

**Surficial Geology and Geoarchaeology
of San Cristobal and Growler Valleys,
Barry M. Goldwater Air Force Range,
Southwestern Arizona**

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INTRODUCTION

This report summarizes geoarchaeological investigations and surficial geologic mapping conducted on part of the Barry M. Goldwater Air Force Range (BMGR) in southwestern Arizona in 1996. These investigations were done in support of an extensive archaeological survey along San Cristobal and Growler washes, in the west-central part of this vast desert reserve (Slaughter and others, 2000; see Figure 1). The natural and cultural resources of the BMGR are jointly managed by the U.S. Air Force and the Bureau of Land Management. Funding for these investigations was provided by the U.S. Air Force as part of their ongoing efforts to assess and effectively manage the resources of the BMGR.

Detailed surficial geologic mapping done at 1:24,000 scale covers all of the area of the archaeological survey; thus, detailed mapping covers all of the valley axis and substantial piedmont areas as well. Surrounding piedmont areas were mapped on a reconnaissance basis at a scale of 1:100,000. This geologic mapping is summarized in Part 1 that follows, as well as on plates 1, 2, and 3. The geomorphology and geoarchaeology of a number of archaeological sites discovered during the survey was assessed in more detail. These investigations are outlined in Part 2.

Acknowledgments

Numerous individuals contributed to these geomorphologic investigations. We would like to thank all of the members of the archaeological field crew, who were very entertaining company even after they had spent many weeks in the desert. In particular, we thank Mark Slaughter, who oversaw the field efforts, coordinated our field investigations with those of the archaeological survey, provided lots of information about the archaeology of the region, and generally kept us from getting into too much trouble. We also benefited substantially from discussions with Annick Lascaux, Dave Tucker, and Rick Ahlstrom of SWCA, and Bruce Masse of Luke Air Force Base, who provided useful insights into the archaeology of this part of the world. Ken Houser helped coordinate logistical aspects of these investigations. Kirk Vincent and Andres Meglioli provided field assistance and feedback for the geologic and geomorphologic aspects of our investigations. Jeanne Klawon and Tim Orr assisted with production of surficial geologic maps, and Tim Orr is responsible for the final map layout.

PART 1. SURFICIAL GEOLOGY AND GEOMORPHOLOGY

by Philip A. Pearthree and Karen A. Demsey, Arizona Geological Survey

Introduction

This portion of the report summarizes the surficial geology and geomorphology of the San Cristobal and northern Growler valleys of southwestern Arizona, in the central portion of the Barry M. Goldwater Air Force Range. The purpose of these investigations is to provide a geologic and geomorphic framework for an archaeological survey of San Cristobal and Growler washes that was conducted for the Air Force by SWCA, Inc, and Arcadis Geraghty and Miller. Maps included with this report are a 1:100,000-scale reconnaissance surficial geologic map of the entire area covered and several 1:24,000-scale maps that cover portions of the study area (Figure 1). Interpretation of aerial photographs and 1:100,000-scale mapping was done primarily by K. Demsey, with limited field checking by P. Pearthree. Larger-scale mapping was done primarily by P. Pearthree, with aerial photo interpretation by K. Demsey and field assistance from Andres Meglioli, Andrea Freeman, and Kirk R. Vincent.

Several previous geologic investigations have been conducted in this area. Kirk Bryan explored this area as part of a project to locate and evaluate potential water sources. He described the general geology and physiography of this area, and made many astute observations about the processes that have shaped this landscape. This portion of Arizona was mapped on a reconnaissance basis by E.D. Wilson and R.T. Moore as part of their efforts to develop a 1:500,000-scale geologic map of Arizona (Wilson and others, 1969). The bedrock geology of the Ajo 1:250,000-scale sheet, which includes the project area, has subsequently been mapped in somewhat more detail (Gray and others, 1988). The bedrock and surficial geology of the Aguila Mountains 15-minute quadrangle was mapped by Tucker and Tosdal (Tucker, 1980). Most of their efforts were focused on mapping the bedrock and geologic structures of the mountain range, but they also mapped the surficial geology of the surrounding areas. They differentiated and described four alluvial units that range in age from Holocene (see Table 1 for definitions of age terminology used in this report) to early Pleistocene. They mapped one unit that is dominated by eolian deposits and landforms. The generalized surficial geology of the Ajo sheet was mapped by Morrison (1983) at 1:250,000 scale. Mayer and others (1984) measured clast sizes on Pleistocene and Holocene surfaces in the Mohawk - Stoval area in northern San Cristobal Valley. They found that Holocene sediments are coarser near the mountain fronts, but the particle sizes decrease more rapidly away from the mountain front in Holocene deposits. They found that more coarse sediment was supplied to the streams from the mountain hillslopes during the Holocene than during the late Pleistocene. From these data they infer that vegetation was more abundant on hillslopes and colluvial cover was more extensive and more stable during the late Pleistocene, which caused rock to weather into smaller fragments on the hillslopes prior to being supplied to the stream systems. Bull (1991) developed a conceptual framework for understanding the impacts of climatic changes on arid region fluvial systems of the lower Colorado River region.

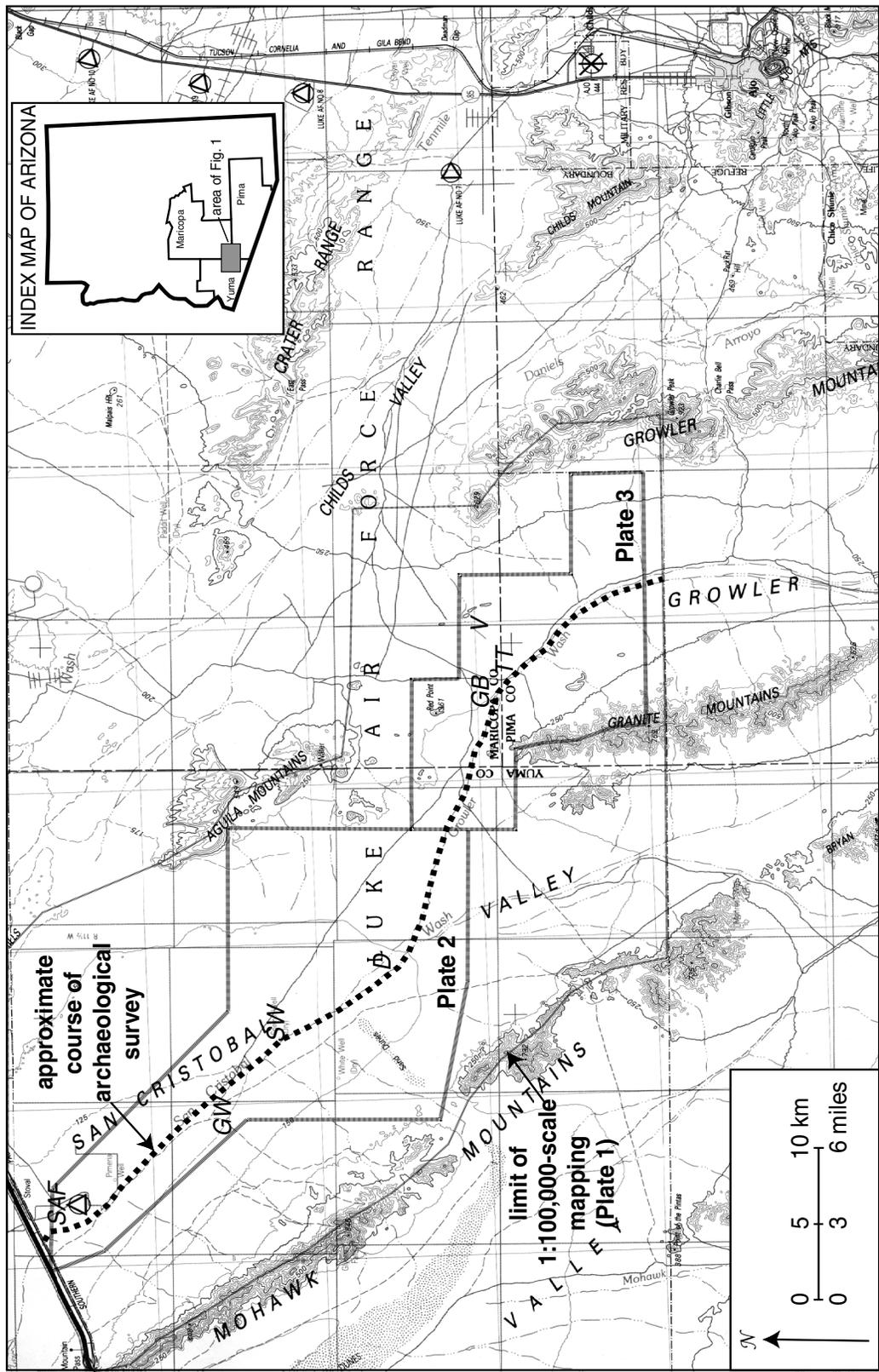


Figure 1. Approximate limits of surficial geologic mapping for this project. The reconnaissance 1:100,000-scale map (Plate 1) outlines the geologic setting of the archaeological survey. Larger-scale surficial geologic mapping covers the archaeological survey in San Cristobal Valley and in the Tony Tank - Growler Bend area (Plates 2 and 3). Sites mentioned in the report are labeled as follows: SAF, Stoval Airfield; GW, Garcia Well; SW, Spains Well; D, Dune site; TT, Tony Tank; and V, Verbena Village.

Period	Epoch	
Quaternary (0 to ~2 Ma)	Holocene (0 to 10 ka)	late Holocene (0 to 2 ka) middle Holocene (2 to 8 ka) early Holocene (8-10 ka)
	Pleistocene (10 ka to ~2 Ma)	late Pleistocene (10 to 150 ka) middle Pleistocene (150 to 750 ka) early Pleistocene (750 ka to ~2 Ma)
Tertiary (~2 to 65 Ma)	Pliocene (~2 to 5.5 Ma)	
	Miocene (5.5 to 22 Ma)	
	Oligocene (22 to 38 Ma)	
Cretaceous (65 to 145 Ma)		
Precambrian (570 Ma to 4.5 Ga)		

Table 1. Time intervals as used in this report. “Thousands of years before present” is abbreviated as **ka**; “millions of years before present” is abbreviated as **Ma**; “billions of years before present” is abbreviated as **Ga**. The first two columns list formal subdivisions of geologic time with established ages, although there is some dispute regarding the age of the inception of the Quaternary. Subdivisions are listed only if there are lithologic units of that age in the study area. The last column consists of informal time subdivisions defined for this report.

