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Surficial Geology of the Northern Verde Valley, Yavapai County, Arizona

Clarkdale, Page Springs, Cottonwood, and Cornville Quadrangles

by

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Introduction

This report contains four detailed maps depicting the distribution of Quaternary alluvial deposits and their associated geomorphic surfaces in the northern portion of the Verde Valley. Preliminary age estimations based on relative age criteria and soil development characteristics are assigned to each unit. Each map also depicts the distribution of generalized bedrock types in the area. Geologic structures in the bedrock units other than the principal trace of the Verde Fault are not included in these maps.

Each map in this report contains a wealth of geological information concerning the effects of Quaternary climatic fluctuations on the evolution of the Verde River, its major tributaries, and adjacent piedmont areas. Evident in these maps is the strong influence of drainage basin and substrate lithology on the evolution of the regional landscape and the persistence of landforms. In addition, the maps contain information relevant to the distribution and character of flood hazards, vegetation assemblages, and potential soil problems.

Methods and Materials Used in Mapping

Preliminary mapping was based on interpretation of aerial photographs. The aerial photos used included: 1:24,000 scale black and white photos taken in 1977 and 1984; 1:24,000 scale color photos taken in 1984; 1:12,000 scale aerial photos taken in 1990; 1:20,000 scale black and white photos taken in 1954; 1:48,000 scale black and white photos taken in 1950; 1:58,000 scale color infrared photos taken in 1980; and 1:129,000 scale black and white photos taken in 1972. Stereoscopic analysis of these photo sets helped to accurately delineate the Quaternary deposits and the bedrock units. Aerial photo interpretation was augmented by field reconnaissance investigations. Final mapping was compiled on mylar overlays of 1:24,000-scale orthophoto maps. Mapping was then transferred to 1:24,000-scale topographic base maps (7 1/2' quadrangles). Aerial photos used in the mapping were provided by the Coconino National Forest Supervisors Office and the Soil Conservation Service Flagstaff Field Office. Mapping of Quaternary alluvium along the Verde River supplemented previously completed mapping by Pearthree (1993). In the Cottonwood and Clarkdale quadrangles, most of the generalized bedrock mapping was taken from previously published maps (Anderson and Creasey, 1958, 1967; Lehner, 1958). Bedrock mapping in portions of the Cornville and Page Springs quadrangles was based in part on previous work (Ranney, 1989; Karlstrom et al., 1984; Weir et al., 1989).

Map Unit Descriptions

The surficial deposits of the northern Valley are divided into 19 units based on their ages and source areas. These surficial deposits range in age from early Pleistocene-latest Pliocene (~2 Ma) to modern. Ten of these units were deposited by piedmont streams, and eight different ages of major river deposits (river channels and terraces) were recognized. In addition to the surficial deposits, our maps depict the distribution of two facies of basin-fill deposits (the Verde Formation) and four generalized bedrock units.

Surficial geologic units are arranged in a hierarchy based on approximate age and the source of the deposits. This hierarchy gave us the flexibility to differentiate units fairly precisely where feasible, but also permits us to group units or to use a less precise age designation for a unit where necessary. The five major groups of piedmont alluvial-fan and terrace deposits are the early Pleistocene-latest Pliocene Oxbow group, the middle Pleistocene Montezuma fan complex, the middle Pleistocene to early Holocene Chuckwalla group, the late Pleistocene to Holocene Sheepshead group, and late Holocene stream deposits. Most of these major groups have one or more levels of subgroups that are mapped separately in some areas and grouped in others. Terrace deposits of the major rivers are differentiated based on physical characteristics and height above the river. These river terraces are tentatively correlated with the major piedmont alluvial units based on their relative topographic relationships near the rivers. Generalized bedrock map units were developed using published geologic mapping covering this area.

Piedmont Alluvial Units

Oxbow Group: early Pleistocene to latest Pliocene
Map units O, O1, O2, O2a, O2b

The Oxbow group includes three levels of alluvial fans representing the oldest surficial alluvium preserved in the northern Verde Valley. These alluvial-fan remnants range from about 80 to 150 m above modern drainages and were likely deposited during the early Pleistocene to latest Pliocene (0.8 to 2.5 Ma). There is as much as 60 m of relief between older (O1) and younger (O2a and O2b) surfaces, implying that these units were deposited over a substantial interval. Soils developed on these units have well-developed calcic horizons (typically stage III to V; after Machette, 1985) and are extremely clay-rich where well preserved. Oxbow alluvium is a relatively thin veneer capping erosion surfaces cut on the Verde Formation. Deposit thickness typically is several meters and probably does not exceed 10 meters. Deposits are very poorly sorted coarse gravels. Particle sizes range from silt and sand to boulders, and clasts are typically subangular.

O1: latest Pliocene (~2 to 2.5 Ma)

The highest level of alluvial fan remnants in the Verde Valley, which are 100 m or more above modern drainages, are mapped as Unit O1. This unit is found on top of the gravel facies of the Verde Formation (Tvg) very near the Black Hills, and may actually represent the highest level of the Verde Formation. The only obvious difference between underlying gravels and the O1 surficial unit is the color imparted by soil development in the upper few meters of the O1 alluvium. Very few remnants of O1 exist in the map area. The best example of a well preserved O1 surface is "Catpaw Mesa" found in section 18, T15N R3E (Cottonwood quadrangle). This surface now stands more than 100 m (300 ft) above the modern drainages. A smaller, less well-preserved remnant is located approximately 1 mile southeast of Jerome. Elsewhere, possible erosional remnants of this unit are not distinguishable from the younger members of the Oxbow Group and are therefore designated "O".

