Introduction

The area covered by this geologic map includes all of the Wintersburg 7 ½' quadrangle and parts of the adjacent Arlington, Gillespie and Tonopah quadrangles surrounding the Palo Verde Nuclear Generating Station (PVNGS). The map area is located 70-90 km (40 to 55 miles) west of downtown Phoenix. The map area covers the piedmont between the Palo Verde Hills and the Hassayampa River and a 11 km (7 mile) reach of the Hassayampa River. The quadrangle includes the PVNGS, Interstate Highway 10, and numerous Maricopa County roads. It has experienced some suburban development associated with the PVNGS and is currently on the outer fringe of the greater Phoenix metropolitan area, and more development is likely in the future. The small bedrock hills in the southwestern quarter of the quadrangle were mapped by Ferguson in the spring of 2005. Surficial deposits that cover most of the quadrangle were mapped by Pearthree using color aerial photos from 1979, high resolution digital color orthophotos provided by the Flood Control District of Maricopa County, National Agricultural Inventory Program (NAIP) photos from 2010 and 2013, and topographic information from U.S. Geological Survey maps and Google Earth. Field checking was done in the spring, summer and fall of 2005, with additional fieldwork in the fall of 2013 and the winter and spring of 2014. The mapping in 2005 was done in conjunction with geologic mapping of the Flatiron Mountain 7 ½' quadrangle (Spencer et al, 2005) to the north, and this map is one of eight 1:24,000 scale geologic maps covering most of the Hassayampa Valley that were produced in 2004 - 2006. This mapping was completed under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992. Additional mapping completed in 2014 was done in cooperation with Lettis Consultants International (LCI) as part of an investigation of seismic hazards for the PVNGS. Funding for this mapping was provided by Arizona Public Service.

Surficial Geology

The map area is predominantly covered with surficial deposits laid down by the Hassayampa River and numerous smaller tributary stream systems. These surficial deposits were mapped primarily using stereo pairs of color aerial photos taken in 1979 for the Bureau of Land Management, high-resolution digital orthophotos from the FDCMC and the NAIP, and topographic information obtained from the 7 ½' U. S. Geological Survey quadrangle maps. Mapping interpretations were verified by field observations during the spring, summer and fall of 2005; additional field observations were made in 2013-14. Unit characteristics were described and unit boundaries were spot-checked in the field. The physical characteristics of Quaternary alluvial surfaces (channels, alluvial fans, floodplains, stream terraces) evident on aerial photographs and in the field were used to differentiate their associated deposits by age and source. This mapping was compiled over NAIP digital orthophoto bases. Mapping was done in a GIS format and the final linework was generated from the digital data.

Several characteristics evident on aerial photographs and on the ground were used to differentiate various alluvial surfaces and deposits associated with them by age and source. The color of alluvial surfaces is primarily controlled by soil color, desert pavement development and rock varnish, and vegetation type and density. Significant soil development begins beneath an alluvial surface after it becomes isolated from active flooding and deposition (Gile et al., 1981, Birkeland, 1999). Holocene soils typically have relatively subtle horizons and generally are brown or gray in the field and on aerial photographs. More distinct, relatively obvious soil horizons develop over thousands to tens of thousands of years. Typical soil horizons in Pleistocene alluvial sediments of Arizona are reddish brown argillic horizons (zones of clay accumulation) and white calcic horizons (zones of calcium carbonate and silica accumulation). In arid areas such as the lower Hassayampa Valley, clay accumulation and reddening associated with argillic horizon development tend to be relatively weak even on old alluvial surfaces. On color aerial photographs and on the ground, older alluvial surfaces characteristically appear slightly redder or distinctly whiter (on more eroded surfaces) than younger surfaces. Dark rock varnish and gravel pavements also develop with time on stable alluvial surfaces, so well-preserved older surfaces typically have a dark brown color. Differences in the drainage patterns between surfaces also provide clues to surface age. Young alluvial surfaces commonly display distributary (branching downstream) or anastomosing (branching and rejoining) channel patterns. Areas adjacent to active channels commonly have little channel development because unconfined shallow flooding predominates. Dendritic tributary (joining downstream) drainage patterns are characteristic where modern drainages are incised into older surfaces. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereopaired aerial photographs, Google Earth, and topographic maps. Young surfaces are minimally dissected and are less than 1 m above channel bottoms. Active channels are entrenched 1 to 5 m below Pleistocene alluvial surfaces, and the older surfaces typically have been moderately to extensively rounded by erosion. Ages of various surficial deposits of the map area were roughly estimated based on regional correlations to similar surficial deposits in southern Arizona.