General Geology and Geomorphology

San Cristobal and Growler valleys are located in the middle of the Sonoran Desert subprovince of the Basin and Range physiographic province. The Basin and Range province includes southern, central, and western Arizona, all of Nevada, parts of California, New Mexico, Oregon, Texas, and Utah, and much of northwestern Mexico. The physiography of the Basin and Range province is characterized by alluvial basins and intervening mountain ranges that formed as a result of normal faulting related to extension of the crust during the past 30 million years or so (Shafiqullah and others, 1980). Relatively narrow and not very high, north- to northwest-trending ranges and broad, minimally dissected basins are typical of the Sonoran Desert subprovince. These characteristics imply that significant normal faulting has not occurred for millions of years in this area (Shafiqullah and others, 1980; Menges and Pearthree, 1989).

The bedrock geology of the project area has generally been mapped on a reconnaissance basis. Bedrock lithologies consist of metamorphic rock of Precambrian age (Mohawk Mountains), granitic rock of Precambrian or Cretaceous - early Tertiary age (Granite, Mohawk and southernmost Aguila mountains), silicic to mafic volcanic rocks of Oligocene to middle

Miocene age (Aguila and Growler mountains), and basalt (northern Aguila Mountains) (Gray and others, 1988; Tucker, 1980). Several bedrock hills or ridges that rise above the floor of Growler Valley are mapped as Tertiary basalt. Reconnaissance field investigations conducted as part of this survey indicate that at least some of these hills are composed of silicic to mafic volcanic rocks, all of which are coated with dark rock varnish.

Growler and San Cristobal valleys are part of the lower Gila River drainage system. The Gila River has provided a relatively stable base level for these streams through the Quaternary and late Pliocene. Net downcutting on the lower Gila during this period has been about 5 m/m.y. (Menges and Pearthree, 1989), although a fairly recent period of downcutting or lateral erosion by the Gila River has caused San Cristobal Wash to downcut into Pleistocene deposits downstream from the Stoval Airfield area (Bryan, 1925a). The low gradients of the larger streams in this region and the general lack of dissection in the valleys imply that the basins have been slowly aggrading over the long term.

The geomorphology and surficial geology of San Cristobal and Growler valleys may be grouped into three main elements (see Figure 2):

(1) Narrow, rugged, but not very lofty mountain ranges. The topographic fronts of the mountains are very embayed and sinuous, and outlying bedrock hills (inselbergs) are common. The very steep mountain slopes with minimal cover of colluvium attest to the predominance of erosional processes (Bryan, 1925a). Erosion is facilitated by uncommon but intense rainfall and runoff, steep slopes, and sparse vegetative cover. It is likely that significantly more hillslope colluvium covered bedrock slopes in the mountains during glacial pluvial intervals of the Quaternary, especially in mountains composed of granitic or metamorphic rocks (Bull, 1991).

(2) Broad, undissected floodplains and small channels associated with the major washes. The major washes in this region generally flow down the axes of the valleys about midway between the adjacent ranges. Wide floodplains associated with these washes are composed mainly of sand, silt and clay, with local gravelly channel deposits. Multiple small, discontinuous channels are typical, and well-defined channels are unusual. One or a few larger, well-defined channels exist along limited reaches of the axial drainages. Eolian reworking of floodplain deposits is common, especially in areas that have not been flooded recently.

(3) Very wide piedmonts with minimal topographic relief that slope gently from the mountains to the axial washes. Piedmonts are covered by alluvial and eolian deposits, most of which are fairly young. Upper piedmont areas typically have tributary (converging downstream) drainage systems. Middle and lower piedmonts have weakly integrated, complex distributary (diverging downslope) drainage networks. There is little topographic relief; channels are entrenched as much as 2 to 3 m below adjacent relict fan surfaces on upper piedmonts, but less than 1 m of relief between channels and adjacent alluvial surfaces characterizes middle and lower piedmonts. Eolian deposits and landforms are very common, and they are prevalent on the eastern sides of valleys.

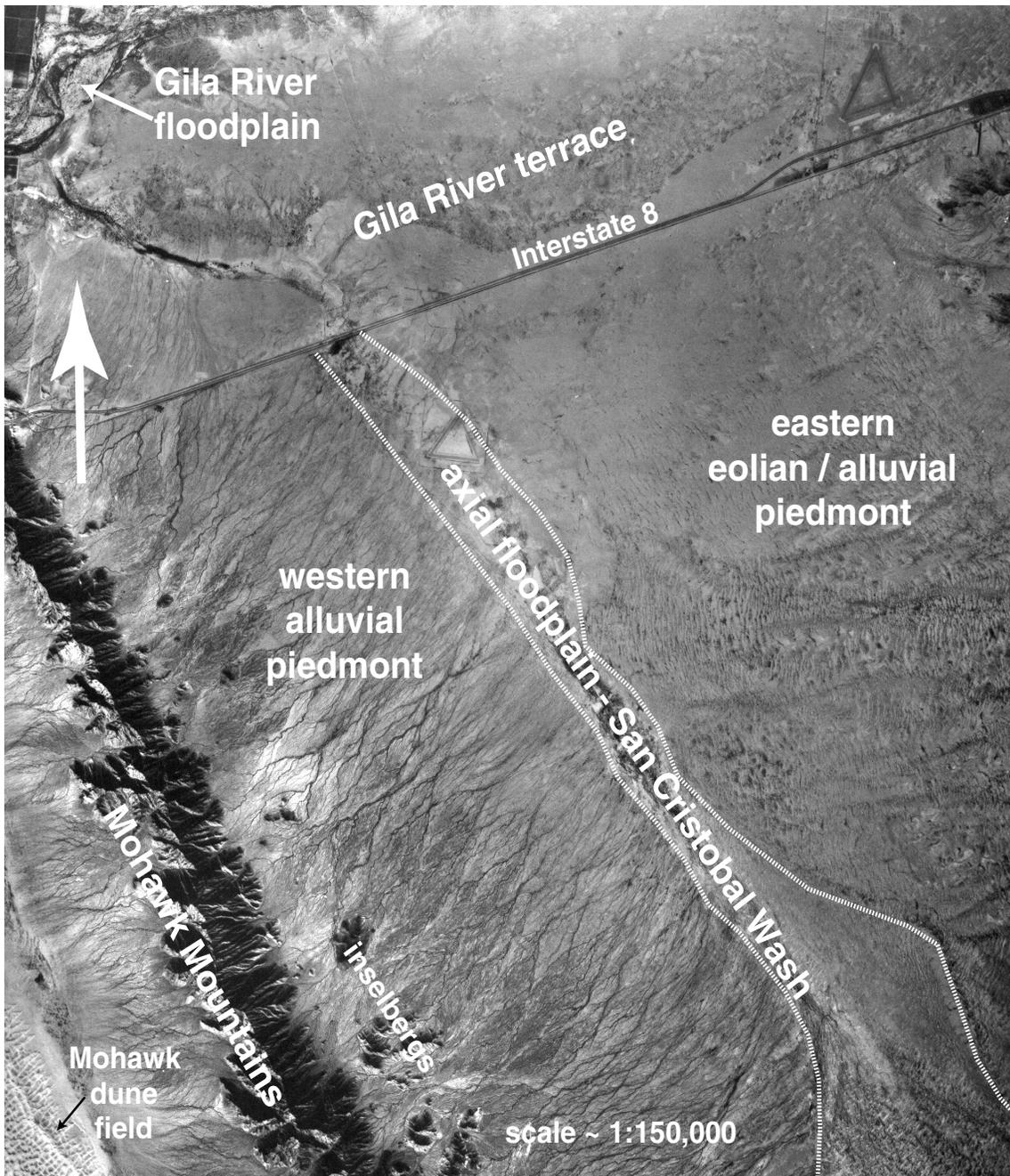


Figure 2. Small-scale U2 aerial photo of northern San Cristobal Valley showing the major landform elements of the project area. The prevalent north- to northwest-trending linear eolian features and the virtual absence of distinct channels on the eastern piedmont are indicative of the dominance of eolian processes in that area.

