# Geologic map of the Fort Thomas area, Graham County, Arizona

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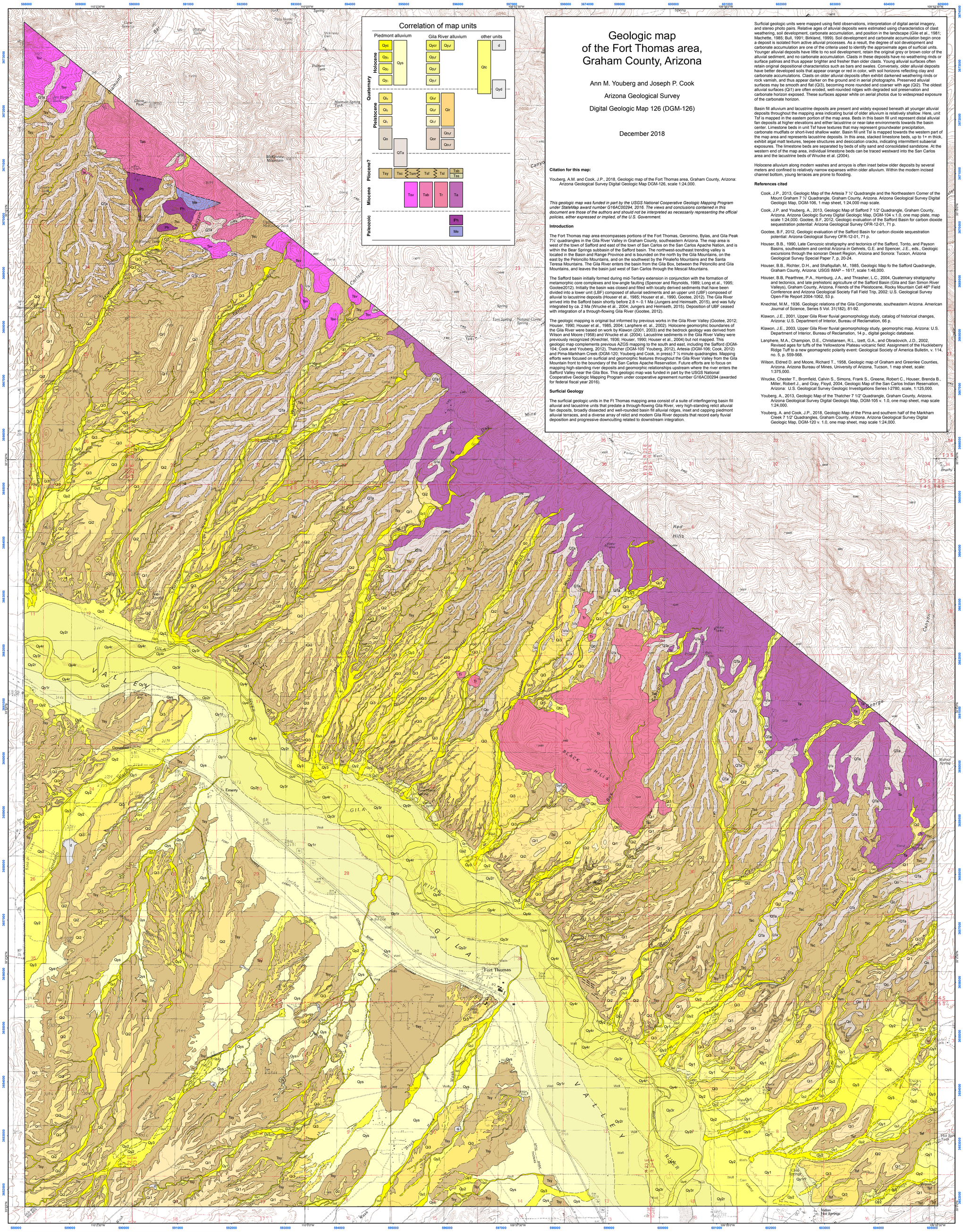


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## Introduction

The Fort Thomas map area encompasses portions of the Fort Thomas, Geronimo, Bylas, and Gila Peak 7½' quadrangles in the Gila River Valley in Graham County, southeastern Arizona. The map area is west of the town of Safford and east of the town of San Carlos on the San Carlos Apache Nation, and is within the Bear Springs subbasin of the Safford basin. The northwest-southeast trending valley is located in the Basin and Range Province and is bounded on the north by the Gila Mountains, on the east by the Pelloncillo Mountains, and on the southwest by the Pinaleño Mountains and the Santa Teresa Mountains. The Gila River enters the basin from the Gila Box, between the Pelloncillo and Gila Mountains, and leaves the basin just west of San Carlos through the Mescal Mountains.

