Surficial Geologic Map of the southern parts of the New River Mesa and Humboldt Mountain Quadrangles, Maricopa County, Arizona

by

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Introduction

This map and report summarize the surficial geology of the southern parts of the New River Mesa and Humboldt Mountain quadrangles on the northeastern margin of the Phoenix metropolitan area. The map area is just north of Cave Creek and Carefree and is approximately 40 km northeast of Phoenix. The map area consists primarily of fairly rugged mountainous terrain, but also includes the valleys of Cave Creek and Camp Creek and the northern part of an extensive dissected bedrock pediment. The mountainous portion of the study area is underlain by Precambrian metamorphic and granitic rocks, and Tertiary basalt and sedimentary rocks. Most of the bedrock at the surface in the mountains has been weathered into hillslope colluvium, although relatively intact bedrock may be observed in gullies. Deeply weathered Precambrian granitic rocks have been eroded into a well-developed pediment at the southern margin of the mapped area. Quaternary alluvium is found primarily along the larger drainages in the mountains and along smaller drainages that cross the pedimented areas on the southern margin of the map area.

Substantial local topographic relief and relatively lush upland vegetation lend tremendous scenic beauty to the map area. Elevations range from about 2200 ft above sea level (asl) along Cave Creek to 5000 ft asl feet on Kentuck Mountain in the eastern part of the map area. Local relief between hilltops or ridges and adjacent valley bottoms of at least 1000 ft is common. Vegetation in the map area ranges from upland desert to sparse juniper woodland. As the elevation increases, so does the abundance of vegetation. Progressing upslope saguaros, other cacti, and palo verde trees give way to thick undergrowths of cat claw and scrub oak. Small juniper trees dot the north-facing slopes in the hills. In some areas saguaro and juniper grow together on the same slopes. Larger washes typically have fairly lush riparian vegetation, including cottonwood and willow trees.

Access to the map area is quite limited. Portions of the southernmost part of the map area are accessible by graded gravel roads emanating from Cave Creek and Carefree. The far southeastern part of the area may be entered via the graded gravel road to Horseshoe Dam. The graded gravel Seven Springs road bisects the map area, but access to areas east and west of the road is very limited. Existing roads that provide access to inactive mines or mining claims are locked and not accessible to the public. Most of the land within the map area is administered by the Tonto National Forest, but much of southern fringe of the map area consists of private land.

The scenic beauty of this area has fostered suburban development, with the construction of expensive homes on the fringes of and within the mountainous terrain.

Mapping of surficial deposits was based on interpretation of color 1:24,000 scale aerial photographs obtained from the Tonto National Forest in Phoenix, with limited field-checking. Mapping was carried out during the summer of 1996. Aerial photo interpretation was done by Karen Demsey and Philip Pearthree; field-checking was done by Pearthree. The map was prepared by Pete Corrao, Jeanne Klawon, and Steve Skotnicki of the Arizona Geological Survey.

Previous Studies

The bedrock and surficial geology of most of the New River Mesa and Humboldt Mountain quadrangles have not been mapped in detail, but several studies of the geology of this region have been conducted. Lewis (1920) provided a reconnaissance geologic map of the western part of the map area. Gomez (1979) mapped the geology around Skull Mesa in the New River Mesa quadrangle. Several geologic mapping efforts by Arizona State University graduate students have been conducted on the southern and western fringes of this study area. Doorn and Péwé (1991) mapped the geology of the Carefree basin, Péwé and others (1985) and Kenny (1986) mapped the geology of the Tonto Foothills, and Jagiello (1987) mapped the New River Mesa area. Skotnicki (1996) mapped the bedrock and surficial geology of the lower Verde River Valley southeast of the study area. Piety and Anderson (1990) made detailed studies of the surficial deposits, including river terraces, along the Verde River several miles north and south of Horseshoe Dam. They also dug trenches across a branch of the Horseshoe Fault and interpreted its recent faulting history.