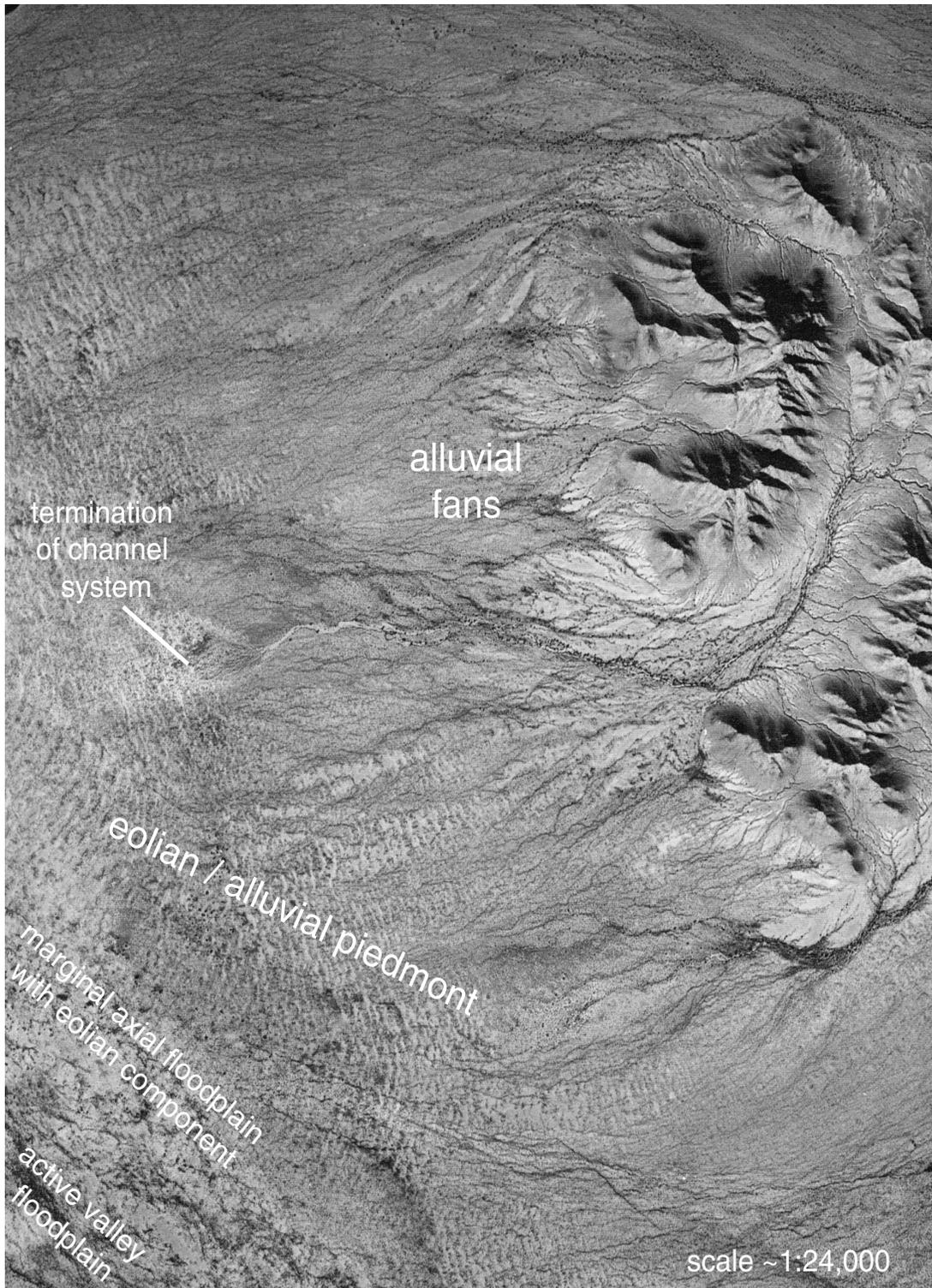


Figure 3. Larger-scale aerial photo of the southwesternmost part of the Aguila Mountains showing some of the surficial deposit assemblages of the project area. Alluvial landforms dominate near the mountains, but the eolian overprint is evident downslope where channel networks essentially disappear.

The archaeological survey followed the course of San Cristobal Wash upstream to its confluence with Growler Wash, and then followed Growler Wash to the Cabeza Prieta Game Refuge boundary. Thus, the continuous survey was conducted almost entirely on young floodplain deposits of the axial streams. Periodic longer transects ventured predominantly onto the lower piedmont deposits, and discretionary surveys covered axial river deposits, piedmont deposits, and bedrock areas.

Mapping Techniques and Ground Control

We employed standard surficial geologic mapping techniques to produce geologic maps of the project area. We developed a reconnaissance 1:100,000-scale surficial geologic map of northern Growler Valley and all of San Cristobal Valley north of the Cabeza Prieta Game Refuge. In addition, we produced 1:24,000-scale surficial geologic maps of several areas of specific interest within the project area. The reconnaissance mapping was based primarily on interpretation of 1:130,000-scale black-and-white aerial photographs flown in 1972, with supplemental interpretation of approximately 1:24,000-scale color photographs flown in 1985 that were supplied by the Air Force. Larger-scale mapping was done using the 1:24,000-scale photographs. Extensive field surveys were conducted in the areas that were mapped at 1:24,000-scale; field checking in the rest of the mapped area was very limited.

Surficial geologic units in the project area were differentiated by the source and process of emplacement of the deposits and their relative age. Surficial deposits were grouped into three broad genetic categories. Piedmont alluvium deposited by tributary streams consists of small channels and adjacent floodplains, terraces, and alluvial fans. Alluvium in the valley floors deposited by larger washes consists of channels, broad floodplains, and low terraces. Eolian and mixed eolian and alluvial deposits consist of relatively small dunes and varying amounts of exposed alluvium. Alluvial deposits in the first two categories were further subdivided based on their ages, using criteria described below. Deposits in the third category were subdivided based on the relative dominance of eolian landforms and by the age of the associated alluvial deposits.

The physical characteristics of alluvial surfaces (alluvial fans, floodplains, stream terraces) may be used to differentiate their associated deposits by age. Initial surface features of alluvial surfaces are shaped by large-scale depositional processes. When surfaces are isolated from further deposition or reworking by large streams, they are gradually modified over thousands of years by other processes, which operate very slowly and on a smaller scale. Modifying processes include (1) small-scale erosion and deposition that smooth the original surface topography; (2) bioturbation, the churning of sediments by organisms, which obliterates depositional structures; (3) development of soils, primarily through accumulation of silt, clay, and calcium carbonate; (4) development of surficial gravel pavements (desert pavements) above zones of accumulated silt and clay; (5) accumulation of rock varnish on surface gravel clasts; (6) development of tributary dendritic (treelike) stream networks on surfaces; and (7) entrenchment of these stream networks below original depositional surfaces and subsequent dissection of these surfaces. Alluvial surfaces of similar age have a characteristic appearance because they have undergone similar post-depositional modifications, and they are distinctly different from both younger and older

surfaces. Young (less than a few thousand years old) alluvial-fan surfaces, for example, still retain clear evidence of the original depositional topography, such as of coarse deposits, swales (trough-like depressions) where low flows passed between bars, and distributary channel networks, which are characteristic of active alluvial fans. Young fan surfaces also show minimal development of soil, desert pavement, and rock varnish and are basically undissected. Very old fan surfaces, in contrast, have not been subject to large-scale flooding for hundreds of thousands of years. These surfaces are characterized by well-developed soils with clay- and calcium-carbonate-rich horizons, well-developed tributary stream networks that are entrenched 1 to 3 m below the fan surface, and strongly developed varnish on surface rocks. Old alluvial-fan surfaces may also have smooth, closely packed desert pavements between the entrenched drainages. The ages of alluvial surfaces in the southwestern United States may be roughly estimated based on these surface characteristics, especially soil development (Gile and others, 1981; Bull, 1991).

Description of Map Units

Surficial deposits on the accompanying maps (Plates 1, 2, and 3) are classified by by source of emplacement and inferred age. Deposits are subdivided by age into Holocene (less than 10 ka; the abbreviation **ka** stands for thousands of years before present), late Pleistocene (10 to 150 ka), middle Pleistocene (150 to 750 ka), and early Pleistocene (750 ka to 2 Ma; the abbreviation **ka** stands for millions of years before present). As was noted above, ages of all of these deposits are estimated by correlation with other similar areas, because no useful constraints have been developed for most of the deposits in these valleys. Piedmont alluvial deposits have no additional letters attached to the unit labels other than age (**Ql**, for example). Deposits associated with major axial drainages have the letter (**r**) added to the age designation (**Qy1r**, for example). Many areas of these valleys are covered by mixed alluvial and eolian deposits. We interpret all of the eolian deposits to be of Holocene age, but the alluvium exposed between eolian deposits may be of Holocene, late Pleistocene, or middle Pleistocene age. Map units indicate this mixture by the addition of the letter (**e**) to the alluvial unit designation (**Qye**, or **Qyre**, for example). A few areas are almost completely covered by young eolian deposits, or have fairly high, prominent active dunes. These areas are designated by the label “**Qe**”. Inferred approximate numerical age estimates for the various deposits are given at the beginning of the unit descriptions. Age estimates are based on correlation with the surface chronosequence developed in the lower Colorado River valley by Bull (1991); see Table 2 at the end of this section. **All age estimates are approximate.**

Piedmont Alluvial Deposits

Piedmont alluvial deposits are derived from adjacent mountain ranges. The lithologic composition of clasts reflects these local sources. Thus, clast lithology varies from piedmont to piedmont, and may vary along particular piedmonts as bedrock source lithologies vary in the mountain ranges.

Qy2 - late Holocene alluvium (< 2 ka)

Channels, undissected floodplains, low terraces, and active or recently active alluvial fans. On middle and lower piedmonts, deposits typically consist of sand, silt, and clay, with local channel gravel deposits; channels are small, shallow, and discontinuous. On upper piedmonts, deposits typically consist of sand to small boulders in well-defined channels, with sand and finer deposits on terraces and other areas subject to overbank flooding; braided or distributary channels networks are common. Vegetation is generally sparse, with low desert shrubs and annuals; vegetation density is higher with larger shrubs and some palo verde, ironwood, and mesquite along and near channels. Eolian landforms are evident locally, but coppice dunes around clumps of vegetation have been streamlined by recent flooding. Limited, open gravel lags on surface, but there are no pavements and rock varnish is minimal; surface color is light brown, but may be darker during seasons with above-average moisture because of growth of annuals and other ground covering plants. **Qy2** is probably correlative with units Q4 and Q3c of Bull (1991; see table 2), which are of late Holocene age.

Qy1 - middle to early Holocene alluvium (2 to 10 ka)

Undissected terraces and alluvial fans somewhat isolated from active fluvial systems. Alluvial surfaces typically are < 1 m above adjacent washes and are partially covered by weak pavements or residual gravel deposits composed of pebbles and few cobbles with minimal rock varnish, although deposits are predominantly sand and finer. Vegetation on lag surfaces is very sparse. Locally, there is some eolian overprint consisting of linear to semicircular coppice dunes associated with more vegetation, mainly creosote; dunes crests less than 1 m above adjacent surfaces with gravel lags. Surface color is light brown, typically somewhat lighter than **Qy** surfaces. **Qy1** deposits are probably correlative with unit Q3b and possibly unit Q3a of Bull (1991), which are middle to early Holocene in age.

Qy - Holocene alluvium (< 10 ka)

Undifferentiated Holocene piedmont alluvium, includes both **Qy2** and **Qy1**.

Ql - late Pleistocene alluvium (10 to 150 ka)

Weakly to moderately dissected alluvial fans and terraces that are higher and either lighter-colored or grayer than surrounding **Qy** surfaces. In lower and middle piedmont areas, **Ql** surfaces typically have tributary drainage networks are incised less than 1 m; in upper piedmonts, **Ql**

surfaces may be as much as 2 m above active channels. Surfaces have weak to moderate pavements composed of angular to subangular pebbles and some cobbles; rock varnish typically is weak; surface color is white to gray. Soils associated with this unit are somewhat enriched in clay and silt, and are slightly reddened. **Ql** deposits are probably correlative with unit Q2c of Bull (1991), which is of late Pleistocene age.