Variations in the distribution of surfaces of different ages and sources and concomitant variations in dissection across the quadrangle provide evidence regarding the recent geologic evolution of this area. Generally, areas adjacent to the Hassayampa River are moderately to deeply dissected. The highest terrace remnants of the Hassayampa River (unit Qor) record the level of the river bed in the early to middle Quaternary. Qor terraces rest atop a several hundred-meter-thick aggradational sequence that was deposited during Pliocene to early Quaternary (Shoustra et al., 1976). Tributary washes in adjacent piedmont areas to the west and north were aggrading in the late Pliocene and early Quaternary as well (unit QTs). At that time the river was probably was depositing sediment across a fairly broad floodplain in the eastern part of the map area, and distal alluvial fans on both sides of the river were interfingering with the river floodplain. Since then the Hassayampa River has downcut 10 to 15 m, with incision increasing slightly to the north. Preservation of Pleistocene river terraces recording intermediate levels of the Hassayampa River is poor. The valley bottom along the Hassayampa River consists almost entirely of modern channel deposits (unit Qycr) and late Holocene floodplain deposits (Qy2r). Tributary washes immediately west and east of the Hassayampa River have downcut in response to incision of the river, and late Quaternary deposits are quite limited in extent along these drainages.

In the western 90% of the map area, piedmont washes drain to the south to the Gila River or Centennial Wash, a sizable tributary of the Gila River. Much of this piedmont is mantled by Pleistocene tributary deposits (units Qi1, Qi2, or Qi3). Older Pleistocene deposits (Qi1) have been eroded into broadly rounded. The relatively small tributary washes that drain this area are incised a few meters or less below adjacent Pleistocene alluvial surfaces. Even though the amount of net incision is modest, there is enough topographic confinement of active fluvial systems that late Pleistocene deposits typically are found on the fringes of the eroded middle Pleistocene ridges, and Holocene deposits are found on valley bottoms. Agricultural activity, more recent residential development, aggregate pits and the PVNGS have modified the landscape to greater or lesser degrees. Areas are mapped as “disturbed” where the surficial deposits are profoundly altered (gravel pits, nuclear plant, interstate highway); surficial deposits other areas with less profound disturbance are depicted as more general units with approximate contacts.

Geologic Hazards and Aggregate Resources

The geomorphology and surficial geology of the map area provide important information regarding the extent and character of flood hazards and the availability of aggregate resources. Geologically young fluvial deposits (units Qyc, Qy2, and locally Qy1 along tributary washes and units Qycr, Qy2r along the Hassayampa River) record recent fluvial activity. The Hassayampa River is incised and flooding is restricted to the valley bottom. The fact that the valley bottom is covered almost entirely by late Holocene deposits strongly suggests that the valley bottom is the floodplain, and all portions of it have been subjected to recent inundation and deposition. Flooding is restricted to the valley bottom. The fact that the valley bottom is covered almost entirely by late Holocene deposits strongly suggests that the valley bottom is the floodplain, and all portions of it have been subjected to recent inundation and deposition. Flooding is restricted to relatively narrow corridors along the incised tributary washes that drain directly to the Hassayampa. Flood-prone areas are somewhat more extensive in the western 2/3 of the quadrangle where incision is modest. Valley bottoms covered with young deposits but channels are quite small, implying that shallow sheet flooding and bank erosion along channels are the principal flood hazards. Although valley bottoms are fairly wide, there are no major distributary channel networks or active alluvial fans on the piedmont.

Two approximate or inferred faults are depicted that displace Miocene volcanic rocks. We found no evidence that these faults have been active during the Quaternary, nor did we find any other evidence of Quaternary fault activity in the map area.

Both earth fissures (AZG S, 2015) and giant desiccation cracks (Harris, 2003) have been recognized in the southwestern portion of the map area. An earth fissure opened in the summer of 2000 about 3 miles (5 km) southeast of Wintersburg. The fissure trends nearly north-south and is about 1,150 ft (350 m) long. In two locations the fissure is en echelon, with N W -S E steps. A complex of new earth fissures totaling 620 ft (190 m) opened approximately 400 ft (120 m) to the north-northwest of the initial fissure in the fall of 2014. Those new fissures appear to be an extension of the initial fissure and also exhibit en echelon cracks that splay into a y-shaped arrangement at the northern end. There is no discernable vertical offset across any of the fissures. The location of the fissures, at the edge of the Palo Verde basin and somewhat in line with the trend of a small hill, suggests that a shallow buried bedrock ridge may extend south of the hill beneath the trace of the fissures. If this scenario is correct, the crack may represent fissuring due to compaction and subsidence on either or both sides of the buried ridge. An area of shallow giant desiccation cracks lies between the earth fissure zones. These cracks appeared at the same time as the initial earth fissure. Alignments of established vegetation in some portions of the polygonal desiccation crack network demonstrate that cracking has occurred periodically in the past. Additional areas of giant desiccation cracks were mapped by Harris (2003), and more were identified recently and are included on this map.