General Bedrock Geology

The oldest rocks in this map area are Precambrian metamorphic rocks. In the Carefree area, they are described by Doorn and Péwé (1991) as a meta-argillite - phyllite complex. These rocks are complex and variable in color, fabric, and resistance to erosion. They were probably derived from a variety of sedimentary rocks, and have a strong, near vertical foliation. The metasedimentary rocks were intruded by granite of middle Proterozoic age (~1.4 Ga; Doorn and Péwé, 1991). The granitic rocks have large K-feldspar crystals, and they typically are deeply weathered and not very resistant to erosion. The next youngest rocks in the map area are interbedded volcanic and sedimentary rocks of middle Tertiary age. Based on K-Ar dates on volcanic rocks in the New River Mesa area, this sequence of volcanism and sedimentation probably occurred between about 22 and 14 Ma (Jagiello, 1987; Doorn and Péwé, 1991). Dates on the capping basalt flows of this sequence range from about 13 to 16 Ma (Scarborough and Wilt, 1979; Doorn and Péwé, 1991).

Surficial Geology and Geomorphology

The primary focus of this map and report are the late Cenozoic deposits and landforms. The surficial geologic units used in this mapping are described in more detail below. The primary purposes of this section are to describe the general framework of the mapping and to consider the implications of the surficial geology for the recent evolution of this area. The two general subdivisions of our map units are (1) Quaternary stream deposits; (2) bedrock hillslope landforms and bedrock-derived deposits. The first category is further subdivided based on the age and source of the deposits. The second category is subdivided based on the character of the deposit or bedrock outcrop.

Most of the mountain slopes in the map area are covered by thin deposits of weathered material derived from the underlying bedrock (map unit cl). On a standard geologic map, many of these areas would be depicted as bedrock, as it is relatively easy to infer the bedrock lithologies based on limited outcrops on hillslopes and in gullies and stream valleys. Because this is a surficial geologic map, we emphasize the fact that these areas are hillslope landforms covered primarily by colluvium derived from weathered bedrock. Colluvial cover is thin and discontinuous. Bedrock outcrops can generally be found on these hillslopes, in gullies on the slopes, and on the lower portions of hillslopes adjacent to valley-bottom drainages. Some colluvial slopes are covered by fairly large clasts with substantial rock varnish. These slopes are quite stable. Colluvial slopes that have gullies or rills or are covered by soil and fairly small, minimally varnished clasts are certainly more active and may be subject to small-scale slumps or debris flow activity.

We differentiate talus slopes from colluvium based on the size of the clasts in the deposit and slope steepness. Talus slopes are at or near the angle of repose (30° to 35°) and are mantled with large, angular to subangular clasts. Most talus slopes exist below resistant bedrock outcrops, and the talus clasts are emplaced by some combination of rockfall, rolling, and sliding downslope. In many areas, talus slopes grade downslope and laterally into colluvial slopes; thus, all map contacts between talus and colluvium should be regarded as indefinite.

Outcrops of hard, relatively unweathered rock are fairly limited. The outcrops consist primarily of basalt flows, relatively fine-grained granitic rocks, and rarely, resistant Precambrian metamorphic rocks. They typically form very steep slopes or cliffs. The resistant, exposed rocks weather primarily by mechanical processes such as freeze - thaw cycles, root growth, etc., so rockfalls onto slopes below are a potential hazard.

Extensive areas of dissected bedrock pediment exist on the southern and southeastern fringe of these quadrangles. A bedrock pediment is a relatively planar, low-relief erosion surface. They are commonly developed on rocks such as coarse-grained granite that are relatively susceptible to chemical and mechanical weathering in the shallow subsurface environment. The pediment areas depicted on our maps are part of a very large Pinnacle Peak pediment developed on Precambrian granite that extends southward to the McDowell Mountains (Kenny, 1986; Doorn and Péwé, 1991). The granite exposed in gullies and roadcuts is typically highly weathered; the thickness of this weathered zone may be as much as several hundred feet thick (Doorn and Péwé, 1991). Locally, more resistant granite forms low hills and ridges that rise above the surrounding pediment, and thin, patchy granitic alluvium covers portions of the pediment. This very broad, pediment probably formed over million years when the base level for this area was stable or slowly rising. Subsequent to pediment formation, portions of these pediments have undergone substantial dissection as a result of regional base-level fall. The pediment areas shown on our map have undergone substantial dissection during the Quaternary, as streams draining to the Verde River have responded to the long-term downcutting of the river (Skotnicki, 1996).