Qly - late Pleistocene and Holocene alluvium (0 to 150 ka)

Undifferentiated late Pleistocene and Holocene alluvium, primarily **Ql** and **Qy1**, with minor elements of **Qy2**.

Qm - middle Pleistocene alluvium (150 to 750 ka)

Older relict fans with moderate to strong soil development and well-developed, entrenched tributary drainage networks. Modern channels are incised up to 3 m below **Qm** surfaces. Between modern channels, surfaces typically are very planar, with subdued bar-and-swale topography, moderate to strong pebble to cobble pavements, and gray to black rock varnish. Underlying soil is reddened and enriched in clay and has moderate to strong carbonate accumulation. These deposits are exposed only in middle and upper piedmont areas. They are probably correlative with unit Q2b of Bull (1991), which is middle Pleistocene in age.

Qo - early Pleistocene alluvium (750 ka to 2 Ma)

Oldest, deeply eroded relict fans with moderate to strong soil development. Surfaces have moderate cobble to boulder pavements, rock varnish varies from very strong to weak; surface color is lighter than most **Qm** surfaces because of carbonate-cemented petrocalcic fragments on surface. Tributary drainage networks are strongly developed and entrenched; depth of dissection by tributary drainage networks is similar to **Qm** surfaces, but areas between channels are more rounded by erosion; **Qo** surfaces are only preserved in a few upper piedmont areas where bedrock is resistant fine-grained volcanic rocks. They are probably correlative with unit **Q1**, and possibly Q2a, of Bull (1991); these units are of early middle to early Pleistocene age.

Eolian and Eolian / Alluvial Mixed Units

Each of these units represents a part of a spectrum of surface areas; they grade into one another and there is substantial uncertainty in the boundaries shown on these maps.

Qe - late Holocene eolian deposits (< 2 ka)

Active sand dunes with minimal gravel pavements between them. Dunes range in height up to about 4 m, but are commonly less than 1 m high. Areas with relatively small dunes have very sparse vegetation, with small desert shrubs and grasses; denser and larger vegetation, including small mesquite trees and sparse grasses, is commonly found on and around larger dunes. In some of these large-dune areas, flat surfaces between larger dunes appear to be stripped remnants of late (?) Pleistocene alluvial surfaces based on the slightly reddened surface color.

Qye - Holocene eolian and alluvial deposits (< 10 ka)

Mixed young eolian deposits and alluvium. Weak, limited pavements or gravel lag deposits with small coppice dunes and discontinuous small channels; the extent of gravel lags and the abundance of small channels varies substantially, some areas are composed mostly of small dunes with limited pavements and few channels. Vegetation is very sparse and small on flat areas; desert shrubs, mainly creosote bush, are common on coppice dunes. Surfaces are generally brown to tan on aerial photos, and they commonly have striped appearance. Estimated age of alluvium and eolian deposits is Holocene, but alluvial surfaces between dunes may be late Pleistocene in age in some areas.

Qle - Late Pleistocene alluvium and Holocene eolian deposits (< 150 ka)

Mixed young eolian deposits and intermediate alluvium. Weak to moderate, pebble-cobble pavements and small coppice dunes; flat areas with pavements generally are more extensive than on **Qye** and rocks have weak to moderate varnish. Soil development is moderate with enrichment in clay, silt, and carbonate. Coppice dunes are similar to **Qye**. Pavement surfaces are light gray on aerial photos and eolian features impart striped appearance to surfaces. The estimated age of the alluvium is late Pleistocene, with Holocene eolian features overprinting, or moving over older pavements and soils.

Qme - Middle Pleistocene alluvium and Holocene eolian deposits (< 750 ka)

Mixed young eolian deposits and old alluvium. Moderate to strong pebble-cobble pavements and small coppice dunes; flat areas with pavements are similar to **Qle**, but clast varnish and soil development are somewhat stronger; pavement surfaces appear dark gray on aerial photographs; estimated age of alluvium is middle Pleistocene with Holocene eolian overprint.

Deposits of Larger Washes (Growler, San Cristobal, Daniels, and “Red Point” washes)

Deposits of the major washes are derived from large source areas and typically contain diverse clast lithologies.

Qyr2 - late Holocene stream deposits (< 2 ka)

Deposits in stream channels and on primary floodplains of the major washes. Deposits generally consist of sand, silt, and clay, with local gravel concentrations. Shallow, small, discontinuous channels are common; many of them are linear, suggesting that channels developed along roads or wagon tracks. Vegetation typically is large creosote and low grass and shrubs, with local mesquite, ironwood, and palo verde concentrations. Variegated surface color depends mainly on vegetation density, dark brown color along channels and where vegetated, brown where more sparsely vegetated. Eolian features have been streamlined by flow. This unit also includes arroyo channels, which are steep-walled, less than 2 m deep, and have local gravel deposits.

Qyr1 - Holocene stream terrace deposits (< 10 ka)

Deposits associated with upper or secondary floodplains of major washes. Typically, they are flat surfaces that are on the fringes of and less than 1 m above the primary floodplain. Deposits are generally fine-grained, but surfaces have weak, discontinuous gravel lags composed of mixed lithologies. Some small, poorly defined channels. Surface color typically is light brown, and surface clasts have no varnish. Very limited low (0.5 m high) coppice dunes associated with creosote bushes and bioturbated sand and finer sediment. These surfaces probably are inundated in the largest floods. They merge almost imperceptibly into young lowermost piedmont deposits (units **Qy1** and **Qy2**).

Qyr - Holocene stream deposits (< 10 ka)

Undifferentiated Holocene stream deposits, includes both **Qyr2** and **Qyr1**.

Qyre - Holocene stream terrace deposits and eolian deposits (< 10 ka)

Mixed young river terrace deposits and eolian deposits. Landforms consist of low coppice dunes and intervening flat surfaces with minimal gravel lags and no pavement development, less than 1 m above adjacent floodplains. Drainage networks typically are discontinuous and channels are small. Low coppice dunes are abundant; vegetation is sparse, desert shrubs are relatively concentrated in dunes and along small channels. Predominance of eolian influence indicates that these areas have not been subject to substantial flooding recently; thus, the alluvium in these areas is older than **Qyr1**.

Qlre - Late Pleistocene stream deposits and Holocene eolian deposits (< 150 ka)

Mixed intermediate river terraces and young eolian deposits. Landforms are mainly terraces along Growler and San Cristobal washes, but **Qlre** surfaces form broad alluvial fans near the confluence of these washes and along Daniels Wash. Surfaces are smooth and flat, ~1 m above adjacent floodplains; they have weak to moderate pebble to cobble pavements composed of mixed lithologies, with weak rock varnish on surface clasts. This unit includes varying amounts of low coppice dunes composed of fine-grained, bioturbated sediment. Creosote bushes exist on the dunes, but otherwise vegetation is very sparse. Surface color is light gray on photos due to weakly varnished gravel pavements. These surfaces generally are not inundated by floods on the major washes.

Bedrock Geologic Units

Tv – Tertiary volcanic rock, primarily basalt

Tt – Tertiary tuffs, pyroclastic rock, and andesite

TKg – Tertiary and Cretaceous granite

pCg – Precambrian granite

pCm – Precambrian metamorphic rock, primarily gneiss

Age Range	Lower Colorado River chronosequence (Bull, 1991)	Growler chronosequence (this report)
historical (< 100 yr)	Q4	Qyr2
late Holocene (0-2 ka)	Q3c	Qy2, Qe, Qyr1
middle Holocene (2-7 ka)	Q3b	Qy1
early Holocene to latest Pleistocene (7-15 ka)	Q3a	Qy1?, Ql?
late Pleistocene (15-150 ka)	Q2c	Ql
middle Pleistocene (150-750 ka)	Q2b, Q2a	Qm
early Pleistocene (750 ka to 2 Ma)	Q1	Oa

Table 2. Tentative correlation table for deposits of the lower Colorado River Valley and the San Cristobal - Growler valleys. Mixed eolian / alluvial units are not included because they cannot be readily classified by age.

Summary of the Surficial Geology

The surficial geology and geomorphology of San Cristobal and northern Growler valleys reflect the complex interaction between montane-piedmont fluvial systems, major axial washes, and eolian activity in this arid environment. Many of the piedmont landforms of this region display the combined effects of fluvial and eolian erosion and deposition. Piedmonts on the western sides of these valleys typically are dominated by alluvial deposition, whereas piedmonts on the eastern sides of the valleys have a strong eolian component (Figure 2). This pattern undoubtedly reflects the prevailing westerly to southwesterly winds of this region. It also suggests that the relatively fine-grained deposits of the axial washes are a significant local source for the silt and sand that compose the piedmont eolian deposits. Deposits associated with the major axial washes also reflect the interplay of fluvial and eolian activity. Areas that are flooded fairly frequently have predominantly fluvial landforms, whereas older alluvial deposits have eolian landforms superimposed on them.

Piedmonts are by far the most extensive landscape element in the study area, comprising about 70 percent of the surface area. Upper piedmonts typically contain deposits ranging in age from Holocene to middle Pleistocene. Young deposits commonly are restricted to stream channels and low terraces, although fairly extensive young alluvial fans exist in a few areas. Upper piedmont channels, terraces and alluvial fans are composed of fairly coarse deposits. Eolian overprinting of alluvial surfaces in these areas is minor. The middle and lower portions of the western piedmonts are covered primarily by finer-grained Holocene alluvial deposits, with some isolated remnants of late Pleistocene alluvial fans. Young deposits are generally sand and

finer, with some gravel associated with channels. Some areas between channels are slightly older and more removed from the modern drainage systems. These areas, shown as unit **Qy1** on the detailed geologic maps, may not be subject to flooding in the modern environment.

Most of the eastern piedmonts are covered by mixed alluvial/eolian landforms. Distinctly alluvial landforms dominate the upper piedmonts, but these gradually fade out downslope as the eolian imprint becomes stronger. Drainage networks also become indistinct downstream as evidence of eolian activity increases. In lower piedmont areas, areas covered by solely alluvial deposits are very limited. Eolian landforms are superimposed on late Pleistocene alluvial deposits over broad middle and lower piedmont areas. This suggests that fluvial activity was more prevalent during the last glacial period (~15 to 130 ka), and subsequently eolian action has been dominant. Areas where eolian landforms are completely dominant are fairly limited in extent.