O1 surfaces are quite planar where preserved. They support a low to moderate density acacia thorn scrub community; assorted grasses and prickly pear cactus are abundant. Surface materials consist of pebbles, cobbles, and boulders of metavolcanic rock and basalt in a clayey matrix. Surface color is dull reddish brown (5 YR 4/4). The soil is very clay-rich (heavy clay texture) and has angular blocky to weak prismatic structure. The very strong soil development and the extremely high topographic position of O1 units in the Verde Valley implies substantial antiquity. Menges and McFadden (1981) argued that similar alluvial fan remnants in southeastern Arizona date to the earliest Pleistocene or latest Pliocene. The highest levels of the fine-grained basin facies of the Verde Formation date to about 2 to 2.5 Ma (Bressler and Butler, 1978; Nations et al, 1981). If O1 deposits represent the highest level of the marginal gravel facies of the Verde Formation, they probably date to 2 to 2.5 Ma as well.

O2: early Pleistocene (0.8 to 2 Ma)

O2 units are high, thin, early Pleistocene alluvial fan remnants deposited on erosional surfaces cut into both the lacustrine and gravel facies the Verde Formation. O2 surfaces are fairly widespread in the Black Hill piedmont area south of Black Canyon and north of Cherry Creek. The most extensive well-preserved remnants are found below Catpaw Mesa where the source area lithologies are most resistant to erosion (metavolcanic and volcanic rocks).

In some areas there are two distinct levels of O2 surfaces (O2a and O2b). Physical characteristics of these surfaces are similar, so they can be distinguished only in areas where they are adjacent to each other. In some places, as in the vicinity of Catpaw Mesa, O2a is as much as 15 m (50 ft) higher than O2b. Closer to the Verde River, they differ by as little as 5 m (20 ft). The O2 designation is used in areas where it is not possible to distinguish two discrete surface levels.

O2 deposits are composed of sediment ranging from silt to boulders. Most of the clasts are metavolcanics and basalt. Surface color is dull reddish brown (5YR 4/4-5/4). The soil on well-preserved O2 surfaces is extremely strongly developed. Argillic horizons have heavy clay textures and are dark reddish brown (2.5 YR 3/3). A stage III to IV calcic horizon exists at approximately 80 cm. Soil structure is angular blocky to prismatic. On degraded surface remnants, the argillic horizon has been partially or completely stripped and the calcic horizon is encountered at or near the surface. Well-preserved O2 surfaces support grasses, small acacias, prickly pear cactus, and scattered junipers. In the areas where the surface has been eroded and the calcic horizon is either shallow or at the surface, the density of juniper is higher and crucifixion thorn is abundant. The extremely strong soil development associated with O2 surfaces and the high topographic positions they occupy indicate that they are very old. The fact that O2 surfaces were deposited at levels that are much lower than adjacent O1 surfaces implies that they are significantly younger than unit O1.

Montezuma alluvial fan complex: middle Pleistocene (~500 ka)
Map unit M

Extensive middle Pleistocene Montezuma alluvial fans comprise the thickest Quaternary deposits observed in the map area. These fan remnants are inset well below adjacent Oxbow surfaces but are 25 to 30 m (80-100 ft) above modern drainages. In the vicinity of Black Canyon, the alluvium is locally at least 25 m (80 ft) thick. Considerable variations in thickness of this unit suggest that it partially filled fairly deep valleys carved into the Verde Formation after deposition of the O2 alluvium. The best example of an M surface occurs along the northern side of Black Canyon in the southern portion of the Cottonwood quadrangle.

Montezuma surfaces are dominated by angular clasts of metavolcanic, volcanic, or granitic rocks. In some places a weak desert pavement is developed on the surface. The M surface is dull yellowish brown to brown. It hosts a low to moderate density community of prickly pear, mesquite and assorted desert grasses. Closer to the mountains and at higher altitudes the plant community is composed of moderate to high density stands of acacia, mesquite, and holly. Greater vegetation densities are also associated with M surfaces derived from granitic source areas south of Black Canyon. Soils associated with M surfaces are strongly developed with clay textures and moderately developed calcic horizons (stage II to III) at an approximate depth of 90 cm. Soft carbonate concretions are present below about 40 cm.

Chuckwalla Group: middle Pleistocene to early Holocene
Map units C, C1, C1a, C1b, and C2

The Chuckwalla group consists of relatively thin, broad, alluvial fans, and narrow stream terraces. Surfaces of the Chuckwalla group are much closer to the altitude of modern drainages than adjacent M and O surfaces. There typically is not substantial relief between the three units in the Chuckwalla group (C1a, C1b, and C2). Soil development differs substantially between the three units, however, indicating that the Chuckwalla group probably spans much of the late Quaternary (~250 to 10 ka).