Quaternary deposits are rather limited in the map area. Cave Creek, which is by far the largest drainage in the map area, has fairly well-rounded, coarse deposits that are similar to deposits associated with other rivers in the Phoenix area. These deposits are subdivided from all of the other alluvial deposits in the map area. Terraces of Cave Creek, which record former positions of the floodplain, are up to 200 ft above the modern floodplain. These terraces record the progressive downcutting of Cave Creek through the Quaternary. Cave Creek is entrenched into

Pleistocene deposits or bedrock throughout the map area, and thus the Cave Creek floodplain is quite well-defined and of limited extent.

Limited Quaternary deposits associated with smaller streams are scattered across the map area. These deposits typically are associated with stream terraces or small alluvial fans. Deposits are poorly sorted, with clasts typically ranging in size from cobbles to sand. Soil clay and calcium carbonate content generally increase with deposit and surface age, such that middle Pleistocene and older deposits have strong, clay-rich argillic horizons or petrocalcic horizons. As with the Cave Creek terraces, older deposits may be far above the modern channels, recording the progressive downcutting of tributary drainages through the Quaternary.

The deposits and landforms of the map area record the increasing dominance of erosional proceses during the late Cenozoic. Probable late Tertiary basin-fill sediments along upper Camp Creek were deposited in an aggrading basin prior to its integration with the modern Verde River system. A similar sequence of basin-fill sediments in the Cave Creek - Carefree area is deeply dissected (Doorn and Péwé, 1991). The dissection of these basin-fill deposits indicates that stream downcutting dominated the evolution of the landscape after the basins filled to their highest levels. Relict terrace deposits associated with Cave and Camp creeks and with lesser tributaries are high above the modern channels. These terrace deposits attest to the dramatic downcutting of these streams during the Quaternary. In addition, much of the bedrock pediment along the southern margin of the map area has been dissected.

The Verde and Salt rivers are the fundamental controls on the development of alluvial landforms throughout the map area because all tributaries are graded to them. Downcutting of the major rivers has driven downcutting of all of their tributaries, resulting in dissection of the piedmonts and enhanced erosion in the valleys of the mountainous portions of the map area. The long-term downcutting of the major rivers may have been driven by regional uplift of the Transition Zone relative to the Phoenix basin during the Pliocene and Quaternary (Péwé, 1978; Menges and Pearthree, 1989). Periods of river stability or aggradation have been superimposed on the long-term downcutting trend, resulting in the formation of a suite of relatively thin river terrace deposits of different ages. Five distinct levels have been identified along Cave Creek (Doorn and Péwé, 1991). These terraces range in age from historical (the modern channel and floodplain) to early Pleistocene-late Pliocene (Little Elephant terrace).

Geologic Map Units

Map units described below are grouped into Quaternary surficial deposits and bedrock landforms and associated deposits. Quaternary deposits are further subdivided by age and origin. Age subdivisions of the Quaternary used in this report are Holocene (Qy; 0 to 10 ka); late Pleistocene (Ql, 10 to 250 ka); middle Pleistocene (Qm, 250 to 750 ka); and early Pleistocene (Qo, 750 ka to 2 Ma). Surficial deposits are also divided into two categories by their origin. These categories are Camp Creek and smaller tributary alluvium (no letter added; Qy, for example); and Cave Creek channels and terraces (lower case "r" added; Qyr, for example).

Quaternary

Piedmont Deposits

Qy **Holocene alluvium (< 10 ka).** Unconsolidated sand to boulders reaching sizes up to 1 m in diameter upstream but smaller and fewer downstream. Larger clasts typically are basalt or fine-grained granite. Smaller clasts are subangular granite or metamorphic rock. Qy deposits are characterized by stratified, poorly to moderately sorted sands, gravels, and cobbles frequently mantled by sandy loam sediment. On this surface the main channel commonly diverges into braided channels. Locally exhibits bar and swale topography, the bars being typically more vegetated. Soil development is none to weak, typically with only slight texturally or structurally modified B horizons and slight calcification (Stage I). Some of the older Qy soils may contain weakly developed argillic horizons. Because surface soils are not indurated with clay or calcium carbonate, Qy surfaces have relatively high permeability and porosity.

