SURFICIAL GEOLOGIC MAPS OF THE NORTHEASTERN, SOUTHEASTERN, AND SOUTHWESTERN PORTIONS OF THE TUCSON METROPOLITAN AREA

by

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EXPLANATION

With continued expansion of Tucson into peripheral areas, growth is being met with geologic limitations and hazards, such as shrink-swell potential in soils and collapsing soils. Knowledge of surficial geology is important in understanding these conditions. This series of maps, an extension of previous work in the central and northern parts of the basin (McKittrick, 1988), delineates landforms and pertinent lithologies. Three major groups of landforms are found in the basin: stream terraces, alluvial fans and fan terraces, and pediments. The first two have been divided into relative age groups, which correlate well with some potential geologic hazards limitations.

GEOMORPHIC SETTING

The Tucson basin is a broad, low valley surrounded by mountain ranges. Pashley (1966) indicates that a basin has been located here since the middle Tertiary. External drainage of the basin was established during latest Pliocene time (Anderson, 1987). Since then, the geomorphic evolution of the basin has been dominated by downcutting of the through-flowing drainages, with superimposed episodes of climatically induced back-filling. This has produced four major terraces in the basin. On the periphery of the basin, a flight of alluvial fans correlates with the terraces.

The oldest and highest terrace, T5, is preserved only in the central part of the basin. In many places it is capped by a thick petrocalcic horizon; it forms elongate ridges in some areas (McKittrick, 1988). The T5 terrace corresponds to the University terrace of Smith (1938). It is probably early to middle Pleistocene in age (Anderson, 1987). The next terrace, T4, deposited during the middle Pleistocene, is more widespread in the central Tucson area. T4 corresponds to the Cemetery terrace of Smith (1938). A third terrace, T3, is lower in altitude and is much less extensive than T4 or T5. It corresponds to the Jaynes terrace of Smith (1938); it was abandoned during the late Pleistocene. T2 is the lowest major terrace and represents Holocene backfilling of the major drainages. The surface of T2 was the floodplain of the Santa Cruz in historic times. T2 corresponds to the "bottomlands" of Smith (1938). The youngest units mapped are latest Holocene in age. They include a low transitory terrace in the Cienega Creek area (T1); seasonally active stream channels (cha); undifferentiated deposits of less active tributary channels (ch); and active fans, recently active fans, and mid-basin swales (Y).

Incision of the major drainages into the wide mid- to late-Pleistocene terraces is loosely constrained. It occurred sometime between deposition of T3 and T2. Davidson (1973) correlated the Jaynes terrace to deposits outside the Tucson basin with faunal dates. He suggested that the terrace was at most 11,000 years old. This is a weak correlation, however, and geomorphic evidence (see below) suggests an older age. Haynes and Huckell (1986) dated caliche in the Jaynes terrace at about 18,400 yr.B.P.. This radiocarbon date was taken from groundwater caliche eight feet below the surface, so it is a minimum age for the surface. The oldest date within the alluvium of T2 along Santa Cruz River is about 8,000 yr.B.P. (Waters, 1988). Therefore the incision occurred sometime between the latest Pleistocene and the early

Holocene.

A sequence of alluvial fans and fan terraces is preserved on the piedmonts of the Sierrita, Santa Catalina, Rincon, and Tucson Mountains. Climatically induced incision, along with tectonic quiescence, has produced a flight of fans, the highest being the oldest and the youngest being the lowest. All active fans are graded to the axial streams. Thus it is likely that abandoned fans correlate to abandoned stream terraces. Similar geomorphic characteristics and heights above active streams allow a rough correlation of the alluvial fans to the basin deposits. The oldest fans are preserved in isolated patches (O) and are correlative in part, at least, to the Fort Lowell Formation of latest Pliocene-earliest Pleistocene age (Anderson, 1987); O correlates with T5 in the basin.

PEDIMENTS

Pediments are erosional surfaces found adjacent to the mountain front. They may be formed in alluvium, but usually at least part of a pediment is cut into bedrock. Pediments have a thin, discontinuous veneer of active sediments and are planar to subplanar. They may be exposed pediments, or buried, inactive pediments. The Tucson basin contains extensive areas of both exposed and buried pediments. Exposed pediments occur near the northwest flank of Tanque Verde Ridge, north of the Sierrita Mountains, and in Rincon Valley. Exposed pediments are easily mapped from aerial photographs and field checking. Buried pediments were mapped using a combination of well data (Anderson, 1987, Tucson Water Department, unpubl. data) and analysis of mountain front geometry (Pashley, 1966, Davidson, 1973). Inselbergs were mapped as separate from pediments. A depth of 66 m (200 ft) was chosen as an arbitrary cutoff point. All boundaries on the basinward side of buried pediments are approximate. The distinctness of the mountain front varies considerably; where change in slope is gradual, the pediment-mountain front boundary shown is approximate.