C1: middle to late Pleistocene (50 to 250 ka)

The older deposits of the Chuckwalla group consist of extensive alluvial fans and terraces. The two subunits (C1a and C1b) differ primarily in degree of soil development and surface color. In areas where they are indistinguishable or intricately interspersed, they are grouped together in unit C1. C1 deposits cover much of the piedmont of the Black Hills west-northwest of Cottonwood. Unit C1a locally occurs as a terrace surface carved in extensive deposits of Montezuma alluvium. An example of this occurs on the southern side of the large fan emanating from Black Canyon in the Cottonwood and Cornville quadrangles.

C1a and C1b are both composed primarily of coarse sediments ranging from sand to large cobbles and small boulders. The C1a surface color ranges from dull reddish brown to bright brown (5 YR 5/4 - 7.5 YR 5/6). Soils typically have strong argillic horizons with light clay textures and moderately developed calcic horizons (stage II to III). In general, C1a is characterized by a relatively sparse shrub community and fairly good grass cover, but this varies considerably with local conditions and source area lithology. Predominant plants include prickly pear cactus, catclaw, assorted grasses. Based on the relatively strong soil development associated with C1a surfaces, we estimate their age to be ~125 to 250 ka. C1b surface color typically is slightly less red than C1a; soils are characterized by moderately developed argillic horizons (clay loam textures) and relatively weak calcic horizons (stage I to II). C1b surfaces are dominated by a relatively high-density thorn scrub assemblage including acacia, mesquite, and holly. Based on soil development, we estimate that C1b surfaces are significantly younger than C1a (~50 to 125 ka).

C2: latest Pleistocene to early Holocene (5 to 20 ka)

The youngest member of the Chuckwalla group (C2) includes thin alluvial fans adjacent to or very slightly inset into older C1 alluvium. C2 also includes low terraces adjacent to stream

channels confined by higher, older alluvium or bedrock. Areas where C2 surfaces are tightly interspersed with young stream sediments (Yp) are labeled as C2/Yp.

Unit C2 is composed primarily of coarse sediments ranging from sand to large cobbles and small boulders. Near the Verde River at Cottonwood the composition of the C2 alluvial fans is finer-grained and dominated by sand, pebbles, and minor silt. In the middle and upper piedmont areas, the C2 surface is characterized by a dense thornscrub thicket including catclaw, mesquite, and holly. Near the river, the vegetation is sparse. Much of the recent development in the city of Cottonwood has been on C2 fans.

Sheepshead Group: late Pleistocene to Holocene
Map units S, S1, and S2

The Sheepshead group consists of relatively fine-grained late Quaternary alluvium eroded from the Verde Formation. Unit S deposits consist of thin alluvial fan remnants, restricted piedmont stream deposits, and colluvium derived from cliffs of the Verde Formation. In many areas, unit S can be subdivided on the basis of soil development and relative topographic position (units S1 and S2). In areas where such distinction is not possible, the alluvium is labeled S. Sheepshead alluvium is extensive in most of the Page Springs quadrangle, the Cornville quadrangle between Oak Creek and the Verde River, along the flanks of the White Hills throughout the map area, and in the vicinity of Hayfield Draw in the Cottonwood quadrangle where a clay-rich unit in the Verde Formation is extensively exposed.

S1: late Pleistocene (10 to 125 ka)

The older unit of the Sheepshead group is most extensive along the foot of the White Hills in the Page Springs quadrangle. Here the unit is fairly oxidized such that the surface color is approximately bright reddish brown (5YR 5/8 - 5/6). The degree of reddening imparted by soil development and weathering is uncertain because of an abundance of red sandstone layers in the Verde Formation in this vicinity, but the soil color is redder than that of S2 alluvium. The unit consists of primarily relatively fine-grained sediments (clay, silt and sand) with lesser amounts of gravel. Because these sediments are derived from the Verde Formation, the soil is very calcareous. Vegetation is dominated by creosote and assorted grasses of low to moderate density.

S2: Holocene (0 to 10 ka)

The younger unit of the Sheepshead Group includes small alluvial fans, discontinuous stream deposits and low stream terraces adjacent to modern piedmont drainages. Along the east flank of the White Hills (Page Springs quadrangle) this unit is easily distinguished from S1 because it is not as red. The surface color is grayish grayish brown to dull brown (7.5 YR 6/2 - 6/3). S2 alluvium is typically fine-grained and consists primarily of clay, silt, sand, and minor gravel. The soil is very calcareous due to the abundance of calcium carbonate in the source rocks. Deeply incised, narrow arroyos are common in areas of S2 alluvium. Creosote bush and assorted grasses are common plants; vegetation density is variable.

Verde Mix: Indeterminate age
Map unit Vx

Unit designation Vx is used in areas where weathered bedrock, alluvium, and eolian materials are essentially indistinguishable. Typically, this unit consists of a very thin mantle of unconsolidated deposits of uncertain origin over Verde Formation. Unit Vx is exclusively related to the Verde Formation; it is most extensive in the Page Springs quadrangle and in the area north of the confluence of the Verde River and Oak Creek in the Cornville quadrangle. Some contacts between Vx and Sheepshead alluvium are arbitrary because they grade together. In general the Vx designation was reserved for interfluve areas relatively high above modern washes.