Ql **Late Pleistocene alluvium (10 to 250 ka).** Moderately sorted, clast-supported sandstones and conglomerates containing much granitic grus in a tan to brown sand and silt matrix.. Ql surfaces are moderately incised by stream channels but still contain constructional, relatively flat interfluvial surfaces. Desert pavement is not stronly developed. Ql soils typically have moderately clay-rich, tan to red-brown argillic horizons. Ql soils contain substantial pedogenic clay and some calcium carbonate, resulting in relatively low infiltration rates. Thus these surfaces favor plants that draw moisture from near the surface. Ql soils typically have Stage II calcium carbonate development.

Qml **Middle and late Pleistocene alluvium, undivided (10 to 750 ka).**

Qm **Middle Pleistocene alluvium (250 to 750 ka).** Sandy to loamy, tan-colored gravels. The deposits are moderately consolidated and locally weakly indurated by carbonate. Argillic horizons typically are weak to moderate, probably because they have been eroded, but are strongly developed where original depositional surfaces are well-preserved. The unit is fairly deeply dissected and ravines reveal relatively thin deposits, typically less than 2 meters thick..

Qmo Middle to early Pleistocene alluvium, undivided (250 ka to 2 Ma)

Qo **Early Pleistocene alluvium (750 ka to 2 Ma).** Relatively thin (<4 m-thick) deposits of moderately sorted conglomerates containing mostly pebble- to cobble-size clasts of basalt in a sand to silt granitic matrix. Qo deposits rest on top of high levels of Tertiary basin-fill deposits the upper end of Camp Creek, although Qo deposits are below the highest levels of basin fill. Qo soils are characterized by a variably preserved, dark brown clay-rich argillic horizon. No petrocalcic horizon was observed associated with Qo deposits, but exposures are poor and such a horizon may exist.

River Deposits (associated with Cave Creek)

Qycr **Active river channel, bar, and low terrace deposits.** Unconsolidated, rounded to subangular, moderately sorted to poorly sorted, clast-supported sand, cobbles, and small boulders. Rounded cobbles 10-30 cm dominate channels and are characteristically imbricated downstream. Low terraces typically covered by sand and silt. Minimal carbonate accumulation. Little vegetation in channels, bars and terraces may have abundant riparian vegetation.

Qyr **Holocene river terrace deposits (0 to 10 ka).** Mostly unconsolidated well-rounded pebble- to cobble-sized river gravels surrounded by a sand and minor silt matrix. Also includes overbank (finely laminated clays, silts, and fine sands) sediments. Soil development is limited to slight organic accumulation at the surface and some bioturbation. Qyr surfaces along Cave Creek are highly vegetated. Generally equivalent to the Hidden View terrace of Doorn and Péwé (1991).

Qlr **Late Pleistocene river terrace deposits (10 to 250 ka).** Poorly consolidated well-rounded pebble- to cobble-size river gravels surrounded by a sand and minor silt matrix. Soil development includes moderate clay and calcium carbonate accumulation. Vegetation is moderately dense desert trees and bushes. Generally equivalent to the Hidden View terrace of Doorn and Péwé (1991).

Qmr **Middle Pleistocene river terrace deposits (~250 to 750 ka).** Moderately high river terraces with moderate to strong soil development. Deposits consist of rounded to sub-angular pebble- to cobble-size river gravels with sand and silt. Soil development includes well-developed clay-rich argillic horizons and moderately developed petrocalcic horizons. Vegetation is desert shrubs and some trees. Equivalent to the Cahava Ranch terrace of Doorn and Péwé (1991).

Qor **Early Pleistocene river terrace deposits (~750 ka to 2 Ma).** High, poorly preserved river terrace deposits with moderate soil development. Deposits are coarse rounded to subangular cobbles to boulders with sand and silt. Soil development includes variablly preserved argillic horizons and strongly developed petrocalcic horizons.