The Safford basin initially formed during mid-Tertiary extension in conjunction with the formation of metamorphic core complexes and low-angle faulting (Spencer and Reynolds, 1989; Long et al., 1995; Gootee2012). Initially the basin was closed and filled with locally derived sediments that have been divided into a lower unit (LBF) composed of alluvial sediments and an upper unit (UBF) composed of alluvial to lacustrine deposits (Houser et al., 1985; Houser et al., 1990, Gootee, 2012). The Gila River arrived into the Safford basin shortly before 2.8 +- 0.1 Ma (Jungers and Heimsath, 2015), and was fully integrated by ca. 2 Ma (Wrucke et al., 2004; Jungers and Heimseth, 2015). Deposition of UBF ceased with integration of a through-flowing Gila River (Gootee, 2012).

The geologic mapping is original but informed by previous works in the Gila River Valley (Gootee, 2012; Houser, 1990; Houser et al., 1985, 2004; Lanphere et. al., 2002). Holocene geomorphic boundaries of the Gila River were based on work by Klawon (2001, 2003) and the bedrock geology was derived from Wilson and Moore (1958) and Wrucke et al. (2004). Lacustrine sediments in the Gila River Valley were previously recognized (Knechtel, 1936; Houser, 1990; Houser et al., 2004) but not mapped. This geologic map complements previous AZGS mapping to the south and east, including the Safford (DGM-104; Cook and Youberg, 2012), Thatcher (DGM-105 Youberg, 2012), Artesia (DGM-106; Cook, 2012) and Pima-Markham Creek (DGM-120; Youberg and Cook, in press) 7 ½ minute quadrangles. Mapping efforts were focused on surficial and geomorphic features throughout the Gila River Valley from the Gila Mountain front to the boundary of the San Carlos Apache Reservation. Future efforts are to focus on mapping high-standing river deposits and geomorphic relationships upstream where the river enters the Safford Valley near the Gila Box. This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under cooperative agreement number G16AC00294 (awarded for federal fiscal year 2016).

## Surficial Geology

The surficial geologic units in the Ft Thomas mapping area consist of a suite of interfingering basin fill alluvial and lacustrine units that predate a through-flowing Gila River, very high-standing relict alluvial fan deposits, broadly dissected and well-rounded basin fill alluvial ridges, inset and capping piedmont alluvial terraces, and a diverse array of relict and modern Gila River deposits that record early fluvial deposition and progressive downcutting related to downstream integration.

Surficial geologic units were mapped using field observations, interpretation of digital aerial imagery, and stereo photo pairs. Relative ages of alluvial deposits were estimated using characteristics of clast weathering, soil development, carbonate accumulation, and position in the landscape (Gile et al., 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, retain 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 on 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 (Qi1) are often eroded, well-rounded ridges with degraded soil preservation and carbonate horizon exposed. These surfaces appear white on aerial photos due to widespread exposure of the carbonate horizon.

Basin fill alluvium and lacustrine deposits are present and widely exposed beneath all younger alluvial deposits throughout the mapping area indicating burial of older alluvium is relatively shallow. Here, unit Tsf is mapped in the eastern portion of the map area. Beds in this basin fill unit represent distal alluvial fan deposits at higher elevations and either lacustrine or near-lake environments towards the basin center. Limestone beds in unit Tsf have textures that may represent groundwater precipitation, carbonate mudflats or short-lived shallow water. Basin fill unit Tsl is mapped towards the western part of the map area and represents lacustrine deposits. In this area, stacked limestone beds, up to 1+ m thick, exhibit algal matt textures, teepee structures and desiccation cracks, indicating intermittent subaerial exposures. The limestone beds are separated by beds of silty sand and consolidated sandstone. At the western end of the map area, individual limestone beds can be traced westward into the San Carlos area and the lacustrine beds of Wrucke et al. (2004).

Holocene alluvium along modern washes and arroyos is often inset below older deposits by several meters and confined to relatively narrow expanses within older alluvium. Within the modern incised channel bottom, young terraces are prone to flooding.