Young Piedmont Alluvium: late Holocene (< 5 ka)
Map unit Yp

This unit consists of modern channel deposits and low terraces along piedmont drainage courses. It also includes small alluvial fans that have prograded onto the youngest terraces of the Verde River and Oak Creek. Composition ranges from extremely coarse very near the Black Hills (sand, gravel, cobbles, and boulders) to more fine-grained (silt, sand, gravel) elsewhere. Unit Yp is found throughout the map area in and near ephemeral drainage courses.

Major Stream Deposits

Oxbow Terraces: early Pleistocene (0.8 to 2 Ma)
Map units OT1, OT2, OT3

Three very high and old terrace remnants are found along Oak Creek and the Verde River. These O terraces were grouped together because of their topographic isolation above other

terraces. The oldest terraces (OT1) are about 85 to 100 m (280-350 ft) above the modern river channels; OT2 terraces range from about 55 to 70 m (180-220 ft) above the river; OT3 terraces range from about 50 to 55 m (160-180 ft) above the river. They all likely date to the early Pleistocene, and thus were deposited during the same general interval as the Oxbow piedmont alluvial units.

The oldest river terraces (OT1) are about 200 m (700 ft) below the highest levels of the fine-grained facies of the Verde Formation. Thus, OT1 is almost certainly much younger than the O1 piedmont surfaces, which probably represent the highest levels of the Verde Formation. O2a alluvial-fan remnants are at about the same altitude as OT2 near the Verde River, so they are of similar age. O2b can not be directly correlated with OT3, but O2b is well above the level of the next younger river terrace (MT), suggesting that it generally correlates with OT3. Terraces in the O group are found much farther from the present courses of Oak Creek and the Verde River than any of the younger terraces. Deposits are typically fairly thin, poorly sorted silt to gravel. Soil development is strong, with substantial clay and calcium carbonate accumulation; locally, soil horizons are cemented with calcium carbonate.

Montezuma Terraces: middle Pleistocene (~500ka)
Map unit MT

Montezuma terraces (MT) are still high above the modern rivers but are found in locations relatively close to the present positions of the Verde River and Oak Creek. MT terraces are not, however, restricted to the interiors of relatively narrow canyon reaches and in fact are often found on bedrock shelves that line the periphery of such reaches. They are typically 25 to 30 m (80-100 ft) above the modern river channels. The Montezuma alluvial fan complex is clearly graded to the MT near the Verde River, so they must be of equivalent age (middle Pleistocene). Soil development is fairly strong, and deposits are typically coarse gravel facies.

Chuckwalla Terraces: middle Pleistocene to early Holocene (5 to 250 ka)
Map units CT1 and CT2

Chuckwalla terraces are found in very close proximity to the present positions of the Verde River and Oak Creek. They are of limited areal extent and are restricted to the interior of narrow canyon reaches. The older terrace (CT1) ranges from about 12 to 18 m (40-60 ft) above modern river channels; C1 piedmont deposits are graded to terrace CT1. CT1 thus dates to the middle to late Pleistocene. The younger terrace (CT2) is about 6 to 12 m (20-40 ft) above modern river channels; C2 piedmont deposits are graded to CT2 terraces, implying that CT2 terraces are of

latest Pleistocene to early Holocene age. Typically, deposits are coarse gravel facies of relict channels and bars and are less than 5 m thick. Soil development is moderate, with some clay accumulation. CT terraces are fairly resistant to stream erosion and are not inundated during large floods.

Young Terraces: late Holocene (<5 ka)
Map unit YT

This unit comprises the young, relatively thin terrace deposits along the Verde River and Oak Creek. YT terraces are less than about 6 m (20 ft) above the lowest portions of river channels and are almost always found directly adjacent to the channels. The principal exception to this is at Peck's Lake in the Clarkdale quadrangle, where a meander of the Verde River has evidently been cut off quite recently leaving a low area covered with late Holocene deposits. Yp piedmont channels are graded to YT terraces in some places. YT terrace deposits are composed of two distinct facies, a coarse gravel facies composed of abandoned channels and bars, and a fine facies composed of sand deposited in low velocity, slack-water areas during large floods. YT deposits are weakly consolidated and are susceptible to bank erosion, although riparian vegetation tends to stabilize these deposits. YT terraces have minimal soil development. We estimate that they are less than 5 ka in all cases, and are typically tens of years to a few thousand years old. Most if not all YT terraces may be subject to inundation during large floods.

Active Channels of Major Streams: Modern
Map unit Yr

Active channel and flood channel deposits of the Verde River and Oak Creek. This unit consists of silt, sand, gravel, and cobbles in the active channel areas of both major drainages in this portion of the Verde Valley. Most of this unit is the active bed of each stream, the remainder includes areas that convey floodwaters frequently enough to limit the development of mature riparian plant communities (i.e. dense stands, no large trees).

Generalized Bedrock Units:

Verde Formation: late Miocene to Pliocene

Tvl: lacustrine facies: composed of freshwater limestone, sandstone, siltstone and marl This unit is exposed throughout the map area particularly in the White Hills and along the Verde River south of the Oak Creek Confluence. In most areas, the Verde Formation is a cliff-

forming unit, but in areas where clay rich layers are exposed it is characterized by soft-looking slopes and occasional badlands-type topography.