GEMORPHIC CRITERIA FOR LANDFORM CLASSIFICATION

After a depositional surface is abandoned, geomorphic processes cause progressive, systematic changes in the surface and soil morphology with time. Relative ages can be established from differences in these morphologies. Criteria can be classified into three groups: altitudinal, topographic, and pedogenic.

Incision of the Tucson basin began during the latest Pliocene and continues to the present. This allows altitude to be used as an indicator of surface age. When stream power is enhanced by climatic change, downcutting occurs. Younger stream and fan terraces are progressively lower in altitude.

When a surface becomes isolated from active deposition, degradation begins immediately. On alluvial fans, this begins with infilling of bar and swale topography. The surface becomes more smooth. As this smoothing occurs, downcutting in the distal reaches of the fan, perhaps caused by downcutting of the axial drainage, leads to headward erosion in the fan itself. Gradually a tributary stream system develops, the reverse of the distributary pattern of an active fan. The divides between the fan channels, or interfluves, have flat crests and sharp banks initially. These may also be termed fan terraces. With time, the fan terrace scarp degrades and becomes less steep. The result is a rounded interfluve. The channel itself is modified through time. Initially, channels are V-shaped and narrow. With time the channels widen and become large enough to carry their own channel deposits, usually medium to coarse sand. Channel depth increases with time, also. The oldest fan surfaces are usually remnants of interfluves.

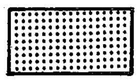
Terraces of the central basin are not as conspicuously affected by pulses of aggradation and degradation. Nonetheless, similar topographic criteria help distinguish surfaces.

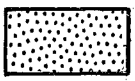
Degradation of terrace scarps is systematic. For similar heights, an older scarp will be more gentle than a younger scarp. Scarp crest sinuosity increases with age, as rills and gullies erode into the material. The oldest terraces are longitudinal ridges with broad, gentle bounding slopes. Scarps bounding the youngest terraces are commonly above the angle of repose, and consequently very unstable.

Another indicator of surface age is soil development. Many soil properties have been shown to change systematically with time (e.g., Harden and Taylor, 1983). In this study area, gross changes in soil morphology were noted on a reconnaissance basis to make distinctions between the major surfaces. The most basic characteristic is development of an argillic horizon, which generally indicates a Pleistocene age. Presence, thickness, and morphology of carbonate horizons can also used (Bachman and Machette, 1977). The oldest surfaces have thick petrocalcic (K) horizons and often this is the only part of the soil preserved. Thick laminations on the top of the K horizon indicates great antiquity (eg., Typic Paleorthid).

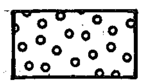
Surficial clasts are also modified through time. On all surfaces, biological processes result in varnish development. Varnish darkens with time. Gniessic clasts commonly have dark brown or black varnish on the exposed side. On the face down side, a bright orange-red varnish may develop.

SYMBOLS

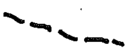
 exposed bedrock pediment

 buried pediment; cover up to 66 m (200 ft) thick

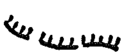
 areas underlain by Rillito I beds; dominantly mudstone*; may be exposed or veneered by younger sediments

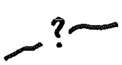
 areas underlain by Rillito I beds; interbedded mudstone and conglomerate*; may be exposed or veneered by younger sediments

 unit boundary

 gradational boundary; location approximate

 mountain front boundary

 bedrock pediment-mountain front boundary; location approximate

 contact location uncertain

*from Pashley (1966)

UNIT DESCRIPTIONS

Mapping was carried in a reconnaissance fashion, using aerial photographs (1:60,000) and fieldchecking. Because of the discrepancy between the scale of the photographs and the scale of the maps (1:24,000), some differences between the mapped and actual unit boundaries may exist.

cha- Active stream channel. This is topographically the lowest surface. Sediments are very poorly sorted. Flooding and sediment transport occur seasonally. Found in the largest washes.

ch- Historically active channel deposits. Includes very low terraces, bars, and boulder berms about 1 m or less above the stream channel. No soil development or varnish. Vegetation is not well established on these surfaces. Flooding and sediment transport are frequent but not necessarily annual. Often associated with cha in floodplains of major incised streams, but also is found in smaller tributaries.

T1- Lowest and youngest distinct terrace. It is recently abandoned and has only incipient soil development. Generally between one and two meters above the modern stream channel. It occurs discontinuously in reaches of Cienega Creek and Tanque Verde Creek. Latest Holocene to modern in age.

T2- Historically abandoned stream terraces occurring on the Santa Cruz River and Pantano Wash. Forms wide floodplain inset into stream valley. Soils are weakly developed (Torrifluvents). Topographically higher than T1 but several meters below T3. Gravelly sand dominates the sediments. Banks are unstable; recent incision and lateral erosion has left the banks standing at an angle greater than the angle of repose, often vertical. Middle to late Holocene in age.