<u>**Hillslope Deposits and Landforms**</u>

cl **Colluvium and weathered bedrock.** Mixed unit that includes locally derived hillslope colluvium, weathered bedrock, and smaller areas of relatively unweathered bedrock. Colluvial cover consists of poorly sorted angular cobbles and pebbles, with substantial sand, silt and clay. Deposits consist of weathered bedrock fragments and finer-grained soil derived from rock weathering and dust. Although locally colluvium may be several meters thick, more commonly it is less than one meter thick. Weathered bedrock underlies and merges upward into colluvium, and in many places is at the surface. Less weathered bedrock is commonly exposed on hilltops and ridgecrests, in hillslope gullies, and on lower hillslopes along the valley-bottom drainages.

tl **Talus deposits.** Coarse, angular talus deposits that mantle some of the steeper hillslopes below ridgelines and bedrock outcrops. Talus deposits consist of angular to subangular boulders to cobbles. Slopes are at or near the angle of repose (30° to 35°). Talus clasts are emplaced by some combination of rockfall, rolling, and sliding downslope.

R **Relatively unweathered bedrock.** Outcrops of resistant, relatively unweathered bedrock. Outcrops consist primarily of basalt flows that form high mesas, relatively fine-grained granitic rocks that form fairly smooth, steep slopes, and small areas of resistant Precambrian metamorphic rocks that outcrop on hill tops. Outcrops typically are have joints and fractures that facilitate mechanical weathering, and have very steep slopes, so rockfalls onto slopes below are a potential hazard.

df **Debris flow channels and deposits.** Recent debris-flow channels and deposits were identified along some the steeper hillslopes and drainages of the map area. Debris-flow channels are erosional features formed in gullies on steep hillsides. They may have intermittent boulder levies along their margins. These channels end downslope in debris-flow lobes, where decreasing topographic confinement or channel slope causes debris flows to dissipate and deposit coarse, very poorly sorted sediment.

pd **Bedrock pediments.** Relatively planar, low-relief erosion surfaces cut into bedrock. In the map area, pediments are formed on coarse-grained Precambrian granite. Highly weathered bedrock is exposed in channels, in roadcuts, and along ridge lines. Pediments of the map area are dissected; valleys up to 40 ft deep have been carved by drainages that flow across the pediment. Valley bottoms typically are covered by Holocene alluvium. Some preserved pediment areas are undoubtedly covered by a thin, patchy cap of Pleistocene alluvium.

Geologic Hazards

A variety of potential geologic hazards may be encountered in the study area. The primary geologic hazards that may affect this area are flooding, debris flows, rockfalls, and soil problems. Specific geologic hazards that correlate with particular map units are mentioned in the unit descriptions. The general character of these hazards and the areas that may be affected by them are considered below.

Flooding. Flood hazards of the area consist of flooding associated with Cave Creek, Camp Creek, and their tributary streams in the mountains and on the piedmonts of the area. Hazards associated with floods on the creeks are inundation of the channels and low terraces, erosion of roads that cross these creeks at grade, and erosion of banks and lateral migration of river channels. The larger floods on these relatively large streams are likely to result from regional storms that occur during the fall and winter. The channels and floodplains of the Cave Creek in the map area are natural, without artificial bank protection. Along much of the creek, the channel banks are formed in late Quaternary alluvium. Major changes in channel position and size have occurred in past floods on alluvial rivers in Arizona (Péwé and Kenny, 1989), and should be anticipated in future floods as well. Flood hazards associated with these creeks may be mitigated by avoiding building on channels and Holocene river terraces (map units Qyrc and Qyr).

Flood hazards on tributary drainages may be subdivided into (1) localized flooding along well-defined drainages, where there is substantial topographic confinement of the wash; and (2) widespread inundation in areas of minimal topographic confinement. Nearly all of the tributary drainages in the map area are topographically well-defined. Floods leave behind physical evidence of their occurrence in the form of deposits. Therefore, the extent of young deposits along confined drainages (unit Qy) is a reasonably accurate indicator of areas that have been flooded in the past few thousand years. Areas that are covered by young deposits are most likely to experience flooding in the future, and flood hazards may be mitigated by avoiding building in these areas. Relatively steep tributary drainages that flow in the bottoms of steep-sided valleys may be affected by debris-flow activity. Debris flows are discussed below.

