Mapping of River Alluvium Along the Verde River and Major Tributaries, Central Arizona

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Abstract

In 2010, the Arizona Geological Survey (AZGS) released a series of 1:24,000-scale geologic strip maps showing the extent of Holocene channel and floodplain deposits along the Verde River and five large tributaries in central Arizona. The primary purpose of this mapping was to contribute to the legal differentiation of river subflow from groundwater in surrounding areas, as Arizona courts have established the lateral extent of Holocene river alluvium as a key component in delineating subflow zones. These maps also define the physical architecture and geomorphic framework of the river systems, depicting river and tributary deposits of Holocene to late Pliocene age, Pliocene and older basin filling deposits, and various bedrock units. We employed standard geomorphic and geologic criteria to differentiate and map river and tributary alluvial deposits of different ages. The degree of clast rounding, lithologic diversity, and landform/terrace slope were used to differentiate river from piedmont alluvium.

The through-flowing Verde River developed several million years ago, linking several closed or partially integrated basins. When the Verde River became integrated, it began to downcut along its entire course, and this in turn drove deep incision along all of its major tributaries. The maximum amount of incision has probably occurred along the middle Verde River in Verde Valley, where the river has incised at least 300 m below the former valley floor since the late Pliocene. High standing relict terrace deposits all along the Verde River record former river levels through the Pleistocene. Because the Verde River and its tributaries have incised deeply into both bedrock and less-resistant sedimentary basins, the lateral extent of Holocene river alluvium varies dramatically from less than 30 m to over 1 km across. Within this corridor, we mapped up to 6 Holocene units, including active channels, bedrock-lined active channels, flood channels, and several levels of terraces. The extent of active channels, flood channels and low bars change with virtually every large flood. Young terraces are more stable, and typically are subject to shallow inundation in floods. Dates from archaeological sites and paleoflood studies suggest that nearly all of the Holocene deposits along the river are less than 4 ka.

AZGS River Mapping
11/2008 - 06/2010

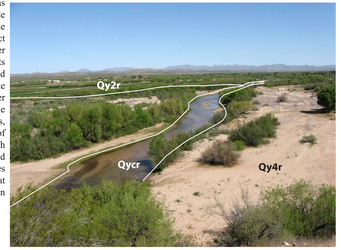
Introduction

Geologic mapping is a primary function of the AZGS, so in cooperation with Arizona Department of Water Resources (ADWR) staff we have established procedures and protocols for documenting and mapping the extent of Holocene floodplain alluvium along rivers in Arizona. These practices were first conducted along the entire length of the San Pedro River, Babocomari River, and Aravaipa Creek (AZGS DM-RM-1). More recent mapping efforts have resulted in new and updated surficial geologic mapping covering over 370 river miles depicted in 2-mile-wide strip maps centered on the Verde River and each major tributary. The maps and reports (AZGS DM-RM-2, DM-RM-3) describe river and tributary deposits of Holocene to late Pliocene age, Pliocene and older basin filling deposits, and various bedrock units along the river at a scale of 1:24,000. Several existing AZGS 7 ½' quadrangle geologic maps in the Verde Valley were updated and re-released based on this new mapping as well as the availability of higher resolution aerial imagery. The strip maps provide basic information on the geology of the river corridors that may be used in future water rights adjudications and define the physical setting of the river systems.

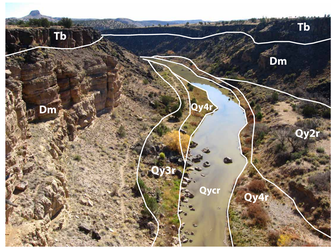
Methods

Mapping strategy:

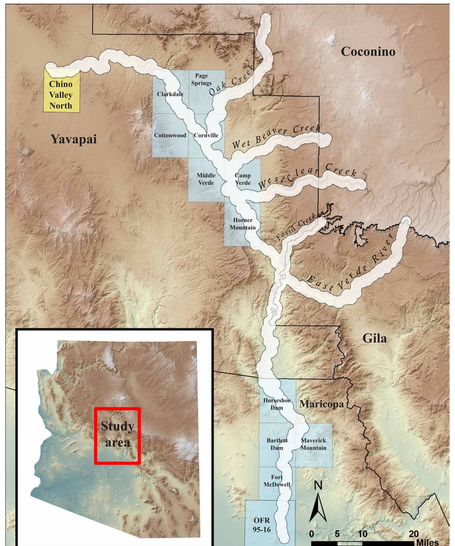
- Compilation of existing geologic mapping in an ArcGIS framework
- Re-evaluation and revision of existing mapping using aerial photos and topographic data
- New mapping of Holocene river alluvium where no large-scale geologic mapping had been conducted previously
- Field-checking of the boundaries of Holocene alluvium in various geologic environments along the river, including systematic collection of GPS field points with observations and ground photos
- Depiction of all Holocene river alluvium units on 1:24,000-scale strip maps associated with this report