T3- Narrow, discontinuous terrace intermediate in height between T2 and T4. Occurs near Pantano Wash. It is equivalent to the Jaynes terrace of Smith (1938). Soils have weakly to moderately developed argillic horizons and weakly developed calcic horizons. Banks commonly degraded to the angle of repose or lower. Late to latest Pleistocene in age.

T4- Widespread older terrace with variable but well-developed soils. Broad surface in central part of the Tucson basin; forms a narrow strip along Pantano Wash in the southeastern part of the basin. Scarp highly degraded, with a gentle slope and high sinuosity. Carbonate horizon development is strong stage III or weak stage IV (see Birkeland, 1984, table A-4). Fairly well-developed argillic horizon commonly present. Incipient development of ridge and valley topography. Experiences isolated sheetwash in gentle swales. Corresponds to the Cemetery terrace of Smith (1938). Middle to late Pleistocene in age.

T5- Highest and oldest preserved terrace. Widespread in the south-central and east central parts of the basin. Two to three meters above T4. Moderately developed ridge and valley topography. Isolated from flooding of axial streams. Thick petrocalcic horizons are present locally, often at or near the surface. Well-developed argillic horizons mostly eroded. Terrace scarps are no longer preserved. Corresponds to University terrace of Smith (1938). Probably represents a former level of maximum alluvial fill in the Tucson

Basin. Flooding restricted to lower ends of largest gullies. Early to middle Pleistocene in age.

Y- Active and recently active alluvial fans and broad, unincised channels low in the basin. Fans are incised less than one meter. Soil is undeveloped to weakly developed (Torriorthents and Torrifluvents), showing slight increases in carbonate and clay. Surficial clasts lack varnish. This unit is widespread at the southern end of Avra Valley, west of Black Mountain. It is also found in broad, shallow swales in the southern half of the Tucson Basin. Otherwise, it is generally restricted to the mountain fronts. It is topographically lower than other surfaces. Flooding occurs seasonally in broad channels. and somewhat less frequently in mountain front fans. In alluvial fans, Y is often a veneer less than 2 m thick; it is composed of subangular clasts less than 1 m in diameter. In the broad swales , it may veneer well-developed soils. Sediment transport and flooding are dominated by discontinuous ephemeral streams. Correlates with T2 and younger channel deposits.

M2- Recently abandoned alluvial fans. Streams headed in the fans are up to 2 m deep. Interfluves are flat to slightly rounded. Soils are weakly to moderately developed (Typic Torriorthents and Typic Haplargids). Carbonate stage I to II+ (see Birkeland, 1984). Elevation is intermediate between Y and M1. Flooding and sediment transport occur on distal reaches in the larger gullies. Desert Pavement is slightly developed but discontinuous. Clasts show light red varnish in some locations, but generally varnish is incipient. M2 occurs mainly at some distance from the mountain front, and is inset into older fans and pediments. Possibly correlative with T3.

M1- Older alluvial fans. Soils commonly contain petrocalcic horizons and argillic horizons may or may not be present. Rounding of interfluves has occurred, creating a hummocky surface. Incision up to 5 m present. Pavement moderately developed, and varnish is more common and more developed than in M2. Occurs close to the mountain fronts and may be associated with low pediments, particularly near the Sierrita Mountains. Flooding is restricted to the largest gullies. Fans are isolated from active depositional and fluvial processes. The gullies are U-shaped in cross-section and have sandy floors. Correlative with T4.

O- Highest and oldest alluvium in map area which has a preserved geomorphic surface. Rock varnish well-developed, being black on exposed side of rocks and bright red on the underside. Clasts consist mainly of cobbles and boulders, often capping Tertiary sediments and forming elongate ridges. Channels developed on fan surfaces are incised up to 10 m . Soil is rarely preserved. Where preserved, it contains a thick petrocalcic horizon (Typic Paleorthids). Flooding and sediment transport limited to gullies. O is found only near mountain fronts. Correlative to T5.

QTbf- Highly eroded gravelly alluvium, latest Pliocene to early Pleistocene in age. Geomorphic surface no longer preserved. Ridge and valley topography well-developed. Correlates to the Fort Lowell formation (Davidson, 1973).

Tsc- Relatively coarse-grained conglomeratic Tertiary sediments. Corresponds to the Rillito II and III beds of Pashley (1966). Found primarily in the northeast corner of the basin. Mapped from Pashley (1966).

Ts- Fine-grained Tertiary sediments. Includes the Rillito I beds of Pashley (1966). These are potentially subject to shrink-swell processes. Found primarily in the northeast corner of the basin. Mapped from Pashley (1966).

Br- Bedrock and bedrock pediments formed on rocks that pre-date Rillito I beds.

Ts-Y/Ts This represents a highly dissected area where underlying unit, in this case Ts, is widely exposed, but also capped by Y in many places. Cappings are often too narrow or discontinuous to map at this scale.

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