Landforms associated with the major axial washes of this region consist of floodplains, low terraces, channels, and large alluvial fans of Holocene or late Pleistocene age. Growler and San Cristobal washes have broad floodplains covered with late Holocene deposits. Channels are small and discontinuous, with the exception of the arroyo that has developed in the Growler bend area. Slightly higher portions of these floodplains, labeled **Qyr1** and **Qyre** on the geologic maps, may not be subject to significant inundation or may only be flooded during extreme flood events. Relict late Pleistocene river deposits form low terraces. Inundation during floods along the floodplains of axial drainages is very widespread. In early 1996, there was abundant evidence of a recent, fairly large flow event that inundated a swath at least 3 km wide at the confluence of Growler and San Cristobal washes. Fluvial landforms associated with Daniels Wash in Growler Valley and Growler Wash in San Cristobal Valley are very broad and fan-shaped. Thus, they are best characterized as large alluvial fans. Complex active distributary drainage networks associated with Holocene deposits range up to 5.5 km wide in these areas. Even broader elements of these fans are composed of relict late Pleistocene surfaces. Although we were not able to examine stratigraphic sections through the Pleistocene axial wash deposits, their surfaces are much more gravelly than any younger surfaces associated with the major washes. These coarser deposits may reflect greater competence of these streams to carry bedload sediment during the late Pleistocene. All of the late Pleistocene surfaces associated with axial washes have a significant eolian overprint.

Archaeological Implications of Surficial Geologic Mapping

Surficial geologic mapping of the project area provides information that may be useful in evaluating the recently completed archaeological survey and for planning future surveys in this area. The reconnaissance 1:100,000-scale surficial geologic map outlines the geologic framework within which the archaeological survey was conducted. This mapping confirms that the vast majority of the survey was conducted on very young floodplain deposits of the major washes. Reconnaissance and larger-scale mapping document the distribution of alluvial surfaces of different ages and their associated deposits. The age and character of these deposits have

implications for where artifacts are likely to be found and whether they will be on the surface or buried by recent deposition.

The age and character of the various surficial geologic units in the project area have some implications for the potential for discovery of archaeological features. On alluvial deposits of late Pleistocene age or older (units **Ql**, **Qm**, and **Qo**), artifacts will almost certainly be found only on the surface. These Pleistocene alluvial surfaces have moderate to well-developed gravel pavements that are fairly coarse near the mountains. If these pavements contain lithologies such as fine-grained volcanic rocks that are suitable for the manufacture of stone tools, then they are likely sites for stone tool acquisition. Old alluvial surfaces near the Growler Mountains and the southern part of the Aguila Mountains fit this description. Finer-grained Pleistocene deposits in the middle and lower piedmonts, and Pleistocene deposits derived from the granitic rocks of the Granite and Mohawk mountains, generally do not have clasts on the surface that would be suitable for working. In the broad piedmont areas covered by mixed Holocene eolian deposits and Pleistocene alluvium, artifacts might be buried by small dunes, but it is more likely that they would be exposed on the dunes or on intervening gravel pavements.

Channels, floodplains, terraces and alluvial fans of Holocene age may have surface or subsurface artifacts associated with them. The floodplains of the axial washes generally are covered with late Holocene to modern sediment. It is likely that large, infrequent floods result in the inundation of most of these floodplains, thus depositing sediment and reworking much of the floodplain surface. In these floodplain environments, archaeological features could be (1) exposed intact at the surface because minimal deposition or erosion has occurred; (2) buried and not detectable through surface surveys; or (3) exposed at the surface after having been buried and subsequently uncovered by recent erosion. Slightly higher elements of the floodplain (unit **Qyr1** and **Qyre**) have not been subject to as much recent flooding, so any archaeological features are more likely to be exposed in these areas. These areas could have exposed or buried artifacts. Deposition on some young piedmont fans and terraces certainly post-dates the prehistoric occupation of this area, but it is likely that in most young fan and terraces minimal deposition has occurred in the past 1,000 years or so. Artifacts might be found on the surfaces of these landforms or they might be buried beneath them.

Moderately large dunes associated with unit **Qe** may have been viewed as favorable sites for temporary occupation by prehistoric inhabitants or visitors to this area, based on the number of archaeological features associated with them. Several-meter-high dunes are fairly common in San Cristobal Valley. They typically have small mesquite trees on them, and generally provide a relatively lush microenvironment. The shelter provided by the dunes and the availability of firewood may have made these areas attractive in this otherwise rather severe environment.

PART 2. GEOARCHAEOLOGY OF ARCHAEOLOGICAL SITES

By Andrea K.L. Freeman and Philip A. Pearthree

Introduction

This part of our report summarizes the results of geoarchaeological fieldwork in the San Cristobal and Growler valleys from Interstate Highway 8 to the boundary of the Cabeza Prieta Wildlife Refuge. The geologic and geomorphologic investigations summarized here were conducted as part of an archaeological survey of this portion of the Barry M. Goldwater Range conducted jointly by Arcadis Geraghty and Miller, Inc. and SWCA, Inc. The continuous archaeological survey covered a 0.5-km-wide, 60-km-long strip that follows San Cristobal and Growler washes. Lateral transects conducted every few km covered 120-m-wide, 3-km-long swaths centered on the continuous transect. In the course of this survey, several archaeological sites were discovered and some known sites were documented in greater detail. In this report all archaeological sites are referenced with Arizona State Museum (ASM) site numbers.

Physical Setting

The archaeological survey followed San Cristobal and Growler washes from Interstate Highway 8 southeast to the northern boundary of the Cabeza Prieta Game Refuge (Figure 1). These washes are moderately large, wide, ephemeral drainages that join the Gila River approximately 8 km north of Interstate Highway 8 near Dateland, Arizona. San Cristobal Valley is bounded by the Mohawk Mountains to the west, the Aguila Mountains to the northeast, and the Granite Mountains to the southeast. Within the project area, Growler Valley is bounded by the Granite Mountains to the west and the Growler Mountains to the east. Growler Wash heads in the Ajo Mountains southeast of Why, Arizona, crosses a low pass in the Growler Mountains, flows northwest for about 50 km in Growler Valley, and then joins San Cristobal Wash after passing through a low pass between the Granite and Aguila Mountains. San Cristobal Wash above the confluence with Growler Wash is a relatively minor tributary, draining upper San Cristobal Valley and part of Mohawk Valley to the west.

The study area is located in the middle of the Sonoran Desert in the Basin and Range physiographic province. The Basin and Range province consists of alluvial basins and intervening mountain ranges that formed as a result of normal faulting related to extension of the crust during the past 30 million years or so. The Sonoran Desert region is characterized by relatively narrow and not very high, north- to northwest-trending ranges and broad, undissected basins. These characteristics imply that significant normal faulting has not occurred for millions of years in this area (Shafiqullah and others, 1980; Menges and Pearthree, 1989). The regional drainage is integrated into the Gila River system, but the low gradients of the larger streams and the general lack of dissection in the basins suggests that basins are slowly aggrading.

As noted above, the archaeological survey followed the course of San Cristobal Wash to its junction with Growler Wash, and then continued up Growler Wash to the Cabeza Prieta National

Game Refuge. Thus, most of the survey was conducted on late Holocene sediments of the floodplains of Growler and San Cristobal washes. Lateral transects commonly ventured onto the lower piedmont slopes that fringe the floodplain. These lower piedmont slopes are dominated by terraces, small channels, and alluvial fans of late to middle Holocene age. Occasionally, transects traversed older stream terraces, relict piedmont alluvial-fan surfaces, or bedrock inselbergs.

Vegetation within both valleys is sparse Sonoran Desert scrub. Creosote is predominant with occasional larger shrubs and trees including palo verde, ironwood and mesquite found clustered in channels and gullies. Annuals are probably an important ground cover during relatively wet years, but they were very sparse in 1996 when fieldwork for this project was conducted.

Historical Geomorphology

Several scientists traveling through the area in the late 1800s and early 1900s provided general descriptions of what was known then as “the Papago Country”. Kirk Bryan, a geologist/geomorphologist working for the U.S. Geological Survey, provided the most detailed and useful descriptions of this region. Bryan was hired in 1917 to map and provide directions to the locations of reliable water sources (“watering places”) in the desert regions of southwestern Arizona. This study was part of a larger survey that covered Arizona, Nevada, New Mexico, Utah, and parts of California, Colorado, Idaho, Oregon, and Texas. This project was funded by a special appropriation from Congress in 1917, and the work was assigned to the U.S. Geological Survey. Additional funding from the U.S.G.S. regular budget supplemented the Congressional appropriation. Publication of the reports describing watering places in the western United States occurred after World War I.

Bryan was very interested in the geology and geomorphology of desert regions and he produced several documents related to this work that describe the geomorphic processes that produced the landforms in his large project area (Bryan 1922a, 1922b; 1925a, 1940). A succinct description of Bryan’s career in the American Southwest and his scientific rapport with Ernst Antevs is provided by Haynes (1990). Bryan’s reports provide the earliest good descriptions of Quaternary deposits and fluvial systems in southwestern Arizona. The scope of his work was large, however, and he did not include many detailed descriptions of the area covered by this report.

Among Bryan’s interests was the cause and apparent synchronicity of arroyo incision in the Southwest. For obvious reasons, he (along with many others) was interested in whether the incision of arroyos in the Southwest during the late 1800s was due to natural processes or whether human intervention played a significant role. Discussion of this problem became highly charged and the interests of those involved were usually intertwined with their conclusions (Cooke and Reeves 1976; Haynes 1990). *Agriculturalists, foresters, and conservationists commonly indict man for his excesses. In contrast, some geologists, paleontologists, and archaeologists have sought and found “natural” explanations.* (Cooke and Reeves 1976:6). In reality, the causes of arroyo formation are likely the result of a number of factors, and probably include both secular trends in climate and changes in human land use during the historic period.

Bryan's interest in the "arroyo problem" made him a passionate researcher, describing the desert streams he encountered with great care and detail. Because of this, his descriptions of the Growler and San Cristobal Valleys, though few, are quite useful for geologists and archaeologists interested in Quaternary geology.

