Surficial Geologic Maps of the Northern Avra Valley-Desert Peak Area Pinal and Pima Counties, Southern Arizona

by

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Introduction

These nine maps depict the general ages and distribution of Quaternary geomorphic surfaces and associated alluvium of the northern Avra Valley-Desert Peak (AVDP) area, Pinal and Pima counties, southern Arizona. The area mapped includes portions of the piedmonts surrounding the Silver Bell, Picacho, and Tortolita mountains, and the basin flats between them. The southern margin of the study area is approximately 40 km northwest of downtown Tucson. The AVDP area is one of many broad valleys in the Basin and Range physiographic province of southern Arizona. The Basin and Range province in the vicinity of the study area is characterized by relatively small mountain ranges with fairly low relief separated by wide, gently sloping piedmonts and basin bottom river drainages. The major drainages flowing through study area are the Santa Cruz River, Brawley Wash, and McClellan Wash. By indicating the age and physical characteristics of surficial alluvial deposits, these maps provide a basis for evaluating the Quaternary geologic history of the area and assessing potential geologic hazards.

Alluvial deposits differentiated for these maps are assigned to Quaternary and Upper Tertiary age categories primarily on the basis of the estimated age of cessation of major deposition on geomorphic surfaces associated with the deposits. Relative topographic positions of each surface, drainage patterns, surface characteristics, and degree of soil development associated with the surface are the principal criteria used to assess surface age. Six ages of surfaces are differentiated in these maps. Map units are further subdivided into piedmont and basin axis units. The characteristics of each map unit are described below. The estimated ages of the units are inferred by correlation with similar surfaces and soils dated elsewhere in the southwestern United States (Gile and others, 1981; Bull, 1991; Menges and McFadden, 1981). Generalized lithologies of exposed bedrock are also depicted on the maps.

Mapping of surficial deposits is based primarily on interpretation of black-and-white, 1:12,500-scale aerial photographs. Initial unit designations were later field-checked throughout the map area. In extensive agricultural tracts where natural surface characteristics are altered, published soil surveys (Soil Conservation Service, 1972) were used to evaluate soil development and to delineate boundaries between surfaces of different ages.

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Description of Map Units

Piedmont Units

Y2 - Late Holocene alluvial fans, stream channels, and low terraces, estimated age < 4 ka (ka = thousands of years before present)

Late Holocene deposits comprise extensive alluvial fans in lower piedmont areas and restricted channel and low terrace deposits extending into upper piedmont areas and mountain ranges. Young alluvial fan deposits on the lower piedmont are composed of fine sand and silt. Active channels farther upslope are composed of sand, silt, and gravel, generally coarsening closer to the mountains. Young alluvial fan surfaces are typically undissected and display distributary drainage patterns, although 1.5-m-deep arroyo cuts occur locally. Surfaces are typically smooth with very little bar and swale topography developed due to the fine-textured sediments. Desert pavement and rock varnish are absent. Minimal to no soil development has occurred. Typical soil great groups are Torrifluvents and Camborthids. These areas are subject to frequent to rare flooding.

Y1 - Middle to early Holocene alluvial fans, estimated age 4 to 10 ka.

Middle to early Holocene deposits primarily consist of extensive alluvial fans in middle piedmont areas and restricted terrace deposits in upper piedmont areas. Y1 deposits are slightly gravelly silty sand. Surface relief is typically less than 0.5 m above active channels. The surfaces are smooth and flat with an incipient dendritic drainage pattern. Weakly developed pebble to granule desert pavement is present over most of the surface. Desert varnish is absent. Minimal soil development has occurred in the underlying deposits. Soil great groups are Camborthids and Torriorthents. These areas are not subject to frequent flooding. However, they should be regarded as potentially flood prone because they may be subject to flooding in extreme events and they could become subject to frequent flooding through aggradation of the shallow channels dissecting the surface.

Y1p - Late to early Holocene pediment fans, estimated age 0 to 10 ka.

Thin Holocene deposits covering pediment surface eroded into granite at the north end of the Silver Bell Mountains. Surface age is based on the minimal degree of soil development in the thin veneer of transported pebbly sand derived from weathering of the granite. Surface age should not be considered as the time of major pedimentation. Surface relief is typically less than 0.5 m above active channel bottoms. The pediment-fan surface is smooth and largely undissected, with small bedrock knobs protruding 5 to 20 m above the surface. Although shallow channels are present on the surface, no integrated drainage pattern is discernible on aerial photographs. Soil great groups are Camborthids and Torriorthents. These areas may be subject to occasional flooding.