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## Map Unit Descriptions

### Gila River alluvium

**Qyf** — **Active river channel deposits** - Deposits are dominantly unconsolidated, very poorly sorted sandy to cobbly beds exhibiting bar and swale microtopography, but can range from fine silty beds to coarse gravelly bars in meandering reaches based on position within the channel. Clasts are lithologically diverse and typically well-rounded but may be angular to sub angular. Qycr deposits are typically unvegetated to lightly vegetated and exhibit no soil development. Qycr deposits are entrenched up to 4 m (13 ft) or more below adjacent early historical floodplain deposits depending on location, geomorphic relationship, and local channel conditions. Some of these deposits are submerged by the low-flow river channel, and remaining areas are submerged during higher seasonal or extreme flow events. These areas are subject to deep, high velocity flow and lateral bank erosion.

**Qyyf** — **Flood channel and low terrace deposits** - Deposits are found adjacent to active channels and form lightly vegetated in-channel bars, small planar fluvial terraces within 2 m (6 ft) of low-flow river channel elevation, and recent erosional meanders outside the presently active channel. Qyyr deposits are composed of poorly sorted unconsolidated sediment ranging from fine silt to cobbles and boulders depending on location in the channel at the time of deposition. Pebbles and cobbles are typically well-rounded to sub-rounded but may be sub-angular to angular. These surfaces are commonly inundated under moderate to extreme flow events and are subject to occasional deep, high velocity flow and lateral bank erosion. These deposits do not exhibit soil development but may exhibit light to moderate vegetation cover consisting of mesquite, desert broom, and grasses.

**Qyyf** — **Historical floodplain, bar and valley-floor deposits** - Terrace deposits occupy elevations from 2 - 3 m (6 - 10 ft) above Qycr or Qyyr deposits and are inset below the pre-incision historical floodplain. These surfaces are generally planar but locally exhibit bar and swale microtopography. Much of the Holocene Gila River floodplain in the Gila Valley has been utilized for agricultural purposes first by native peoples inhabiting the region and later by angio settlers in the late 1800s. As such, much of the Gila River historical floodplain has been disturbed since before the earliest aerial photographs in the 1930s. Qyyr deposit boundaries were delineated using modern and historical aerial photo stereo pairs and mapping by Klawon (2001, 2003). The outer margins of Qyyr deposits farthest from the modern Gila River channel correspond with the Pima soil boundary from Klawon's map. This boundary is thought to represent a limit of lateral channel migration by the Gila River for the past several hundred years (Klawon, 2001, 2003). Although minimal or no soil development is present, dense grasses, shrubs, cottonwood, and small mesquite trees abound. These deposits consist of poorly sorted silt, sand, pebbles and cobbles, but most commonly the deposits are capped with fine sand and silt. Exposures reveal trough crossbedding, ripple marks, and stacked gravel deposits. Pebbles and cobbles are well-rounded to sub-angular. These deposits are prone to inundation during floods, and undercutting and rapid erosion of Qyyr surfaces is possible during lower flow events.

**Qyyf** — **Latest Holocene to historical river terrace deposits** - Late Holocene floodplain and overbank deposits of the Gila River. Qyyr deposits are associated with broadly planar surfaces that locally retain the shape and extent of past river meanders. Qyyr surfaces are located up to 4 m (13 ft) above the modern Gila River channel (unit Qycr) and floodplain (unit Qyyr). Qyyr deposits are typically fine grained floodplain deposits with occasional pebbly to cobbly interbeds. Most Qyyr surfaces have been altered by long term agricultural use. Where undisturbed, mesquite bosque and tall grasses are present on these surfaces. The extent of Qyyr deposits throughout the map area was delineated using modern and historical aerial photo stereo pairs and mapping by Klawon (2001, 2003). The "Pima soil boundary" and "geomorphic limit" bracket Qyyr deposits. The geomorphic limit approximates a limit of surface modification by floods and lateral channel migration of the Gila River for at least the past 1,000 years (Klawon, 2001, 2003) These surfaces appear predominantly fine grained at the surface due in part to the input of organic matter and windblown dust deposition but are composed of interfingering coarse sandy to pebbly braided channel and fine sand to silty river floodplain deposits. Qyyr deposits are not subject to inundation by moderate river floods, but may be flood-prone during extreme floods. Qyyr deposits are also subject to catastrophic bank failure due to undercutting and lateral erosion during flow events where adjacent to Qycr or Qyf deposits. Distal piedmont fan deposits (unit Qy2) onlap onto Qyyr deposits although an interfingering relationship likely exits in the subsurface.