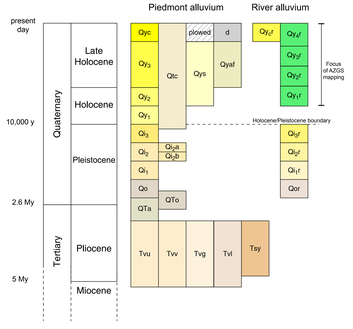
Distribution of Holocene river alluvium in an unconfined reach in the Fort McDowell Yavapai Nation. Flood channel (Qy4r) terraces are extensive and lightly vegetated. Qy2r terraces are often obscured by agricultural use. Holocene river alluvium is bound by onlapping alluvial deposits and eroded basin fill deposits.



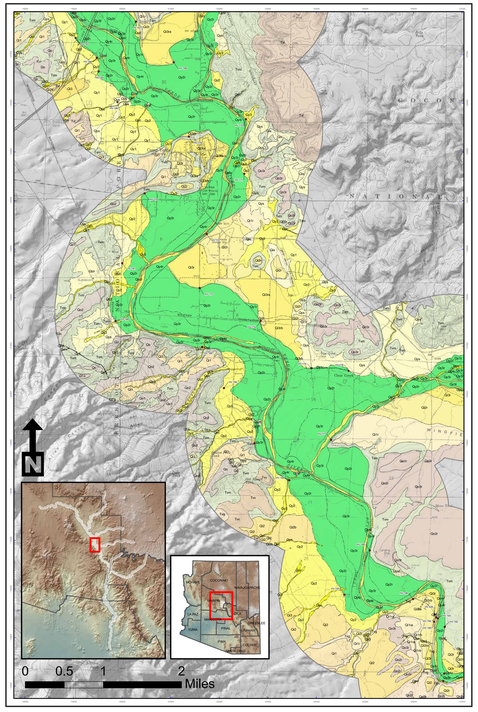
Distribution of Holocene river alluvium in narrow bedrock canyon reach in the upper Verde River near Paulden, AZ. All preserved Holocene river terraces are narrow and bound by tall bedrock walls and onlapping colluvium.



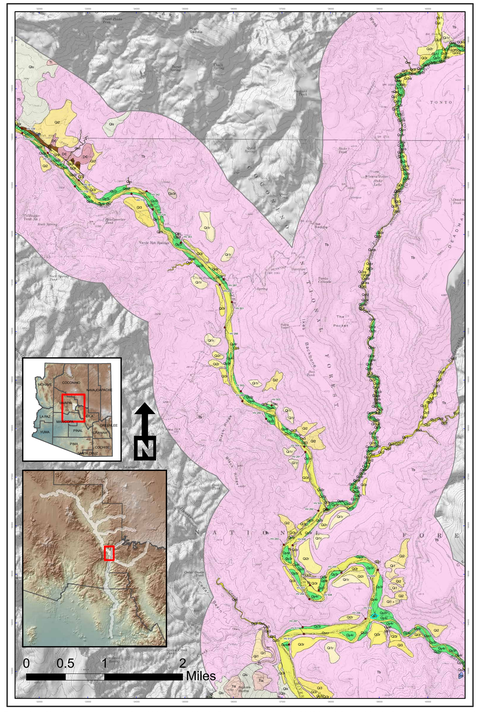
Footprint of two mile wide map corridor centered on Verde River and mapped tributaries (AZGS DM-RM-2, and 3). Blue boxes represent previous AZGS mapping, the yellow box represents concurrent AZGS mapping. Compilation of existing USGS bedrock mapping outside AZGS mapped areas was also conducted.



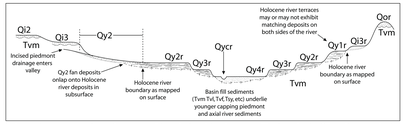
Correlation diagram for surficial mapping units in the mapping area. Various bedrock units compiled from existing maps not shown.