Historic Descriptions and Data

There are few records available that offer detailed information regarding the geology and environment of the Growler and San Cristobal Valleys around the turn of the century, when Euroamerican settlers first entered the area. Although some wells were dug as early as the late 1800's, Euroamerican attempts to homestead the land came later. Early General Land Office maps and records show that Euroamerican settlers were attempting to improve the valley as early as 1914 (see Dave Tucker chapter), when Melancthon Walters filed for a right-of-way to construct a ditch in the Stoval area. These homesteaders were interested in farming cotton (Bryan, 1925a:361). Bryan actually believed that the land was capable of supporting grazing (1925a:205). He was, however, uncertain about the ability of the area to support cotton, a plant that requires relatively little irrigation.

Bryan provides a general description of Growler and San Cristobal washes:

...the main wash of Growler Valley, which pursues a northwesterly course for about 30 miles to the Mesquital, an adobe flat that is similar to the one east of Growler Pass and lies southeast of the southern point of the Aguila Mountains. From the Mesquital, a channel leads to the axial stream of San Cristobal Valley. This axial stream has a well-defined channel about 50 feet wide trending northwestward, but near Garcia Well it fades out into an adobe flat which gradually increases in width until 9 miles farther on, at the Southern Pacific Railroad, it is almost 2 miles wide. Around the borders of the flat are low bluffs which are 2 to 5 feet in height near Garcia Well and increase to 20 feet in height near the railroad. In this flat the channels are very small, but at the railroad a channel about 20 feet wide and 3 to 4 feet deep begins, which increases in width and depth until it reaches the flood plain of the Gila River (1925a:104).

Adobe flats are described as:

A generally narrow plain, having a slope of 5 to 20 feet to the mile built of fine sandy clay or adobe brought down by an ephemeral stream, having a smooth surface that is usually unmarked by stream channels, but where so marked the channels are insignificant. (1922a:86).

The “low bluffs” to which Bryan refers are the low topographic scarps that mark the boundary between the floodplain of San Cristobal Wash and the piedmont on either side. The piedmont deposits along this reach of San Cristobal Wash are primarily Holocene alluvium or eolian deposits. The higher scarps near Interstate Highway 8, however, are formed in middle Pleistocene alluvium. The presence of low bluffs or scarps indicates that San Cristobal Wash previously flowed at approximately the level of the adjacent piedmont alluvium and has subsequently entrenched itself below that level, probably in response to base-level changes driven by the Gila River. The two areas with the most abundant archaeological remains; the area around Stoval Airfield (downstream from Garcia Well) and the *Mesquital* (near Tony Tank), fortuitously were described in moderate detail by Bryan.

Geoarchaeological Site Descriptions

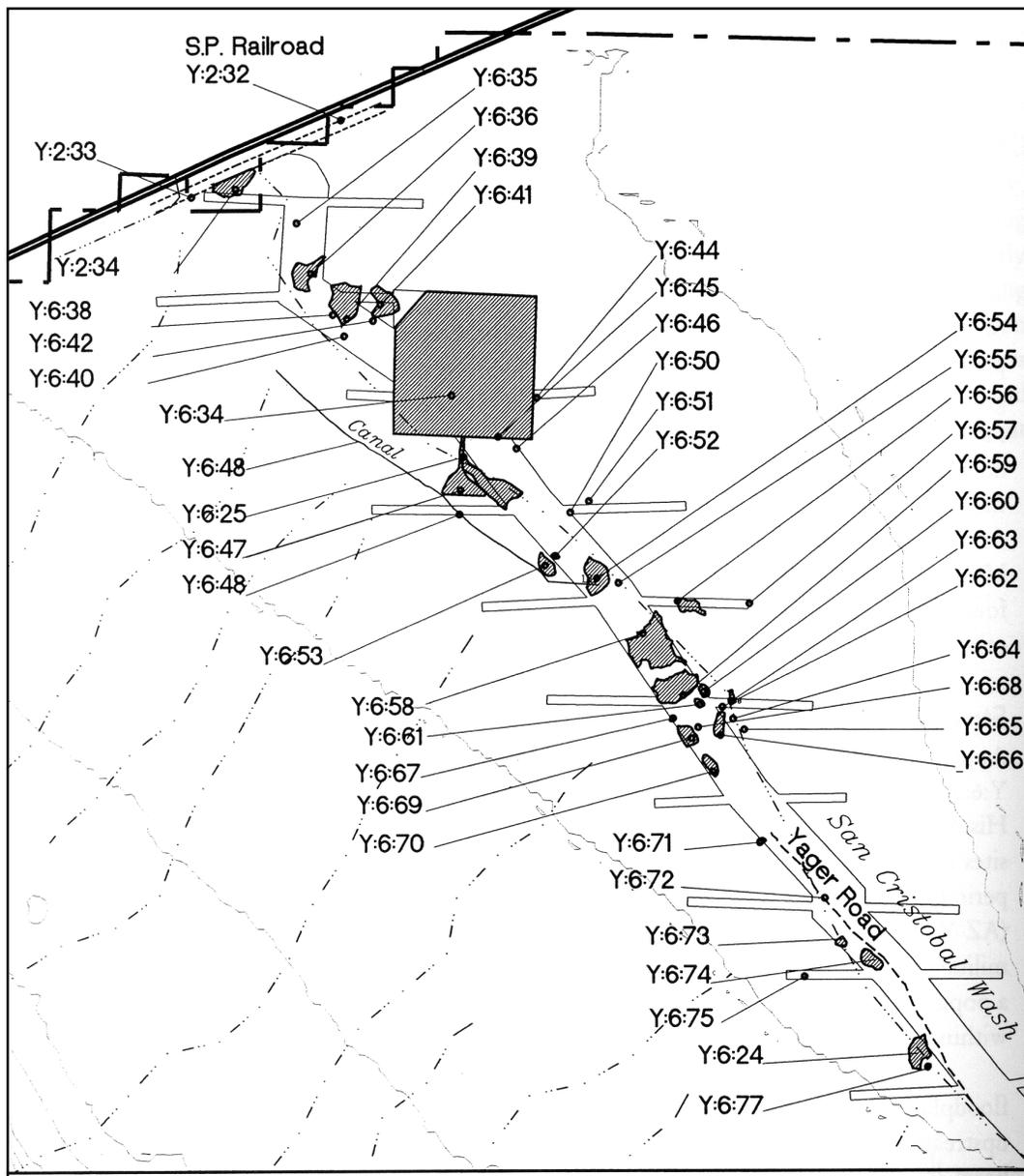
Geoarchaeological evaluation of the project area was conducted by field reconnaissance of the area within and surrounding concentrations of archaeological sites and by observation of both recent and historic aerial photographs of the area. There are two primary concentrations of cultural resources within the Growler Wash project area: a group of sites within a 7 km radius of Stoval Airfield and a group of sites within a 5 km radius of Tony Tank. The latter includes the Verbena site (AZ Y:8:11), previously documented by Dames and Moore, the Pearthree site (AZ Y:7:58), the Cutbank site (AZ Y:11:14), and clusters of isolated artifacts and sites further downstream to the point where Growler Wash is constricted by the Granite and Aguila Mountains. In addition to these two concentrations, several isolated clusters of sites are found between these two areas: one in a dune field in the vicinity of transect 20 and the other near Spain’s Well in the vicinity of transect 14.

Stoval Airfield Area

Approximately 46 sites were discovered within a 7 km radius of Stoval airfield (AZ Y:6:34) (Figure 4). One-quarter of the sites in this area are historic or have historic components to them. There is a higher concentration of historic sites in the area around Stoval, which is probably due to the presence of two historic wells (Garcia Well, Y:6:24) and Pimeria Well, Y:6:54) and the railroad (AZ Y:2:32) nearby. Although some of the sites, such as the airfield itself, are historic military installments, GLO records indicate that the area surrounding Stoval airfield was a popular place to attempt to homestead [see Dave Tucker chapter]. Several prehistoric sites were also discovered within the area surrounding Stoval airfield.

Stoval airfield is a triangular-shaped series of runways built on the Holocene floodplain of San Cristobal Wash (Plate 2). A berm was constructed on the upstream side of the airfield in order to divert floodwater around it. Upstream of this berm is a ditch constructed in 1914 by Melancthon Walters, which is today locally breached by channels to the west.

Between the ditch and the airfield is a large area that exhibits features similar to Bryan’s description of an adobe flat. Mud cracks found in this very sparsely vegetated area are probably relicts of large sheet-like floods that occasionally cover the area. Water from these sheet floods pools for a short period of time before it is lost to evaporation. Fine-grained sediment entrained



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- Survey Boundary
- Site Location and ASM Site Number

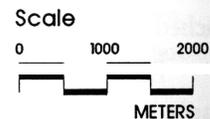


Figure 4. Map of Stoval Airfield area showing sites discovered during archaeological survey. Sites are identified by their Arizona State Museum Site Number. The Yager Road is a 19th century wagon road that is preserved in some places. Figure is modified from Slaughter and others (2000).

in the flood waters is deposited in the quiet water and as the water evaporates. The absence of vegetative cover in this area may be due to a number of factors. The eolian blanket typical of the area to the east and less so to the west is absent. Eolian and vegetative cover has likely been removed by water erosion in sheet floods combined with some deflation. East of the airfield, eolian deposits are more predominant. West of the airfield and the unvegetated drainage area, low, discontinuous channels enter the wash. These alluvial deposits are locally covered with a light blanket of eolian material. An occasional gravel lag is present on the undissected portions of the surface.

Many small prehistoric artifacts such as chipped stone were found on this barren landscape. These artifacts may have been transported short distances by sheet flow or exposed by fluvial erosion and left in approximately their original position. The likelihood of recovering *in situ* artifacts and features in this area is low; however, undisturbed areas east of this unvegetated area may contain *in situ* archaeological resources.

The installation of Stoval airfield across the most of the floodplain has not obviously affected the direction or velocity of flow in the area. The earliest available aerial photographs of the area from 1953 show little difference between the course and the size of the wash at that time and today. Stoval was built in 1941 and it is possible that the stream already changed its course by 1953, but the installation of Stoval may have had little influence on the direction or size of the wash. The slope of the floodplain in this area is very low from Interstate Highway 8 upstream to beyond Pimeria Well, and there is no perturbation associated with Stoval field (Figure 5). The channel may have naturally selected the current course, or other features in the area have more direct influence on the direction and velocity of flow. Larger features in the area that may produce such effects include the low bluffs formed in Pleistocene alluvium and the Southern Pacific Railroad, located north of the airfield.