**Qyyf** — **Late to early Holocene river terrace deposits** - Deposits associated with slightly higher terraces that represent higher elements of older Holocene aggradation periods. These terraces appear predominantly fine-grained on the surface but often exhibit coarse gravelly to cobbly beds in the subsurface. Surface features have often been historically disturbed by agriculture and extensive portions of Qyr1r deposits in the Gila Valley are obscured by the towns of Safford, Thatcher, Pima, and Solomon. Qyr1r deposits are the most laterally extensive Holocene Gila River deposits in the valley, sometimes exceeding 3.2 km (2 miles) wide. Holocene fan onlap extends out onto Qyr deposits by as much as 2,000 m (6,560 ft) although an interfingering relationship likely exists in the subsurface. Qyr1r deposits are mapped outside the geomorphic limit of Klawon (2001, 2003). Soil development is moderate and surface color ranges from 10 to 7.5 YR 4/4 although some terraces appear more reddish due to local source lithologies and clasts derived from distal fan onlap. A light dusting (incipient stage I) of calcium carbonate accumulation is evident on the undersides of some buried clasts. Qyr1r surfaces stand up to 9 m (30 ft) above the active channel typically are 3 m (10 ft) higher than adjacent Qyyr surfaces.

**Qir** — **Buried Gila River deposits** - Qir deposits are exposed in bluffs of washes or in slopes below capping Quaternary deposits. Qir deposits are composed of well-rounded to subangular indurated pebble to cobble river gravels and fine-grained river deposits. Qir deposits are preserved below younger, onlapping Quaternary alluvial fan deposits near the valley center, and are typically pebble-cobble-boulder lag exposed on side slopes. Qir deposits are similar to older, higher-standing Gila River deposits but are lower in the landscape and record the downcutting of the Gila River into basin fill sediments.

**Qlyf** — **Low-intermediate Gila River terraces** - Qli3r deposits comprise Latest Pleistocene river terrace deposits along the Gila River. Qli3r deposits associated with the Gila River occupy lower elevations in the landscape than Qi2r deposits, from 20 - 30 m (65 - 100 ft) above the modern Gila River channel. Qli3r terraces are located up to 4 km (2.5 miles) outside the margins of the modern Gila River channel and are inset into older, higher-standing Gila River gravel-capped basin fill deposits. Lava Creek B ash deposits, which date to 0.64 Ma (Houser et al., 2002), were found interbedded within these deposits in the eastern area of the valley. Qli3r deposits consist of well-rounded to subangular pebbles to cobbles of diverse lithology with cross-bedded coarse sandy interbeds. Qli3r soils are moderately developed with orange to reddish brown (7.5YR) sandy loam to clay loam argillic horizons and stage II+ calcium carbonate accumulation. Qli3r terrace surfaces are planar, often capping basin fill deposits, and are lightly vegetated by creosote, cactus, and grasses.

**Qlyf** — **Intermediate-high Gila River terraces** - Middle to late Pleistocene river terrace deposits along the Gila River. Qli2r deposits associated with the Gila River are similar to Qli3r deposits in morphology and vegetation, but occupy higher positions in the landscape, up to 50 m (165 ft) above the modern Gila River channel. Terrace surfaces are extensive and planar to moderately rounded near edges. Clast composition is diverse. Well-rounded pebbles, cobbles, and boulders are abundant in cross section while the extensive planar cap is dominantly fine grained. Surface clasts on some well-preserved Qli2r deposits exhibit mild to moderate rock varnish and weak pavement formation. Vegetation on Qli2r deposits is dominated by creosote and includes ocotillo, bunch grasses, and mesquite. Qli2r soils are moderately well developed, reddened (5 YR), exhibit clay-rich argillic horizons, with obvious clay skins and subangular to angular blocky structure. Underlying soil carbonate development is typically stage I to IV, with abundant carbonate through at least 1 m (3.3 ft) of the soil profile. This carbonate cemented cap armors Qli2r and underlying Tsy deposits from erosion. Soil development is more evident in finer grained sections. A Qli2r terrace in the eastern portion of the valley was dated using burial cosmogenic dating techniques to 1.3 +/- 0.1 Ma (AZ32; Jungers and Heimsath, 2015). Qli2r surfaces are typically found as high-standing isolated mounds surrounded by distal fan alluvium or as elongate terraces inset into older river, fan, or basin fill alluvium. Locally, Qli2r deposits are subdivided into two members with similar morphology that occupy different positions in the landscape. Qli2r Gila River deposits are only preserved on the north side of the Gila River in the map area.