Tvg: gravel facies. alluvial fan deposits composed of primarily gravel and cobbles. Diverse lithologies. This unit is concentrated along the eastern flank of the Black Hills and occurs as rounded, high-standing hillocks that are conspicuously gray-colored.

Tvu: undifferentiated Verde Formation. This designation is used in areas where the lacustrine and gravel facies are interbedded or indistinguishable.

Basalt: Miocene and Pliocene

Tb: Late Cenozoic basalt flows and local sediments. This bedrock type is found scattered through the map area. It caps Mingus Mountain and several mesas along the Mogollon rim. Some basalt also occurs in Box canyon along the Verde River north of Clarkdale where flows occur within the Verde Formation. The largest exposure of Tb is in the Page Springs Quadrangle in the area between the White Hills and Oak Creek.

Sedimentary Rocks: Paleozoic

Pzs: Sedimentary rocks ranging from limestone and dolomite to sandstone. These rocks are abundant in the Black Hills west of the Verde Fault and in scattered locations in the foothills. The largest exposures are in the Black Hills and Mogollon Rim areas north and east of Clarkdale.

Metavolcanic Rocks: Precambrian

Xmv: Metavolcanic rocks ranging from basalt to rhyolite. These rocks are found throughout the black hills north of Black Canyon

Intrusive Igneous Rocks: Precambrian

Xqd: Quartz diorite. This rock is most abundant in the Black Hills south of Black Canyon.

General Geologic Setting of the Verde Valley

The Verde Valley is one of several roughly northwest-southeast trending basins in the Transition Zone geological province of Arizona. Structurally, it is a half-graben bounded on its southwest margin by the Verde Fault, a high angle normal fault along which the Black Hills have been uplifted. The Valley is bounded on the north and east by the Mogollon Rim, a prominent escarpment marking the southern edge of the Colorado Plateau.

In the late Miocene the ancestral drainage from the Verde Valley was blocked, probably by a combination of structural subsidence and volcanic activity at the southern margin of the valley (Bressler and Butler, 1978; McKee and Elston, 1980). The absence of consistent external drainage resulted in the deposition of the Verde Formation, an extensive and varied sedimentary unit composed primarily of lacustrine, fluvial, and volcaniclastic sediments and interbedded lava flows. Concurrent with the accumulation of sediments in the middle of the basin, thick deposits of gravel were laid down as alluvial fans by streams entering the basin from the surrounding highlands. Deposition of the rocks in the Verde Formation lasted from approximately 8.5 to 2.5 Ma (Bressler and Butler, 1978; Nations et al., 1981, McKee and Elston, 1980). Interbedded basalt flows in the Verde Formation have yielded dates of 4.5 Ma, 5.5 Ma, (McKee and Anderson, 1971) and 8.3 Ma (McKee and Elston, 1980).

The geomorphic evolution of the Verde Valley changed dramatically in the latest Pliocene. Major stream downcutting and basin dissection was initiated when the through-going Verde River drainage began to breach the natural volcanic/structural dam at the southeastern end of the Verde Valley. This transformation occurred sometime in the latest Pliocene (Bressler and Butler, 1978; Nations et al., 1981). Subsequently, the geomorphology of the valley has been shaped primarily by the long-term downcutting of the Verde River and large-scale climatic variations during the Quaternary period.

Quaternary Geology and Geomorphology of the Northern Verde Valley

Quaternary deposits and associated landforms mapped in this study record the recent geologic evolution of the northern Verde Valley. Quaternary deposits consist of extensive, usually thin, alluvial fans and eroded alluvial fan remnants along the flanks of the surrounding highlands and sediments deposited by the Verde River and Oak Creek. Each Quaternary deposit has an associated geomorphic surface existing in some degree of preservation ranging from pristine to degraded.

A fluvial geomorphic surface is a distinct landform resulting from the attainment and subsequent abandonment of an equilibrium level of aggradation or degradation. The term equilibrium refers to the condition in which a balance exists between the rate of delivery of

sediment to a stream system and the rate of removal of sediment from the system (Bull, 1991). A disruption in the balance may lead to either aggradation or degradation by the affected stream. The attainment of equilibrium results in the formation of a relatively uniform, planar surface (alluvial fan, pediment, or stream terrace) composed of, or capped by, alluvium. Abandonment of a fluvial geomorphic surface is usually associated with incision by streams in response to changes in the sediment and/or water discharge characteristics of their tributary drainage basins; however, abandonment may simply occur in response to major lateral changes in stream channel positions. The first mechanism involves a departure from equilibrium conditions and can have the most lasting effect on the landscape through isolation of surfaces from major episodes of erosion for thousands to hundreds of thousands of years. The stimulus for this type of change can come from climatic change, tectonic processes, or some combination of the two. In the Verde Valley, climatic change and the long-term tendency for stream downcutting have dominated the area's geomorphic evolution over the past 2 million years.