As in the other valleys that border on Gila River, the general level of this valley is adjusted to the level of the terrace and not to the present flood plain of the river. The axial stream of the valley, however, has cut back as far as the Southern Pacific Railroad at Stoval. South of the railroad the stream lies in an adobe flat in which there are only insignificant channels. The flat is bounded by bluffs which are especially noticeable on the east side, being about 20 feet high near Stoval, but which decrease gradually and disappear 8 miles to the south, near Garcia Well. This trenching of the valley floor seems to be an adjustment to a new base-level, which has not been definitely correlated. (1925a:202).

The description above may prove useful for understanding the Stoval area, since it establishes the general relationship between San Cristobal Wash and the features in this area prior to construction of the airfield. Additional field investigations of the area around Stoval could help to determine whether the area is aggrading or degrading. As noted above, however, installation of Stoval airfield has not obviously affected the slope of the floodplain, which implies that it has not caused substantial aggradation upstream of the facility. Testing archaeological sites within the

unvegetated area is unlikely to yield significant subsurface deposits; however, it is possible that cultural materials may be found near those discovered on the survey in the area covered by eolian material to the east. Unfortunately, the area is too large to recommend testing in a specific locality.

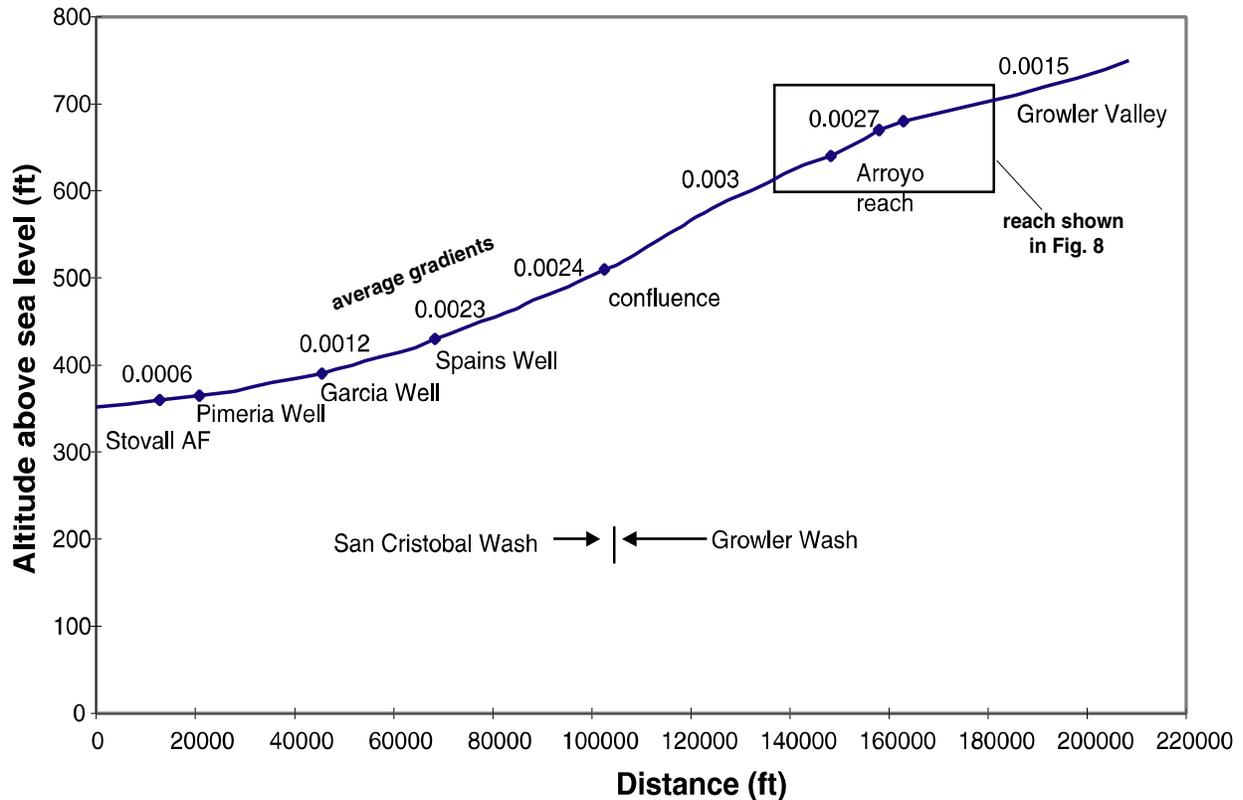
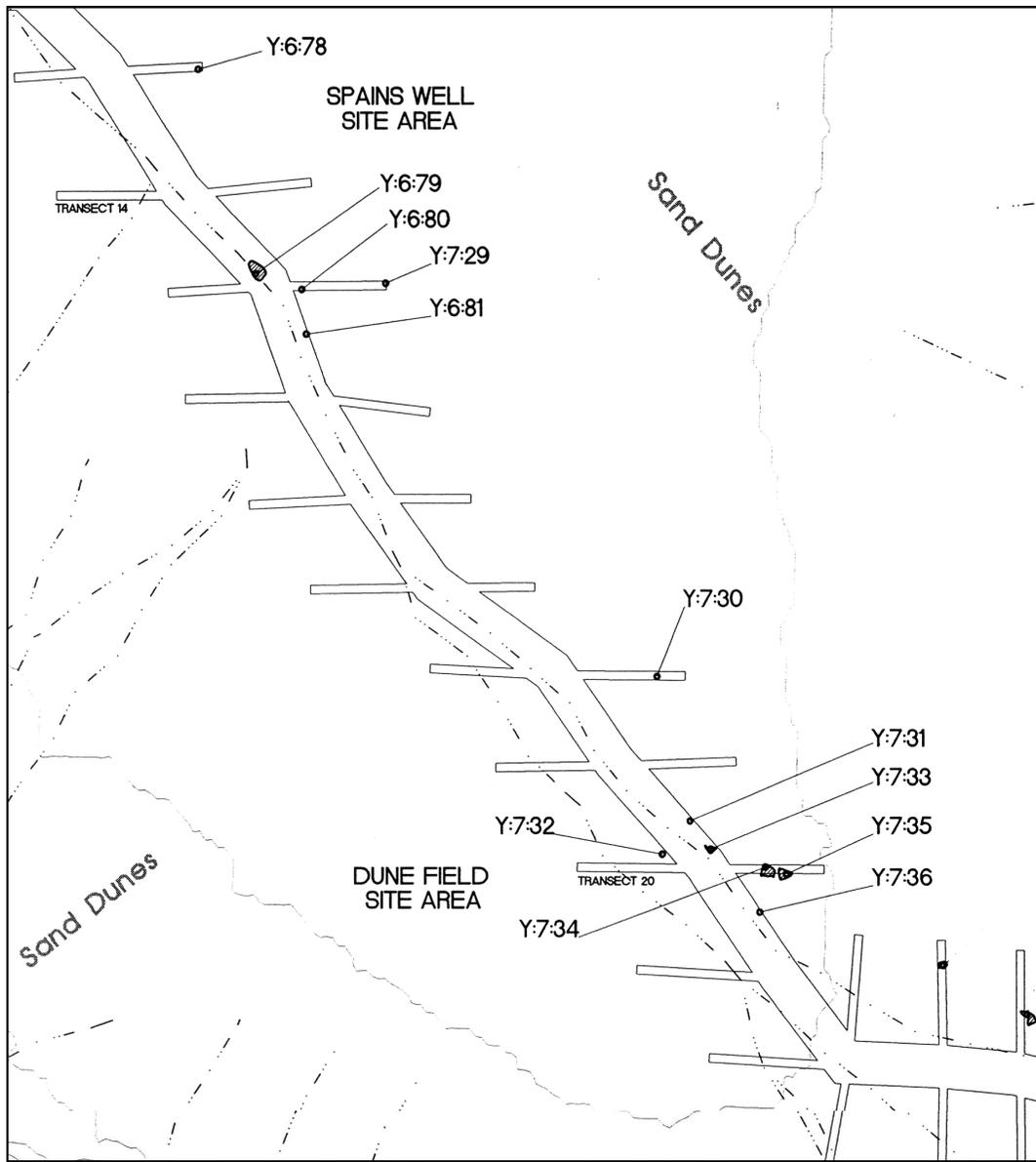


Figure 5. Longitudinal profile of the floodplain of San Cristobal and Growler washes from the Interstate Highway 8 bridge to just south of the Cabeza Prieta Game Refuge boundary in Growler Valley. Average reach slopes are shown above the profile.

Transect 14: Spain's Well

Four sites were discovered on or near archaeological survey transect 14, which crosses Spain's Well (AZ Y:6:79) (Figure 6). Three of the four sites contain historic components. Only two sites have prehistoric components (AZ Y:6:80 and AZ Y:7:29). Another prehistoric site (AZ Y:6:78) is located approximately half the distance between Spain's Well and Stoval airfield.

Archaeological survey transect 14 and the surrounding area was examined once. The area includes the floodplain of San Cristobal Wash, fine-grained of young alluvial fans, and numerous



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- Survey Boundary
- Site Location and ASM Site Number

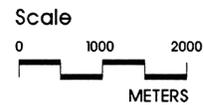


Figure 6. Map of Spains Well and Dune Field areas showing sites discovered during the archaeological survey. Modified from Slaughter and others (2000).

very small, discontinuous gullies. Some eolian overprint is present, especially east of the floodplain. Toward the center of the wash, eolian landforms (small coppice dunes) surrounding vegetation are streamlined by recent flooding. In the middle of the floodplain, a series of small channels are present. Creosote is predominant toward the western portion of the transect; however, in the center of the wash, small clusters of mesquite are present and vegetation density is slightly higher.

The floodplain of San Cristobal Wash narrows substantially in the vicinity of Spain's Well. Upstream, around the confluence of Growler and San Cristobal washes, the floodplain is as much as 5 km wide. In the Spain's Well area, the floodplain is about 0.5 km wide (see Plate 2). This decrease in floodplain width probably serves to concentrate flow and may increase the amount of water available to sustain vegetation. The presence of a historic well in the vicinity may indicate that ground water availability was better here than in areas upstream.