**Qor** — **Very high Gila River deposits, undivided** - Qor deposits represent the oldest, highest standing Gila River deposits in the map area. These deposits are located up to 140 m (460 ft) above the modern Gila River channel. Qor deposits are composed of well-rounded to subangular indurated pebble to cobble river gravels and fine-grained river deposits. Qor deposits are preserved below younger, onlapping Quaternary alluvial fan deposits near the mountain front, and are typically pebble-cobble-boulder lag exposed on side slopes. Where exposed in cross-section, Qor deposits are poorly sorted, exhibiting alternating sand and pebble dominated beds with coarse cobble to boulder interbeds.

**Qo2r** — **Very high Gila River deposits, younger member** - Qo2r deposits closely resemble Qo1r deposits in morphology but occupy slightly lower positions in the landscape; up to 15 m (50 ft) below Qo1r deposits.

**Qo1r** — **Very high Gila River deposits, older member** - Qo1r deposits closely resemble Qo2r deposits in morphology but occupy slightly higher positions in the landscape.

### Piedmont alluvium

**Qyc** — **Active stream channel deposits** - Qyc deposits are composed of unconsolidated, very poorly sorted sand to cobbles in lightly vegetated piedmont channels. Channels may be flat-bottomed or exhibit bar and swale microtopography with bars composed of coarser sediments. Qyc deposits are generally devoid of vegetation and exhibit no soil development although small shrubs and grasses may be found on slightly elevated in-channel bars. Qyc deposits are lined by cottonwood and oak in near mountain reaches and mesquite, acacia, creosote, and desert broom farther from the mountain front. 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 .25 - 1.5 m (1 - 5 ft) below adjacent Holocene alluvium and may be incised into adjacent Pleistocene alluvium by 2 m (6.5 ft) or more.

**Qys** — **Sheetflood deposits and swales, reworked basin fill deposits** - Laterally extensive, unconsolidated fine-grained alluvium in valley bottoms and mantling the lower parts of adjacent slopes on eroded basin fill (Tsy) deposits. These sediments are light brown to light tan to white in color and consist of sand, silt, clay, and gravel. Occasionally weakly channelized flow occurs but minor gradient changes or vegetation cause aggradation that leads again to sheetflow or infiltration. In valley bottoms, these deposits are primarily silt and sand beds with a small component of thin and discontinuous gravel beds. Weakly developed buried soils are common. On the toes of slopes, sandy to pebbly calcium carbonate aggregate nodules are common. Surface soil development is weak.

**Qy3** — **Low swales, tributary drainages, and weakly incised channels** - Piedmont alluvium located along active drainages including small channels, adjacent low terraces, or floodplain areas. Qy3 deposits are composed of unconsolidated, unvarnished sand, gravel, and silt deposits. Qy3 deposits may also exhibit significant cobble and boulder accumulations reworked from adjacent Qy2 and Qy1 terraces and splay deposits. Qy3 drainages are often wider, lower energy, and more heavily vegetated than the Qyc channels they drain into. In upper piedmont areas Qy3 includes active stream channels where Qyc cannot be broken out at the map scale. Soil development is generally absent or incipient on Qy3 deposits which exhibit pale brown to light brown (10 YR) surface coloration.

**Qy2** — **Broad drainages and piedmont terrace deposits** - Qy2 deposits consist of terrace deposits located primarily along the flanks of incised drainages and low-relief terraces inset into Pleistocene age fan deposits. Some Qy2 deposits comprise extensive low relief alluvial fans where unconfined by older piedmont alluvium. These deposits consist of predominantly fine grained unconsolidated to weakly consolidated sediments with sub-rounded to sub-angular pebble to cobble bars on the surface and beds and lenses in cross section. Where inset into older alluvium, Qy2 deposits are planar with remnant bar and swale microtopography. Planar Qy2 terraces are typically elevated from 30 cm - 1.5 m (1 - 5 ft) above active channels. Soil development on Qy2 deposits is minor, characterized by no to incipient stage I-II calcium carbonate accumulation in the form of small filaments and medium brown (10 YR) surface coloration. Vegetation on Qy2 surfaces consists of small shrubs, weeds, bunch grass, yucca, Mormon tea, prickly pear, desert broom, and the occasional cholla. 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.