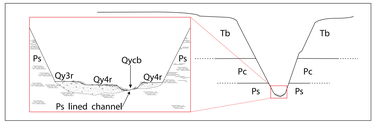
Example of laterally extensive Holocene Verde River deposits in the Verde Valley, central Arizona. The Verde River incising into the relatively erodible Verde Formation (lacustrine, mudstone, limestone, gypsum, and diatomite deposits) has resulted in widespread Holocene deposit preservation. The active channel represents only a small part of the river system with much wider flood channel deposits and extensively preserved young terraces. Tributary deposits grade to similarly aged river terraces and in some places cover them. Lateral topographic constraints are composed of older river deposits, eroded basin fill deposits, or onlapping tributary alluvium.



Example of bedrock canyon confined Holocene Verde River deposits in the Wild and Scenic Verde River, downstream of the Verde Valley. Here the active and flood channel make up much of the canyon bottom. Preserved river deposits are more susceptible to inundation, undercutting, and erosion than in unconfined reaches. High standing Pleistocene Verde River deposits are perched atop bedrock cliffs well above the modern channel. Here. tributaries to the Verde are also incised into bedrock and exhibit narrow, confined channel bottoms and preserved Holocene river terraces.



Schematic cross section of geomorphic relationships between Tertiary basin fill sediments (units Tvm, Tvl, Tsy), Pleistocene piedmont and river deposits (units Qi_y, Qi_r, Qo_r), and Holocene piedmont and river deposits (units Qy_y and Qy_r).



Schematic cross section of geomorphic relationships in narrow bedrock canyon sections. Deposits are bound by steep bedrock walls, terraces are generally thin, channel sediments are coarse, and bedrock may be exposed locally in the channel bottom. Subsurface relations are not well constrained and likely vary along the river course.

Active channels - Qycr
- Unconsolidated sand to cobbles
- Pool and riffle sequences
- Lined by riparian trees and vegetation
- Commonly submerged

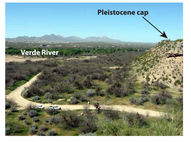
Flood channels - Qy4r
- Adjacent to Qycr deposits
- Inundated under higher flow (seasonal or flood)
- No soil development
- Unvegetated to lightly vegetated
- Often show signs of recent flooding

Floodplain / low terraces - Qy3r
- Higher than Qy4r surfaces
- Only inundated during more extreme flow
- Riparian trees and grasses
- Former floodplain and river meanders
- Mild soil development

Young river terraces - Qy2r
- Higher in landscape than Qy3r terraces
- Generally fine grained with gravel lenses
- Some soil development, minor soil carbonate accumulation
- Typically are presently or were historically plowed and irrigated; many now developed
- Usually most laterally extensive terrace

Older river terraces - Qy1r
- Higher in landscape than Qy2r terraces
- Fine grained with gravel to cobble lenses
- Better soil development, minor soil carbonate accumulation
- May have different vegetation populations than Qy2r terraces

Pleistocene river terraces - Qi1r, Qi2r, Qi3r
- Clay rich, reddened soil horizons
- Obvious $CaCO_3$ accumulation
- Planar to moderately rounded
- Stand high in the landscape relative to the modern river



A Pleistocene Verde River deposit capping basin filling sediments near the Verde/Salt confluence stands 165 feet above the modern channel.

New surficial mapping of Holocene river alluvium was conducted along the entire length of each channel and combined with a compilation of existing AZGS and USGS geologic mapping. Boundaries of Holocene river alluvium were verified through extensive field work and map analysis. We collected GPS control points, digital photos, and made field observations at the lateral margins of Holocene river alluvium at approximately 1 mile intervals along each side of the river. We used standard geologic nomenclature (solid, dashed and dotted lines) to depict the positional uncertainty of the lateral limits of Holocene river alluvium.

Where they exist and have been investigated, archaeological sites, paleontological remains, and other dated organic material provide direct numerical age estimates for Holocene and latest Pleistocene deposits. We reviewed the records of these investigations and visited several of the sites in the field. Dated archaeological material buried in terrace fills provide a maximum age for the overlying deposits and geomorphic surface, whereas dated archaeological material on a terrace tread surface provide a minimum age for the underlying deposits.

Summary

Through the course of developing and implementing repeatable standards for mapping the extent of Holocene alluvium for ADWR the entire length of the Verde River has been mapped consistently. The depiction of boundary uncertainties has been uniformly applied over the course of the Verde River and 5 major tributaries. The width of Holocene river alluvium varies dramatically with the geologic and geomorphic setting. Comparing our recent mapping with pre-existing maps covering the same area in Verde Valley showed agreement in the extent of Holocene Verde River alluvium in most areas but changed the lateral extent in others. We attribute these differences to substantially better available aerial imagery, mapping in a GIS environment, and the use of field-collected GPS control points.

