two areas in Sacramento Valley where it probably underlies the Peach Spring Tuff (Tp), but definitive contact relationships are not preserved. Thickness: 0-60 m.

Tfr — **Tuff of Fort Rock** - A sequence of pumiceous volcaniclastic sandstone and pebbly sandstone with up to 4 felsic ash-fall tuffs. The sequence directly underlies the Peach Spring Tuff and envelops a single mappable ignimbrite called the Cook Canyon Tuff (Tcc). Typically, a pair of ash-fall tuff sets occur below and another pair above the ignimbrite, and the sets in each pair are separated by a few cm of sandstone. The ash-fall tuffs range in thickness up to 2 m and are internally complexly laminated to thin-bedded. The beds consist of moderately well-sorted coarse ash with sparse, small lapilli-sized pumice > lithics. The pumice is fairly phenocryst-rich (containing 5-15% 1-3 mm feldspar and 1-5% <2 mm biotite). Thickness (including the Cook Canyon Tuff): 0-60 m.

Tcc — **Cook Canyon Tuff** - Nonwelded ignimbrite containing phenocrysts of <3 mm plagioclase (20%) and <2 mm biotite (5%), along with minor clinopyroxene, magnetite, zircon, and apatite, and traces of sanidine (Pratt et al., 2014). The ignimbrite ranges from dark gray to deep orange brown (weathered) and includes at least two types of pumice fragments; dark gray to black, and orange brown. The ignimbrite is enveloped within a sequence of volcaniclastic sandstone that includes up to 4 white, coarse ash to lapilli ash-fall tuff beds mapped separately as the unit of Fort Rock (Tfr). Thickness: 0-40 m.

Tt2 — **Upper tuff and sandstone** - Volcaniclastic sandstone and conglomerate with a felsic ash-fall tuff bed up to 2 m thick. The tuff is coarse-grained ash to fine lapilli and biotite-rich. This unit occurs within the basaltic andesitic lava (Tba) map unit. Thickness: 0-5 m.

Tba — **Basaltic andesitic lava** - Mafic lava containing 5-15%, 2-8 mm plagioclase phenocrysts and 1-3%, 1-4 mm mafic phenocrysts (chiefly iddingsite after pyroxene and/or olivine). Thickness: 0-140 m.

Tt1 — **Lower tuff and sandstone** - Volcaniclastic sandstone and conglomerate with a coarse-grained ash to fine lapilli, biotite-rich ash-fall tuff bed up to 2 m thick. This unit occurs between the basaltic lava (Tb) and basaltic andesitic lava (Tba) map units. Thickness: 0-10 m.

Tb — **Basaltic lava** - Basaltic lavas containing 1-7%, 0.5-3 mm phenocrysts of iddingsite (after olivine). Lavas are generally < 10 m thick with sparse interbeds of red, scoriaceous volcaniclastic sandstone <2 m thick. Near the base of the sequence, several prominent sandstone and conglomerate sequences are present that are mapped separately (Tc). Basaltic lavas (Tb) locally contain several percent mafic xenoliths, but these are not ubiquitous, as they are in the xenolithic (Tbx) mafic lavas. Basaltic lavas (Tb) in the easterly adjacent Kingman map area underlie and overlie the xenolithic (Tbx) mafic lavas, but on this map definitive age relationships are not preserved. Thickness: 0-200 m.

Tbx — **Xenolithic mafic lava** - Mafic lava with 1-5%, <3 mm olivine, iddingsite, and/or pyroxene phenocrysts, with 0-5%, 2-15 mm xenoliths of two types: quartz-feldspar granitic aggregates, and medium-grained ultramafic rocks (chiefly dunite). <2% grains <3 mm of quartz and feldspar are probably xenocrysts. The type of xenoliths present are somewhat diagnostic of outcrop clusters that probably represent individual vent areas. Thickness: 0-100 m.

Tc — **Conglomerate and sandstone** - Conglomerate and sandstone containing clasts of granite, felsic porphyry, gneiss, and lesser mafic and intermediate lava. Thickness: 0-20 m.

**Cretaceous to Paleocene bedrock