**Qy1** — **High standing broad piedmont terraces** - Qy1 deposits consist of planar terraces along larger piedmont drainages that are 1 - 2 m (3 - 6 ft) higher in the landscape than adjacent Qy2 terraces and eroded, remnant alluvial fan deposits on lower piedmont areas. Qy1 deposits are composed of sandy to pebbly swales with coarser unvarnished to very lightly varnished pebble to cobble bars, and partially overlie Pleistocene deposits in some areas. Near the mountain front, bar and swale microtopography is somewhat muted by generations of vegetation mounding. Pebbles and cobbles exposed in cross section exhibit stage I-II calcium carbonate accumulation within a medium brown matrix of fine sand to silt. Some reddened clay rich aggregate and calcium carbonate coated clast inclusions have been reworked from older deposits. Qy1 surfaces are generally isolated from flooding associated with the modern drainage system although inundation may be possible during extreme precipitation and runoff events. Vegetation on Qy1 deposits is similar to that found on Qy2 deposits with the addition of creosote, whitethorn and catclaw acacia.

**Qlb** — **Low-intermediate terraces and alluvial fan deposits** - Broadly planar terrace and fan deposits elevated up to 3 m (10 ft) above adjacent Holocene (Qyc, Qy3, Qy2, and Qy1) deposits. Surface soil on Qi3 deposits is mildly reddened (7.5 YR 5/4). Cobbles and boulders dominate Qi3 deposits in cross section where exposed by incised channels or roadcuts. Qi3 deposits consist mostly of locally derived clasts but may also include reworked Gila River clasts, especially towards the valley center. On broad planar Qi3 surfaces farther from the mountain front surface soil is composed of sand, silt, and small pebbles with partially buried cobbles to boulders creating remnant bar and swale microtopography. Some Qi3 deposits appear to overlie highly eroded basin fill deposits (units Tsy, Tsc, Tsf and Tsp) and are likely less than a few meters thick. Vegetation on Qi3 deposits is dominated by creosote but includes prickly pear, barrel, and cholla cactus; bunch grasses, small shrubs, whitethorn and catclaw acacia, mesquite, agave, yucca, and mormon tea.

**Qlb** — **Intermediate-high terrace and remnant alluvial fan deposits** - Broadly planar to moderately rounded cobble to boulder dominated terrace and fan deposits capping underlying basin fill deposits (units Tsy, Tsc, and Tsf). Qi2 deposits consist mostly of locally derived clasts but may also include reworked Gila River clasts, especially towards the valley center. Qi2 deposits are elevated up to 45 m (150 ft) above Holocene piedmont deposits near the mountain front and 12 m (40 ft) farther out in the valley. Qi2 deposits are broadly planar to gently rounded caps that exhibit clay rich reddened (2.5 - 5 YR 4/6) soils with calcium carbonate clasts and matrix between clasts (Stage III) where exposed in cross section. In some areas where the contact between Qi2 and underlying Tsy deposits is exposed, an erosional unconformity is evident. Vegetation on Qi2 deposits is similar to that found on Qi3 deposits although creosote is less abundant and more widely spaced. Vegetation includes prickly pear, barrel, and cholla cactus; bunch grasses, small shrubs, whitethorn and catclaw acacia, mesquite, agave, yucca, mormon tea, and ocotillo near carbonate-rich eroded edges.

**Qli** — **High standing relict alluvial fan remnants** - Qi1 deposits are relict alluvial fan remnants overlying Tsy basin filling sediments or bedrock that stand higher in the landscape than Qi2 and younger deposits. Qi1 surfaces are planar to well-rounded near eroded edges. Where extensively preserved, Qi1 deposits exhibit deeply incised mature tributary drainage networks and clay rich, reddened (2.5 - 5YR 3/6) soils. Qi1 deposits commonly cap and preserve underlying finer grained Tsy deposits. Coarse cobble to boulder lag derived from erosion of the Qi1 cap also covers the flanks of underlying Tsy deposits, shielding them from erosion. Qi1 deposits consist mostly of locally derived clasts but may also include reworked Gila River clasts, especially towards the valley center. Vegetation on Qi1 deposits consists of mesquite, grasses, small shrubs, prickly pear, barrel, creosote, agave, ocotillo, and oak near incised drainages.

**Qo** — **Alluvial Fan Deposits** - Early Pleistocene alluvial fan deposits. These deposits are the highest preserved fan surfaces in the Safford basin. Remnant Qo surface vary from planar with well rounded, eroded edges to smaller remnant surfaces of rounded ridges. Qo surfaces cap coarser old alluvial fan deposits near the mountain front (units QTa and Tcs), and finer-grained basin fill deposits (Tsf) towards the valley center. Where preserved, Qo deposits exhibit deeply incised mature tributary drainage networks and clay rich, reddened (2.5 YR 3/6) soils and coarse cobble to boulder lag derived from erosion of the Qo cap. Vegetation on Qo deposits consists of mesquite, grasses, small shrubs, prickly pear, barrel, creosote, and agave.