River vs. tributary deposits

Factor	River	Tributary/piedmont
Gravel character	Diverse lithology, many well rounded	Limited lithologic mix, subangular to angular
Overbank (terrace) deposits	Thick, generally fine sand, silt, and clay with minor fine gravel layers, weakly developed buried soils	Generally thinner, poorly sorted fine gravel to silt
Landform slope	Low gradient, subparallel to river channel	Higher gradient, slopes toward river

Holocene vs. older deposits

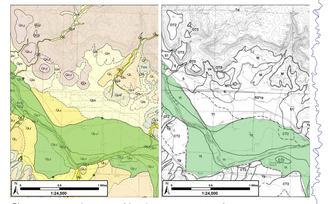
Factor	Holocene	Pleistocene
Surface character	Brown to gray, minimal or no rock varnish	Brown to reddish brown, reddish or brown rock varnish
Soil development	Weak to moderate cambic horizons, slight calcium carbonate accumulation	Moderate to strong, clay argillic horizons, obvious calcic carbonate
Vegetation	Hydro- or meso-riparian	Desert scrub
Height above river channel	0 to 30 feet	50 to 700 feet
Terrace/landform shape	Planar, sharp vertical walls where undercut/incised	Planar to broadly crowned on top, rounded to well rounded near edges

Although our mapping consistently depicts surface relationships it does not address potential subsurface complexities such as burial of distal Holocene river alluvium by onlapping tributary or piedmont deposits. Thickness of Holocene river alluvium likely varies depending on width of the river corridor but generally we think Holocene river deposits are thin. River deposits alternately overlie basin filling sediments and bedrock. The underlying unit may be exposed in narrow canyon reaches. These strip maps provide a fairly detailed description of the physical characteristics of riparian corridors in Arizona.

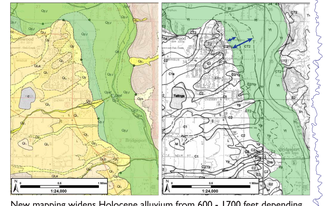
AZGS mapping of the Holocene river alluvium is an important component of subflow delineation but is not the same as subflow delineation as determined by ADWR. Previous AZGS mapping along the San Pedro River in southern Arizona has been used to delineate subflow zones and is currently under adjudication. Whether AZGS mapping along the Verde River will be used in future adjudications pertaining to water rights in central Arizona is yet to be determined.

Acknowledgments

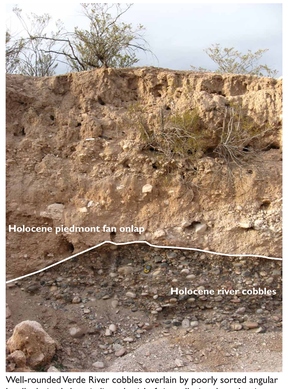
Funding for this project was provided by the Arizona Department of Water Resources. Access along the Wild and Scenic portion of the Verde River was made possible by rangers with the Coconino National Forest.



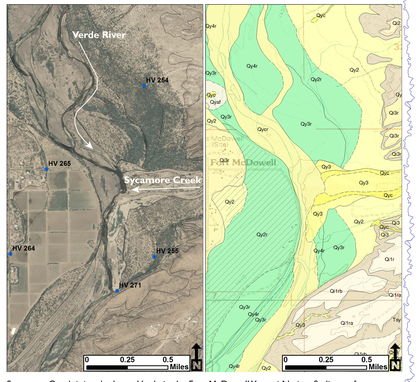
Close agreement between old and new mapping results in very minor changes in lateral extent of Holocene alluvium.



New mapping widens Holocene alluvium from 600 - 1700 feet depending on interpretation of unit CT2 (AZGS OFR 93-16)



Well-rounded Verde River cobbles overlain by poorly sorted angular locally derived clasts indicate burial of river alluvium by onlapping piedmont deposits. The lateral extent of the river deposit beneath the fan deposit is unknown.



Sycamore Creek joins the lower Verde in the Fort McDowell Yavapai Nation. Sediment from Sycamore Creek and nearby fans overlie distal Verde River Holocene alluvium. Although a likely maximum lateral extent of Holocene river alluvim could be assigned near the base of bounding basin fill hills, our maps depict surface relationships only.