Aggregate resources were extracted from several small pits in piedmont surficial deposits near Interstate Highway 10, probably for construction of the highway. Two larger aggregate operations are currently active along the Hassayampa River north of I-10. These operations are apparently mining aggregate primarily from Holocene river deposits, but they may be drawing upon older river deposits as well. The potential for useful aggregate resources in older river deposits that flank the modern floodplain is not known because the thickness of these deposits is uncertain.

Bedrock Geology

Mafic lavas of the 16.9 to 20.7 Ma (Shoustra et al., 1976;) Palo Verde Hills lava field constitute the only bedrock exposed in the area. The volcanic strata are gently dipping and show no sign of major deformation. A minor down-to-the-southwest normal fault offsets the lavas in the hills just north of the PVNGS (Pearthree et al., 2006), but these kinds of faults are common throughout the Basin and Range province of southwestern Arizona and there is no evidence that this or other faults like it that are probably also present in the area have been active in the Quaternary.

Based on extensive geochemical analyses of mafic lavas in the area, Shoustra et al. (1976) recognized two kinds of mafic lava: basaltic andesite and basalt, and as a result defined two bedrock map units: basalt (Tb), and a combined unit of basalt, basaltic andesite, and minor tuff and volcaniclastic rocks (Tba). Later, more detailed mapping by Ferguson (Pearthree et al., 2006) in an area confined to the Wintersburg 7.5’ quadrangle showed that, in the immediate vicinity of the PVNGS, basaltic andesitic lava overlies basaltic lava along a gently northeast-dipping contact that is probably depositional (the contact is exposed in a hill in the north-central part of section 27, T 1N, R 6W. It should be noted that Shoustra et al.’s (1976) definition of basalt versus basaltic andesite (geochemistry) differs from the more recent study (Pearthree et al., 2006), which was based on petrology of the lavas. In the Pearthree et al. (2006) classification, lavas with fairly abundant plagioclase phenocrysts were identified as basaltic andesitic, and those with sparse or minor plagioclase phenocrysts were classified as basaltic. When the Wintersburg quadrangle map was combined with the mapping of Shoustra et al. (1976) to produce this map, no attempt was made to reconcile the different definitions of the mafic rocks. Because of this, we show the basalt and basaltic andesite lavas in the immediate vicinity of the PVNGS as map units Tbl and Tbu respectively and do not attempt to extend these units elsewhere on the map.

Mafic lavas in the hills directly east of the PVNGS are basaltic based on both study’s classifications, but since they show no stratigraphic relationship to the basaltic andesitic rocks (Tbu map unit) adjacent to the PVNGS, they are correlated with the more generic Tb map unit. The Tb lavas in this area were dated by Shafiqullah et al. (1980) as the oldest in the area, which suggests that they may correlate with the Tbl (older) unit. However, as noted by Pearthree et al. (2006), the lava flows in sections 35 and 36, T 1N, R 6W appear to dip moderately to the southwest and they might be a different (older or younger) age than those near the PVNGS. The difference in stratigraphic tilt of the volcanic strata near the PVNGS (northeast), with the southwest-tilted strata in the aforementioned hills indicates that an anticlinal tilt-domain boundary exists in the vicinity of the PVNGS. This should not be taken as evidence of any sort of young structural instability however, since tilt-domain boundaries of this sort are present throughout the Basin and Range province of the American Southwest (eg. Stewart, 1980). In this and nearly all other instances like it, structures related to tilt-domain boundaries in the Basin and Range province have been inactive for millions of years.

Mapping Responsibility

Pearthree is responsible for all of the surficial geologic mapping in the map area. Ferguson mapped the bedrock geology of the Wintersburg quadrangle (Pearthree et al., 2006). Bedrock geologic units for all areas outside of the Wintersburg quadrangle are based on the compilation map of Reynolds and Skotnicki (1993), but map unit boundaries were modified by Pearthree using high-resolution orthophotography and topography. Earth fissures were originally mapped by Harris; some additional fissures were mapped by Cook in 2015.

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