**QTa** — **Fanglomerate** - Very coarse, clast-supported, moderately to strongly consolidated fanglomerate composed of carbonate-cemented pebble-cobble-boulder alluvial fan deposits. This unit is found immediately adjacent to the mountain front and typically overlies pink volcanic breccia or older, finer-grained conglomerate. This unit forms high, rounded ridges, typically with no preserved alluvial surfaces or limited Qo surfaces.

### Basin fill alluvium

**Tsy** — **Basin Fill Deposits, undivided** - Weakly to moderately consolidated silt, clay, sand, and gravel deposited in basins during and after late Cenozoic faulting. Tsy deposits are generally light to medium brown to tan (7.5 YR 6/4) in color. They commonly form high rounded hills and ridges in modern basins, and locally form prominent bluffs when overlain by more consolidated, erosion resistant Quaternary deposits. Where uncapped, these deposits form gently rolling, low relief hills throughout the map area, broadly dissected by tributary drainage networks. Exposures are found along major drainages and are divided into three general facies where exposures permit. Unit Tcs is found nearer the mountain front and represents local alluvial fan deposits interbedded and interfingered with finer-grained distal fan deposits (unit Tsf; 111 Ranch Beds; Houser, 1990). Where possible, the interfingering relationship of these two units are mapped as Tsm, interbedded margin sediments. Towards the valley center, unit Tsf is the dominant basin fill deposit. South of the Gila River, to the east of this map area, are exposures of near-lake and lacustrine deposits that are correlative to the Bear Springs Wash beds (Houser, 1990). In this map area, however, the general Tsy unit is used as underlying basin fill deposits are covered by colluvium. The 111 Ranch and Bear Springs Wash beds record a time when the Safford Basin was closed and Tertiary Lake Graham existed. Houser (1990) suggested that these basin fill deposits may be as young as late Pleistocene, however a clear erosional contact is evident between the basin fill units (Tsy, Tsc, Tsf, Tsm) and overlying, coarser Quaternary units (Qo, Qi1, Qi2, Qi3) suggesting that these basin fill deposits are Pliocene. Vegetation on basin fill deposits ranges from bunch grass ground cover, small shrubs, acacia, desert broom, and mesquite in lowlands to yucca, prickly pear, barrel, larger mesquite, oak, and agave on high standing Tsy deposits.

**Tsc** — **Basin Fill Deposits, coarse-grained** - Exposures of coarser sand-pebble-cobble alluvial fan deposits near the mountain front. This unit includes beds of dark gray sandy pebble alluvial fan conglomerate with varying amounts of carbonate in the form of nodules and root casts, and paleosols. Tsc grades into unit Tsf in some places and interfingers with Tsf in other areas. The observable interfingering relationship is mapped as Tsm.

**Tsm** — **Basin Fill Deposits, interbedded margin sediments** - Interbedded basin margin deposits composed of dark gray sandy pebble alluvial fan conglomerate (unit Tsc) and tan sand to silty sand unconsolidated beds and consolidated flaggy consolidated sandstone beds of distal fans (unit Tsf). Where Tsm is mapped, the interfingering relationship between Tsc and Tsf is observable.

**Tsf** — **Basin Fill Deposits, fine-grained** - This unit represents distal fan and basin center deposits, and is correlative to the 111 Ranch beds described by Houser (1990). Unit Tsf is composed of finer-grained basin-fill deposits of interbedded sand, silt, mud, clay and limestone with sequences that often repeat. Beds in these deposits include tan, massive (5-50 cm) to thinly bedded (< 1-5 cm) to laminar, well-sorted fine sand and very fine sand; tan lenticular and cross-bedded sandstone, brown massive silt to silty clay (5-50 cm) that breaks into blocks; tan sand to silty sand unconsolidated beds and consolidated flaggy consolidated sandstone beds; reddish tan clay and mud over thinly bedded (2-10 cm) limestone beds, minor, thin limestone beds and stringers, and tephra beds. Limestone beds in this unit are variable and may include groundwater precipitates, carbonate mudflats and/or short-lived shallow water precipitates. Unit Tsf represents distal alluvial fan environments towards the mountain front that grades into basin-center lacustrine or near-lake environments. Unit Tsf interfingers with unit Tsc toward the mountain front and grades into unit Tsl towards the west where the evidence of a lake is much stronger.