Y - Undifferentiated Holocene piedmont alluvial surfaces, estimated age 0 to 10 ka.

In some places this designation is used where the Y1 and Y2 surfaces are too intricately intermingled to map separately at this scale. In some lower piedmont areas the designation is used where surface characteristics are not distinctive of either Y1 or Y2 surfaces but are clearly of Holocene age. These areas may be subject to rare to frequent flooding.

M2 - Late Pleistocene alluvial fans and terraces, estimated age 10 to 150 ka.

Late Pleistocene deposits consist primarily of extensive alluvial fans in middle piedmont areas, some restricted terraces inset into older deposits in lower piedmont areas, and a few small alluvial fans in upper piedmont areas. M2 deposits are a poorly sorted, angular to subangular admixture of silt, sand, and gravel. The surfaces are moderately dissected with typically 1 to 3 m relief above active channels. Interfluve areas are broad and flat with a well-developed dendritic drainage pattern dissecting the surface. A poorly to moderately developed cobble to granule desert pavement is found over 50 to 80 percent of the surface. Surface cobbles are typically unvarnished although an orange color is sometimes seen on cobble undersides. Soil great groups are Camborthids and Haplargids. Most M2 areas are free from flooding, although those areas of low relief could become susceptible to flooding with relatively minor shifts in depositional patterns.

M1, M1a, M1b- Middle to early Pleistocene alluvial fans, estimated age 150 to 1,000 ka.

Middle to early Pleistocene alluvial-fan deposits dominate the middle and upper portions of most of the piedmonts in the mapped areas. M1 deposits are also found as restricted terraces and small fans along drainages within the mountain ranges. Deposits are a poorly sorted, angular to subangular admixture of silt, sand and gravel. The surfaces are moderately dissected with typically 1 to 6 m of relief above active channels but less than 2 m of relief above late Pleistocene (M2) surfaces. Interfluve areas commonly are broad, flat, and smooth, but in areas of more intense erosion interfluves are rounded. A well developed tightly interlocking cobble to pebble desert pavement is found in areas with volcanic gravels that have experienced little erosion (e.g. Silver Bell Mountains and Picacho Peak piedmont). Other areas exhibit an open cobble to granule pavement; sandy silt covers almost 50 percent of the surface. Volcanic cobbles are often varnished black (5YR 1.7/1) on top and reddish brown (2.5YR 4/8) on undersides. On felsic intrusive cobbles varnish is weakly developed to absent; the tops of cobbles are incompletely varnished black (7.5YR 2/1) while the undersides are brown (7.5YR 4/6). Underlying soils are characterized by moderately to very strongly developed argillic horizons (hue 5 to 2.5 YR), commonly overlying a stage IV calcic horizon. Soil great groups are Haplargids and Paleargids. These areas are isolated from active fluvial processes, and only entrenched channels are subject to flooding.

M1 units were further subdivided into an M1a (older) and M1b (younger) unit on the broad western piedmont of the Tortolita Mountains. The M1a units are of middle to early Pleistocene age, and fit the description given above for the M1 unit. M1b units are distinctly younger than adjacent M1a units. Soils on M1b surfaces have weakly developed argillic horizons, commonly overlying a stage III calcic horizon. M1a surfaces are usually distinguishable from M1b surfaces because of their stronger soil reddening, better developed desert pavement, and higher relief than adjacent M1b surfaces. Typical M1 surfaces on other piedmonts are similar to the M1a surface on the Tortolita piedmont; M1 surfaces are not subdivided on these piedmonts because of the absence of an equivalent to the M1b surface.

M1p - Middle to early Pleistocene pediments, estimated age 150 to 1,000 ka.

Pediment surface eroded into basalt in the Samaniego Hills. The exposed bedrock has a stage IV carbonate horizon developed on it indicating that it was at one time buried by a thin veneer of alluvium that subsequently has been removed. Surface relief is typically less than 1.5 m above channel bottoms and is at the same topographic level as adjacent M1 alluvial surfaces. The surface age estimate given applies to the alluvium that formerly mantled the pediment surface.

Op - Late Pliocene to early Pleistocene pediments, >1,000 ka.

Pediment surface eroded into granite at the north end of the Tortolita Mountains. Surface relief is 4 to 10 m above active channel bottoms and typically greater than 2 m above adjacent M1 surfaces. A dendritic drainage pattern is well developed. Interfluve areas are narrow and typically rounded due to extensive erosion of the surface. An open cobbly desert pavement is poorly developed with little to no varnish. Pedogenic carbonate fragments from a laminar petrocalcic horizon are found on degraded surfaces. Soil great group is Durorthids.