Once a surface is abandoned, it is subject to erosion only from hillslope processes, small, superposed drainage networks, and lateral erosion by major streams and tributaries. The long-term preservation of a fluvial geomorphic surface depends on the resistance of its constituent alluvial materials to erosion, the original extent of the surface, its position relative to major streams, and, to some degree, chance. Over time, an undisturbed surface undergoes weathering and soil formation. These processes continue indefinitely unless the surface is obliterated by erosion or buried by renewed aggradation from major streams. Under ideal conditions of surface preservation, the degree of soil development reflects the time that has elapsed since the surface was isolated from major fluvial activity. Specific soil characteristics, such as maximum clay and calcium carbonate contents, change progressively with time. These characteristics can be evaluated and related to dated soils formed under generally similar climatic conditions to estimate the surface age (Gile et al., 1981; Bull, 1991).

The Verde River and Oak Creek are the fundamental controls on the development of alluvial landforms in the Verde Valley because all tributaries are graded to them. The long-term tendency of these major streams has been to downcut, possibly because of regional uplift of the Transition Zone during the Pliocene and Quaternary (Pewe, 1978; Menges and Pearthree, 1989). The pattern of geomorphic change along these major streams must be reflected in the assemblage of landforms in the piedmont areas. Seven distinct levels of Verde River and Oak Creek terraces were identified in this mapping project. These terraces and terrace remnants range in age from recent (the modern channel and floodplain) to early Pleistocene. Seven roughly correlative levels of piedmont alluvial surfaces were also identified, but correlation between terrace remnants and piedmont alluvial surfaces is uncertain in most cases. Only in a few instances do fans clearly grade into terraces. It is

likely that geomorphic processes in major streams and tributary piedmont drainage systems operate on different time scales, and thus their response times vary considerably.

During the Quaternary the Verde River and Oak Creek have downcut at least 300 m (1000 ft) into the basin fill deposits (Verde Formation) of the Verde Valley. Downcutting apparently has been episodic, however, with river terraces representing intervals of stability or minor aggradation. Piedmont landforms indicate that the period of net downcutting has included at least one period of major aggradation during the middle Pleistocene and several periods of base-level stability. At the present time, both the Verde River and Oak Creek appear to be in a downcutting phase because of the presence of bedrock at or very near their beds in many reaches.

Latest Pliocene-Early Pleistocene. The latest Pliocene-early Pleistocene evolution of the Verde Valley is represented by fans and terraces of the Oxbow group. This group comprises three distinct alluvial fan surface remnants and three distinct stream terrace remnants. These units have been grouped together primarily because they are found at considerably higher levels than any of the younger surfaces and their soil development is very strong.

The O1 unit represents the highest and oldest alluvial fan surface remnants in the Verde Valley. Because of its antiquity, it has been obliterated by erosion throughout the valley except in a few isolated locations. The O1 alluvium rests atop the coarse gravel facies of the Verde Formation (Tvg); however, the nature of the stratigraphic relationship between these two units is unclear. Either the O1 surface represents the depositional surface of the Verde Formation fan facies or it is a veneer of alluvium deposited on an erosion surface carved in the Verde formation. The altitude of O1 surface remnants is about 4800 ft above mean sea level (MSL). The highest remnants of the fine-grained facies of the Verde Formation (Tvl) in the mapped area are about 4400 ft above MSL. The highest preserved river terrace remnants (OT1) are about 3700 ft above MSL. These relationships imply that the O1 surface is substantially older than the highest preserved river terrace remnants and could have been graded to the highest levels of the Verde Formation. They also imply that major amounts of downcutting occurred during the latest Pliocene to early Pleistocene.

O2 encompasses two alluvial units that are at least 60 m (200 feet) lower than O1 in the upper piedmont near the Black Hills. Extensive scattered remnants of O2a occur west of the Verde River below its confluence with Oak Creek and in the Cornville Quadrangle, indicating that a large, thin, fan probably associated with the Cherry Creek drainage once occupied a significant portion of this area. Where this fan remnant is adjacent to the modern Verde River channel it is graded to the OT2 terrace remnant. The O2 piedmont units are both thin and cap an erosion surface carved in the Verde Formation. Field observations and aerial photo interpretation indicate

that this unit varies in thickness from approximately 15 m (50 ft) to less than 3 m (10 ft). The O2 fans represent periods of equilibrium during a period of fairly dramatic downcutting.

The distribution of O terraces along Oak Creek and the Verde River reveal periods of relatively widespread lateral planation of the Verde Formation that are generally correlative to the stable intervals represented by the O2 fan remnants. In places, OT remnants are found more than 1.4 km (1 mile) from present channel positions along both streams. The Duff Flat area in the Clarkdale quadrangle illustrates these relationships. The distribution of OT remnants throughout much of Duff Flat indicates that this embayment was carved by the Verde River in the early Pleistocene. Along Oak Creek in the vicinity of the Verde River confluence, an interesting assemblage of OT2 remnants depicts a former, tight meander in the channel. Below the confluence, OT remnants are fairly widespread, but they follow the general trend of the present channel. Deep canyons and embayments adjacent to these terraces in many places were probably carved by the Verde River and Oak Creek during a major erosional interval in the early to middle Pleistocene.