Soil/substrate problems. Several types of soil/substrate problems may be encountered in the study area. Soil compaction or expansion upon wetting or loading may be an important geologic hazard in portions of the mapped area. Soil instability has caused extensive damage to buildings in Arizona (Christenson et al, 1978; Péwé and Kenny, 1989). Changes in soil volume beneath structures may cause damage ranging from nuisance cracks to serious structural damage. Deposits that are susceptible to changes in soil volume are typically relatively fine-grained, young sediments. Fine-grained overbank deposits on young Cave Creek terraces may have the potential to compact upon loading, although generally the fine deposits are quite thin. Clay-rich soils associated with the well-preserved middle and early Pleistocene alluvial fans and terraces (units Qm, Qo, Qmr, and Qor) may have some potential for shrinking and swelling during dry and wet periods, respectively. However, clay-rich horizons associated with these surfaces are generally less than 1 m thick.

The presence of cemented caliche or petrocalcic soil horizons may impact construction excavation and leaching potential. Calcium carbonate accumulates in soils in this desert environment over thousands of years. Typically, the older soils in this area have moderate to strong accumulations of calcium carbonate that form a cemented horizon in the soil. This cemented petrocalcic horizon may be 1 meter or more in thickness, and a laminar cap of calcium carbonate may form in the upper part of the horizon. In the map area, strongly cemented petrocalcic horizons are associated with early and middle Pleistocene alluvial fans and terraces (units Qm, Qo, Qmr, and Qor). Progressively less carbonate accumulation is associated with increasingly younger surfaces, such that Ql and younger deposits have carbonate accumulations but do not have cemented horizons.

Granitic pediments and thin colluvial hillslopes over bedrock present potential limitations for excavation and infiltration. Alluvial cover is thin and patchy over bedrock pediments in the southern part of the map area. These deposits are typically poorly indurated and are composed of granitic grus and much sand- and silt-sized material derived from the granite bedrock. The deposits and the weathered bedrock are fairly easy to excavate. Construction may be impacted by the proximity of bedrock close to the surface, although the granite that forms the pediment appears to be quite deeply weathered in most places. Colluvial hillslope deposits are quite thin over bedrock. Ease of excavation for homesites on hillslopes depends on the extent of weathering of the underlying bedrock, and is undoubtedly quite variable across the map area

Rockfalls and Debris flows. Rockfalls, small landslides, and debris flows are potential hazards on and immediately adjacent to steep slopes. Mass movement of material on steep slopes in this region typically is triggered by intense or prolonged periods of precipitation (Christenson et al, 1978; Péwé and Kenny, 1989). Debris flows are viscous slurries of sediment and water that may convey large boulders substantial distances downslope. In southern and central Arizona, nearly all of the documented historical debris flows have been restricted to mountain slopes and valleys. In this mountainous region, debris flows may be generated by small-scale failures on hillslopes or in gullies on hillslopes. Areas that appear to have been affected by recent debris-flow activity are depicted on the map (unit df). Areas of potential debris-flow activity are probably much more extensive than depicted, however. Most of the gullies draining steep hillslopes and steep channels that drain steep-sided valleys across the map area could convey debris flows.

Rockfalls are potential hazards below bedrock cliffs and where bedrock outcrops exist at or near the top of steep mountain hillslopes. Many of these areas are depicted as talus deposits on the map (unit tl). In these areas, large rocks that are loosened by weathering may cascade violently downhill. The existence of large boulders near the base of a steep slope should be considered evidence of potential rockfall hazard in most cases. The basalt cliffs in the western part of the map area and local exposures of minimally weathered granite outcrops in the eastern part of the map area present the potential for rockfall.

Landslides may be a significant hazard in areas where resistant rocks overlie less resistant rocks. In particular, the flat-lying to gently tilted mesa-capping basalt flows in the western part of the map area overlie less resistant Tertiary sediments and volcanic rocks. Evidence of old landslides has been recognized in this area by previous workers (Jagiello, 1987).

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