Ts - Late Tertiary deposits

Deeply eroded basin-fill sediments of late Miocene to Pliocene age. Particle sizes typically range from silt to boulders. Topography associated with these deposits is alternating narrow ridges and deep ravines; original depositional surfaces capping these deposits are not preserved. These represent the highest level of late Cenozoic basin-filling, and have been deeply eroded during the Quaternary. In the area mapped, these sediments are found only between the northern end of the Tortolita Mountains and the Black Mountains (Chief Butte Quadrangle).

Axial Drainage Units

Y2r - River channels and low terraces, < 0.1 ka.

Active channels and floodplains of the larger drainages. Channels and overbank areas were not separately mapped because channel positions probably shift across these units fairly frequently. Deposits range from silt to coarse sands, but bars composed of well-rounded cobbles are common along the Santa Cruz River. Minimal to no soil development. Flooding occurs frequently in basin axis channels; larger floods inundate all Y2r areas.

Y2rt - Late Holocene river terraces, < 3 ka.

Late Holocene river deposits consist of low terraces adjacent to active channelsAssociated deposits are typically fine silt and sand with common gravel lenses of well rounded cobbles. Terrace surfaces are smooth and up to 4 m above the active basin axis drainages (Y2r). Some of these terraces were probably formed during historical arroyo cutting along the Santa Cruz River. Soil great group is Torrifluvents. Flooding occurs over large portions of these terraces during larger events.

M2rt - Late Pleistocene river terraces, estimated age 10 to 150 ka.

Relict terraces of the Santa Cruz River and Brawley Wash. These terraces are extensive in northern Avra Valley and between the Santa Cruz River and Interstate Highway 10. Deposits associated with these terraces are well-stratified sands and well-rounded gravels. The terrace surface is flat and is separated from the Y2rt terraces in places by a low scarp 0.5 to 3 m high. An incipient dendritic drainage pattern is developed on the surface with less than 0.5 m relief above channel bottoms except along the terrace scarp. Most of the surface is a grass covered plain, although portions are actively farmed. Silty sand covers the surface in most areas but an open granule to pebble desert pavement is locally present. A stage II to III calcic horizon is exposed in road cuts cut into the terrace. Soil great group is Haplargids. Stabilized eolian dunes of unknown age are locally present. M2rt surfaces generally are not prone to flooding. However, flooding on has occurred locally on M2rt surfaces during historical times during extreme events and in areas of human disturbance.

Generalized Bedrock Units

Tv - Tertiary volcanic rocks

Tertiary extrusive volcanic rocks ranging in composition from basaltic andesite to rhyolite. This unit also includes Cretaceous tuffs, flows, and volcanistic sediments in the Silverbell Mountains. These fine-grained volcanic lithologies typically supply coarse sediment to adjacent piedmonts. Piedmont gravel derived from volcanic bedrock units is quite resistant to erosion, which results in good preservation of fairly old alluvial surfaces.

TKg - Tertiary to Cretaceous granitic rocks

Tertiary to Cretaceous granite to diorite. In portions of the Tortolita and Picacho mountains, granitic rocks have a mylonitic gneissic fabric. Coarse-grained granitic lithologies supply adjacent piedmonts with abundant sediment ranging in particle size from clay to cobbles. Sand and pebbles are typically the most common particle sizes. Granitic gravel clasts in alluvium are fairly susceptible to weathering and degradation. Thus, alluvial surfaces composed of granitic sand and gravel are typically more eroded than their counterparts derived from fine-grained volcanic rocks.

MPs - Mixed sedimentary rocks

Mesozoic, Paleozoic and Precambrian rocks of various sedimentary lithologies. These rocks are exposed primarily in the Silver Bell Mountains.

pCg - Precambrian granitic rocks

Granitic rocks rocks dating to approximately 1.4 billion years. Characteristics of piedmonts associated with these rocks are very similar to those of Tertiary to Cretaceous granitic rocks described above.

pCm - Precambrian metasedimentary rocks

This unit typically is composed of schist. Schistose lithologies supply moderate amounts of fine- to coarse-grained sediment to adjacent piedmonts. Clasts of schist are not very resistant to weathering on alluvial surfaces. Thus, alluvial surfaces derived from these rocks tend to be susceptible to erosion and dissection.