Early to Middle Pleistocene. The middle Pleistocene Montezuma alluvium comprises extensive alluvial fans that are the thickest Quaternary alluvial deposits in the northern Verde Valley. Deposition of the Montezuma alluvium represents a major period of backfilling following an episode of relatively deep erosion into the Verde Formation. At sites where Oxbow surfaces and Montezuma surfaces are adjacent to each other, the Montezuma surface is approximately 45 to 60 m (150-200 ft) below the contact between O2 alluvium and the Verde Formation. In the Black Canyon area the Montezuma alluvium is as much as 25 m (80 ft) thick. Thus, piedmont drainages eroded valleys as deep as 80 m after deposition of O2 alluvium ceased and prior to deposition of Montezuma alluvium. This implies that the Montezuma alluvium was deposited long after the O2 surfaces were abandoned. Montezuma alluvium likely represents an interval during the middle Pleistocene when climatic changes drastically increased the sediment supply to piedmont drainages, resulting in a pulse of deposition that temporarily overwhelmed the long-term tendency for downcutting.

At various sites along the Verde River and Oak Creek, M fans are graded to MT terrace remnants. Many MT surfaces along the river south of Cottonwood and north of the Oak Creek confluence that have morphological characteristics typical of terraces (and are mapped as such) are capped by thin fan deposits. In these areas, terrace and fan deposits may interfinger, indicating that the fan/terrace transition may have been variable over a relatively broad area, and that the average position of the river was northeast of its current position. The continuous influx of sediment from aggrading fans along the flank of the Black Hills was probably sufficient to push the river northeast. This situation probably characterized all periods of aggradation along the Black Hills piedmont.

The general positions of the Verde River and Oak Creek were probably established in the erosional interval separating the abandonment of the Oxbow surfaces and the deposition of the Montezuma alluvium. The distribution of O terraces clearly indicates that the channels were relatively mobile at times in the early Pleistocene; however, the distribution of M terraces primarily is limited to bedrock shelves lining the periphery of incised reaches of both streams. This situation may indicate that backfilling along both streams was limited to incised reaches formed following the abandonment of O2 surfaces, and the terrace remnants represent the highest level of backfilling reached by each stream. Attainment of this level was probably accompanied by some lateral planation of the Verde Formation. Subsequent incision along Oak Creek and the Verde River was largely restricted to the alluvium filling the canyons and has re-exposed and deepened the canyons formed in the early-middle Pleistocene.

Middle Pleistocene to Holocene. The alluvium in the Chuckwalla group represents a prolonged period of relative base level stability along the major trunk streams. The group includes three different alluvial units that are topographically much lower than adjacent Montezuma surfaces. Soil development characteristics in the three members of the Chuckwalla group indicate that there is a substantial range in their ages, yet the three surfaces are separated only by minimal amounts of relief. The lack of relief between Chuckwalla surfaces suggests that the middle to late Pleistocene was an extended period of relative base-level stability. This relative stability evidently followed a period of fairly dramatic downcutting and valley formation that followed deposition of the Montezuma alluvial fans. During the Chuckwalla phase piedmont streams eroded laterally and distributed relatively thin deposits over broad portions of the piedmont.

The oldest member of the Chuckwalla group (C1a) is an erosional surface cut in Montezuma alluvium in some places. In some locations bedrock can be seen protruding through the C1a alluvium. The youngest member of the Chuckwalla Group (C2) is inset slightly into the C1 units. The relative topographic difference becomes more pronounced with proximity to the river and C2 fans taper to low terraces adjacent to drainages incised into older fan remnants. Elsewhere, C2 fans become widespread near the river and appear to merge with CT1 surfaces.

In portions of the Verde Valley small streams head in areas underlain entirely by the Verde Formation, and the nature and preservation of Quaternary alluvial deposits (the Sheepshead group) is considerably different from areas where streams head in areas with more diverse and resistant lithology. The probable reasons for the major differences in the nature of the Sheepshead deposits and the other deposits in the valley include the high erodibility of the fine-grained facies of the Verde Formation and the distance of the source basins from the trunk streams. Many of the small streams heading in the White Hills have relatively rugged basins, but they are very small and quite far removed from the influence of changes along the Verde River and Oak Creek. Also, the high erodibility of portions of the Verde Formation results in heavy sediment loads which may

lead to lesser amounts of downcutting in the upper portions of the streams. Additionally, the fine-grained nature of the Sheepshead alluvium is not conducive to the long-term preservation of alluvial surfaces.

Holocene: The geomorphic evolution of the Verde Valley following the deposition of Chuckwalla alluvium has apparently followed a trend dominated by downcutting. The only young units that are widespread in the area are stream deposits and relatively low-lying floodplain terrace deposits associated with the modern drainage net and the major through-going rivers. Along Oak Creek and the Verde River, the young terrace deposits are quite extensive in wide reaches of each stream. Some young, small alluvial fans are found in areas where small piedmont streams debouch onto relatively flat stream terraces of the Verde River and Oak Creek. Because bedrock is exposed in the beds of many piedmont streams and is apparently shallow along reaches of the Verde River and Oak Creek, the late Holocene may represent the deepest level of incision reached in the valley during the Quaternary.