**Tsl** — **Basin Fill Deposits, lacustrine** - Interbedded tan, fine-grained silty sand to consolidated flaggy sandstone beds, limestone beds and, occasionally, tephra. Unit Tsl is found towards the western part of the map area. Here, limestone beds are thicker (up to ~ 1+ m) with thicknesses increasing towards the west and exhibit algal matt textures, teepee structures and desiccation cracks, indicating intermittent subaerial exposures. The limestone beds are separated by beds of silty sand and consolidated sandstone. At the western end of the map area, individual limestone beds can be traced westward into the San Carlos area and the lacustrine beds of Wrucke et al. (2004).

**Tsb** — **Basin Fill Deposits, rounded local clasts** - Rounded local pebble to cobble clasts within or near the top of the fine-grained lacustrine basin fill sediments. These deposits could be channel bar deposits or possibly beach deposits.

**Tss** — **Spring deposits within the Basin Fill** - Localized limestone spring deposits within basin fill deposits, typically units Tsf or Tsl.

### Bedrock

**Tsv** — **Silicieous volcanic rocks** - Light-gray to pale-pinkish-gray rhyolite flows and flow breccias exposed northwest of Ash Flat. Modified from Wrucke et al., 2004.

**Tab** — **Andesite and basalt** - Principally flows of andesitic rock, probably mostly trachyandesite with local interlayers of siltstone, sandstone, and conglomerate containing clasts of basalt scoria and pumice lapilli. Only higher parts of unit exposed. Maximum exposed thickness 300 m. Modified from Wrucke et al., 2004.

**Tr** — **Rhyolite** - Includes tuff and agglomerate. Modified from Wilson and Moore, 1958.

**Ta** — **Andesite** - Includes tuff and agglomerate. Modified from Wilson and Moore, 1958.

**Ph** — **Horquilla Limestone** - Gray, thin- to thick-bedded limestone, cherty limestone, dolomitic limestone, and minor dolomite. Thickness 270-500 m, commonly 300-360 m. Modified from Wrucke et al., 2004.

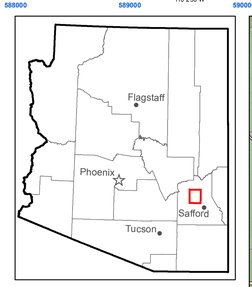
**Me** — **Escabrosa Limestone** - Light-gray to light-yellowish-gray cliff-forming limestone. Mostly thick bedded. Contains abundant fossil debris and nodular to bedded chert; locally oolitic. Locally has fractures filled with red siltstone and zones of limestone breccia with red siltstone matrix. Thickness 58-90 m. Modified from Wrucke et al., 2004.

### Other units

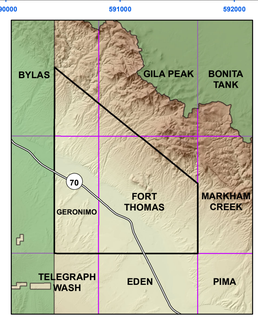
**d** — **Disturbed ground** - Heavily disturbed or altered ground due to extensive excavation, construction of earth dams, and municipal development.

**Qtc** — **Talus and colluvium** - Unconsolidated talus and colluvium on moderate to steep slopes. Very poorly sorted, angular to subangular gravel clasts.

**Qyd** — **Debris-flow deposits and chutes** - Bouldery debris-flow levees and snouts, and erosional scars associated with debris flow activity higher on hillslopes.




Location of map area




- San Carlos Apache Reservation

SCALE 1:24,000

1 0.5 0 1 Miles

0.9 0.45 0 0.9 Kilometers

0 1000 2000 3000 4000 5000 Feet

CONTOUR INTERVAL 20 FEET

TRUE NORTH
MAGNETIC NORTH
9.6°
Approximate mean declination, 2017

Topographic base map derived from the Fort Thomas, Geronimo, Bylas, and Gila Peak 7.5' USGS topographic quadrangle maps originally with NAD27 datum. Reprojected to UTM NAD83 datum (zone 12) using iGage All Topo Maps V9. UTM NAD 83 grid and lat-lon markers produced using ESRI ArcMap v. 10.4.

### Contacts and faults

- Contact, accurate
- Contact, approximate
- Gradational contact, accurate
- Gradational contact, approximate
- Gradational contact, queried
- Fault, accurate
- Fault, approximate
- Fault, concealed

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