Quaternary Geology and Geomorphology

The mapped area is bounded by four mountain ranges: the Silver Bell Mountains to the southwest, the Picacho Mountains and Picacho Peak to the west, the Black Hills to the northeast, and the Tortolita Mountains to the east. Similarities between the piedmonts emanating from these ranges is due to similarities in tectonic and climatic conditions throughout the Quaternary. The age of the predominant piedmont surface decreases away from the mountain front such that the oldest surfaces (M1 and locally Op) are found along the mountain front whereas the youngest surfaces (Y) are found adjacent to the basin axis drainages. This distribution suggests a general tendency towards erosion in upper piedmont areas throughout the Quaternary punctuated by periods of equilibrium or minor aggradation. As a result of erosion during the Quaternary, the early Pleistocene to late Tertiary surfaces are exposed along the mountain fronts. The change from an aggradational to erosional regime may be related to the cessation of tectonic activity in the region, although the major period of normal faulting probably ended in this area prior to 5 Ma (Shafiqullah and others, 1980; Menges and Pearthree, 1989). Integration of the major basin axis drainages and climate changes probably played a important roles in piedmont evolution as well.

Late Pleistocene to middle Pleistocene surfaces (M1 and M2) extend from the upper to lower piedmont and are found over a broad portion of each piedmont. These aerially extensive deposits represent pulses of deposition that punctuated the long-term tendency toward downcutting and erosion on the piedmonts. Distinct differences in soil development and surface geomorphology between M1 and M2 deposits indicate that the interval between deposition of these units was probably hundreds of thousands of years long. However the amount of relief between M1 and M2 surfaces is rarely greater than 1 m, so the net downcutting in the middle Pleistocene was slight. Distinguishing between these two surfaces is sometimes difficult, especially on the broad Tortolita piedmont near Desert Peak. Because of the minimal relief between M1 and M2 surfaces in this area, many small isolated unmapped pods of M1 surfaces are present in the area designated as M2; the contact between the M1 and M2 surfaces should be considered only an approximation in the area to the east of Desert Peak.

The youngest surfaces (Y1 and Y2) are extensive only on the lower piedmont. Deposits associated with these surfaces indicate that they are largely the product of erosion of older alluvium. As well, most drainages supplying sediment to the younger surfaces on the lower piedmont head on M1 surfaces and do not extend into the mountains. Sediment thickness on the young surfaces becomes extremely thin higher on the piedmonts where it is common to see small pods of older units poking through the younger surfaces.

Differences in the alluvial surfaces from piedmont to piedmont is largely due to differences in source area lithology and width of the piedmont. The M1 surfaces of the Silver Bell Mountains and Picacho Peak piedmonts contain extensive areas of darkly varnished well-developed cobble pavements; volcanic rocks are the dominant lithologies in these mountain ranges. In contrast the same-aged surfaces on the granitic and gneissic Tortolita Mountains and Picacho Mountains piedmonts have poorly varnished and moderately to poorly developed cobble pavements. Surface characteristics then are not a good means of correlating surfaces between piedmonts of varying lithology. The M1 surfaces on all of the piedmonts have well-developed tributary drainage networks and soils with red (2.5 YR), clay-rich argillic horizons indicating a similarity in age.

The width of the piedmont (the distance between the mountain front and the axial valley drainage) appears to control the amount of relief between the different surfaces on each piedmont. The gentler slope of wide piedmonts (e.g. Tortolitas) results in negligible relief between surfaces. Surfaces appear to "grade" into each other because there is no distinct topographic breaks. Over large areas differences in soil development and surface characteristics are visible and indicate that surfaces of different ages are present. However, the absence of relief does not permit mapping of sharp, distinctive unit contacts. Distinguishing units of different ages is much easier on narrow piedmonts. The steeper slopes result in greater topographic distinction between surfaces. The greatest relief between M1 and M2 surfaces is observed on the relatively narrow Silver Bell Mountains piedmont.

The absence of substantial relief between the basin axis river terraces suggests there have been no major base-level changes in the Quaternary. Abandonment of the M2rt surface was more than likely due to climatic changes resulting in a change in the fluvial character of the Santa Cruz River. The aerially extensive M2rt surface suggests that the Santa Cruz River was a large braid plain characterized by frequent shifts in channel positions. Modest downcutting along the Santa Cruz River has restricted flow to a narrower portion of the older braid plain, although the extent of inundation during large floods is still quite wide.