Summary

The northern Verde Valley is characterized by a diversity of geomorphic surfaces that document approximately 2.5 million years of fluvial system response to net downcutting along the Verde River and major changes in climate. Geomorphic surfaces along the eastern flank of the Black Hills and along the Verde River and Oak Creek range in age from latest Pliocene to recent. In this report, the Quaternary has been divided into four major phases of fluvial activity. (Oxbow: early Pleistocene, Montezuma: middle Pleistocene, Chuckwalla: late-middle Pleistocene through middle Holocene, and Post-Chuckwalla: middle Holocene to recent).

Lithologic diversity in the surrounding highlands and interior portions of the Verde Valley has resulted in an interesting and varied landscape. Surfaces emanating from basins underlain by volcanic and metavolcanic rocks in the Black Hills have persisted in pristine condition since at least the early Pleistocene; in contrast, no surfaces associated with drainages underlain by the highly erodible Verde Formation are older than about late to middle Pleistocene.

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Plate 1a. Surficial Geology and Generalized Bedrock Geology along the Verde River from Sullivan Lake to Horseshoe Reservoir.

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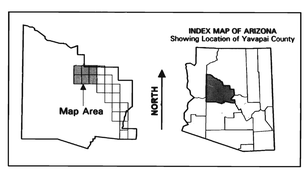

Plate 1b. Surficial Geology and Generalized Bedrock Geology along the Verde River from Sullivan Lake to Horseshoe Reservoir.

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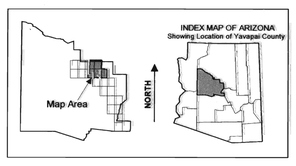

Plate 1c. Surficial Geology and Generalized Bedrock Geology along the Verde River from Sullivan Lake to Horseshoe Reservoir.

Plate 1d. Surficial Geology and Generalized Bedrock Geology along the Verde River from Sullivan Lake to Horseshoe Reservoir.

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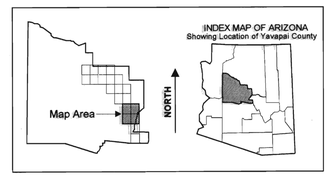

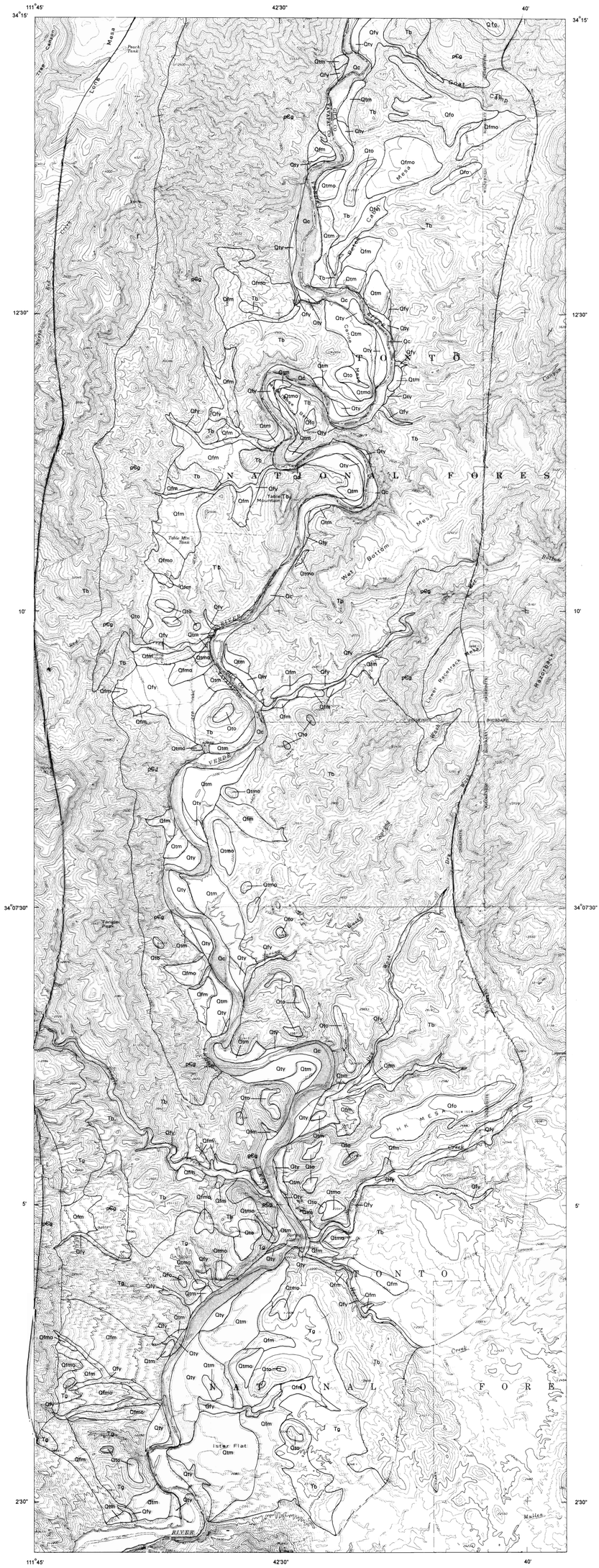

Plate 1e. Surficial Geology and Generalized Bedrock Geology along the Verde River from Sullivan Lake to Horseshoe Reservoir.

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