Geologic Hazards

A variety of potential geologic hazards may be encountered in the AVDP area. The primary geologic hazards that may affect this area are flooding, soil problems, subsidence and earth fissures, and debris flows and rockfalls. The general character of these hazards and the areas that may be affected by them and considered below.

Flooding. Substantial portions of the AVDP area are prone to flooding. Flood hazards in the this area may be divided into two fairly distinct categories based on the nature of flooding and the areas affected. The basin flats are subject to broad inundation and localized high-velocity channelized flow during floods that occur on the major axial drainages. Large floods on the major drainages typically result from storms of regional extent. Both Brawley Wash and the Santa Cruz River have large watersheds and are capable of producing floods that inundate much of the basin-flats. During the flood of October 1983, floodwaters inundated an area as wide as 5 km northwest of Marana (Roeske and others, 1989). Piedmont flooding occurs in confined channels or as broader alluvial-fan flooding. Flooding on piedmonts typically results from intense, localized thunderstorms that may center over one or more small drainage basins on the piedmont or in adjacent mountains. Floodwaters are contained within confined channels in mountain valleys and most upper piedmont areas. Topographic confinement of floodwater diminishes in middle and lower piedmont areas. Alluvial-fan flooding occurs in these areas, where water spreads widely and channels may shift positions during floods.

Surficial geologic mapping provides important information about the extent of flood-prone areas in this region. Floods leave behind physical evidence of their occurrence in the form of deposits. Therefore, the extent of young deposits on piedmonts and in the basin flats is a good indicator of areas that have been flooded in the past few thousand years. These are the areas that are most likely to experience flooding in the future. Following this logic, most of the basin-flats should be considered to be flood prone, as they are covered with very young deposits (Y2rt and Y2r). Most of these areas have in fact been inundated during the largest historical floods. The extent of potentially flood-prone areas on piedmonts varies with the extent of young deposits (units Y2 and Y1). Generally, broad flood-prone areas exist only in the lower and middle portions of piedmonts.

Debris flows and rockfalls. Debris flows and rockfalls are potential hazards in and immediately adjacent to the steeper portions of the AVDP area. A number of debris flows occurred in the steep mountain drainage basins in the Picacho Mountains (just west of the mapped area) between 1983 and 1990. These debris flows apparently were triggered by landslides on very steep mountain hillsides and continued downslope following stream channels for 1 km or less. All of these debris flows were contained within the mountain range, and did not reach the upper piedmont. Rockfalls are a potential hazard below bedrock cliffs and where bedrock outcrops exist at or near the top of steep mountain hillslopes. In these situations, 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.

Soil problems. Although little research has been conducted into soil problems in the AVDP area, several types of soil/substrate problems may exist there. Soil collapse or compaction upon wetting or loading (hydrocompaction) may be an important geologic hazard in a substantial portion of the mapped area. Soil compaction has caused extensive damage to buildings in the Tucson area (Lacy, 1963; Murphy, 1975), and hydrocompaction has been reported in the Marana area (Slaff, 1986). Hydrocompaction is a reduction in soil volume that occurs when susceptible deposits are wetted for the first time after burial. Deposits that are susceptible to hydrocompaction are typically relatively fine-grained, young sediments that are deposited in a moisture deficient environment. Deposits in the AVDP area that are likely candidates for hydrocompaction are the fine-grained alluvial fans of units Y2 and Y1. Silty sands of young river terraces (unit Y2rt) may also have the potential to compact upon loading.

Clay-rich soils associated with the middle Pleistocene M1 unit may have some potential for shrinking and swelling during dry and wet periods, respectively. In addition, M1 units commonly have well-developed accumulations of calcium carbonate (caliche) that may impact excavation potential and near-surface infiltration capacity.

Subsidence and earth fissures. Subsidence and earth-fissure development related to the withdrawal of ground water from basin acquifers has occurred in many basins in southern Arizona. The water table has been lowered by more than 100 ft (30 m) in northern Avra Valley due to ground water pumping, and 1 ft of subsidence was measured near Red Rock between 1948 and 1980 (Schumann and Genualdi, 1986). An earth fissure was reported near the Marana Air Park interchange on Interstate Highway 10 (Red Rock Quadrangle); however, recent attempts to locate this fissure have been unsuccessful. An earth fissure did develop adjacent to the Central Arizona Project canal near Marana, just east of the mapped area, in 1988. A recent analysis suggests that earth fissures could develop in a north-south-trending zone along the west side of Avra Valley in the Red Rock and West of Marana Quadrangles if water levels continue to decline (Anderson, 1989).

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