Several small dune fields are located northeast of this concentration of sites, outside the archaeological survey area (Plate 2). These dunes support some mesquite trees and thus offer firewood and some protection from sun and wind. Given the slightly high density of archaeological sites and isolates surrounding a dune area around transect 20 (to the south), and since this dune field is the predominant feature on the landscape in the Spain's Well area, additional archaeological survey of the dunes may be warranted.

Transect 20: Dune Field

Five prehistoric sites, one dual component prehistoric and historic site, and numerous isolated artifacts were discovered surrounding a series of large dunes within and around archaeological survey transect 20 (Figure 6). An additional prehistoric site (AZ Y:7:30) is located outside this concentration of sites but on the northwestern edge of the dune field and may be part of the overall distribution of sites and isolates surrounding these dunes. These sites are found within the broad area of confluence between Growler and San Cristobal washes.

Several-meter-high dunes rise above the alluvial deposits of San Cristobal Wash in this area. The vegetated dunes are located toward the center and eastern side of the most obvious channels of San Cristobal Wash. Channels surrounding these dunes are well-defined, but small. To the west and north of this area, evidence of recent flooding is visible in the form of mud cracks and streamlined small coppice dunes. Archaeological artifacts appear to be eroding from these smaller coppice dunes as they are inundated by large floods. Testing might reveal more about the context of these artifacts and their possible relationship to features which, once exposed, are easily altered by fluvial or eolian erosion.

Tony Tank

The Tony Tank area is located along the arroyo reach of Growler Wash in northern Growler Valley between the Aguila and Granite mountains (Figure 7). Tony Tank is a stock tank that was built adjacent to Growler Wash in the vicinity of a prominent, unnamed hill composed of volcanic rocks. In this area, a relatively deep channel (in places 2 m deep) forms the main

pathway for water flowing in Growler Wash. The headcut for this incised channel and at least two plunge pools where floodwater cascades from the unentrenched floodplain upstream into the arroyo system are just upstream of Tony Tank (AZ Y:7:55). A relatively dense mesquite grove is present for about 3 km upstream of the arroyo reach. An incised channel associated with the arroyo extends for about 5 km downstream, where the floodplain widens substantially and the channel divides into multiple smaller channels. In the Tony Tank area, several smaller tributary headcuts exist both north and south of the main arroyo.

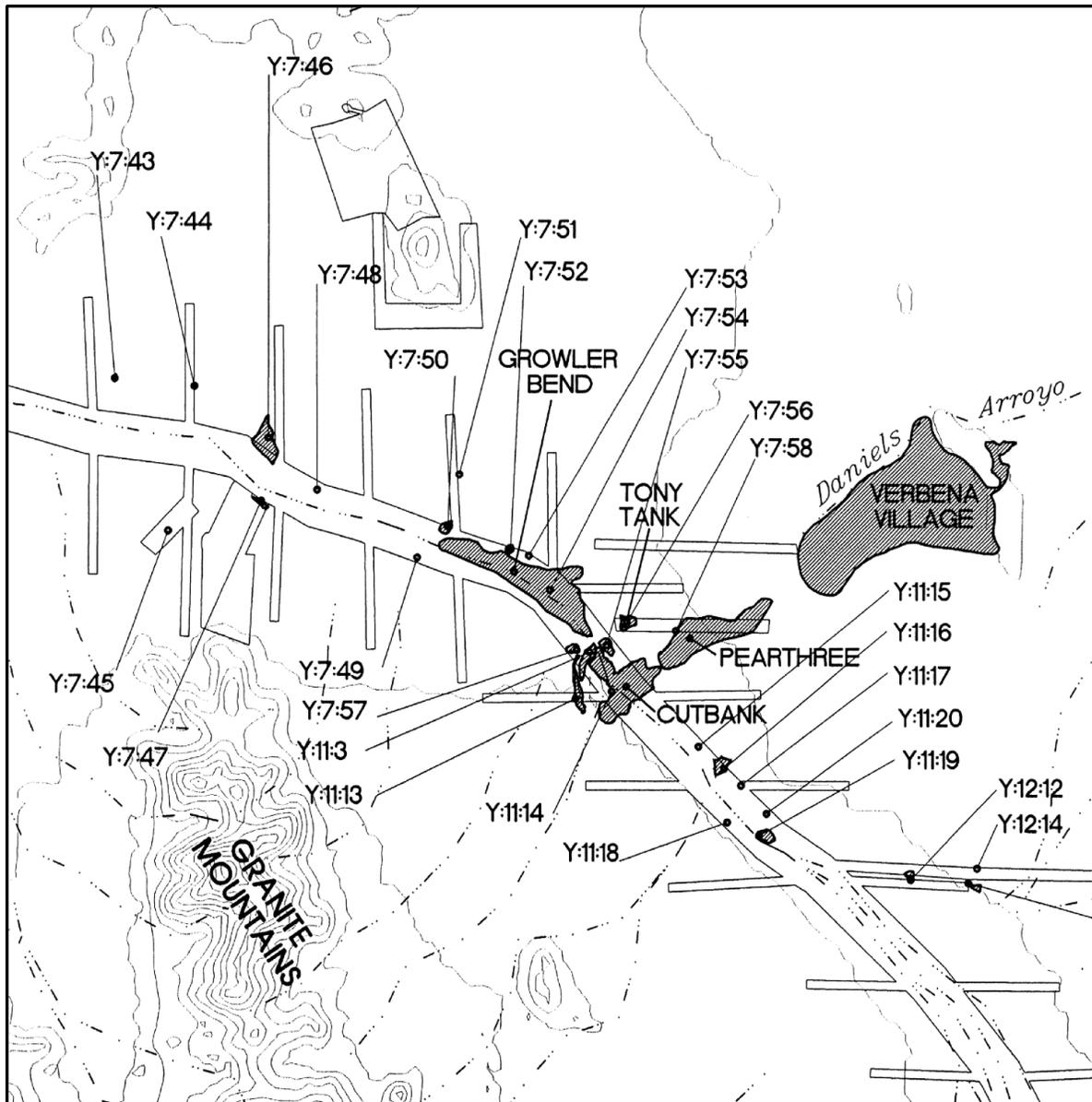
This area has probably changed significantly since Bryan described it:

Growler Valley drains northwestward through an adobe flat called Mesquital, between the Granite and Aguila mountains. The sediments that fill the valley are undissected, and little can be inferred as to their composition in depth. The present streams are carrying rather fine material. In the middle of the valley, where it is crossed by the Tucson-Yuma road, the axial stream carried nothing over 2 inches in diameter in 1917. The heavy rains of September, 1920, produced floods which cut a channel 3 to 4 feet deep at this point and revealed pebbles as much as 4 inches in diameter. (Bryan, 1925a:202)

Bryan's description of the area suggests that incision was not present or was minimal when he visited the area. It is of course possible that Bryan did not see the indications of arroyo incision during his visit or that the dissection visible was so minor that he did not note it. Given his strong interest in arroyo development, neither of these possibilities seem likely. His account also suggests that a distinct channel formed in 1920, which could represent the beginning of arroyo development. Bryan described this area in another account, however, in which he describes a well-defined channel about 50 ft. wide downstream of the *Mesquital* (Bryan, 1922:68). This implies that although flow spread widely in the *Mesquital*, it became confined into a discrete channel downstream. The name *Mesquital* and Bryan's description of similar features in the Growler Valley indicates that vegetation density in the Tony Tank area was higher when he visited it than it is today:

The most remarkable forests of mesquite, however, occur in the interior valleys of the Papago country, where floods spread out in thin sheets over the so-called adobe flats. The mesquite are found here as lines or strings of trees along the channels or spaced at intervals so as to look like orchards (Bryan 1925a:41).

This implies that the mesquite thicket (bosque) present upstream of the arroyo was also present and likely more extensive when Bryan visited the area. The 1953 aerial photograph confirms the presence of a much wider expanse of mesquite along the floodplain downstream from Tony Tank. Burned remnants of mesquite trees evident at present imply that fire removed at least a portion of this bosque of trees.



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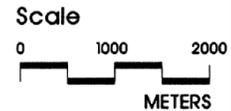


Figure 7. Map of the Growler Bend - Tony Tank area. Site areas mentioned in the text are labeled. Other sites discovered during the archaeological survey are shown as well. Modified from Slaughter and others (2000).

The arroyo on Growler Wash probably developed as a result of human perturbations of a natural system that was close to the threshold of critical power between erosion and deposition (Bull, 1979; 1991). The arroyo developed in a stream reach where the slope of the floodplain doubles, from about 0.0015 upstream to about 0.003 downstream (Figure 5). This change in slope is also evident in the reconstructed pre-arroyo floodplain in this reach (Figure 8). The arroyo developed in the uppermost part of the steep reach, and is now eroding into the flatter reach upstream. The change in floodplain slope has probably been sustained on a long-term basis by some combination of subsurface bedrock control and input of sediment from Daniels Wash and other tributary washes in this area. These factors likely work together to limit downcutting in the Growler Bend area. In addition, the formerly more extensive mesquite bosque in this reach reduced flow velocities and fostered deposition in the thicket. Stream gradients decrease in areas of active deposition, but must increase downstream; flow tends to become concentrated into channels in the steeper downstream reach (Bull, 1979). Based on Bryan's account of this area, it is likely that some kind of channel and alluvial fan system existed downstream from the mesquite bosque prior to Euroamerican occupation. Human perturbations of the natural system, probably including lowering the ground water table to supply stock tanks and establishing wagon roads in the floodplain, may have adversely affected the mesquite grove and provided artificial channels to concentrate flow. These changes may have caused the limited natural channel to develop into a full-blown arroyo beginning in the early 1900's.

Numerous features and artifacts were found in this area. We differentiate three different prehistoric site areas around Tony Tank (Figure 9):

1. *Growler Bend site area*: The 2-km-long reach of Growler Wash west of Brock's site (AZ Y:11:3), which includes the Growler Bend site (AZ Y:7:54) and several other smaller sites. Several other sites are located between the Growler Bend site area and the primarily eolian deposits to the northwest. These sites are too dispersed across geomorphic features to come to any significant conclusions, but probably represent extensions of the general use of these two areas during the prehistoric period.

2. *Verbena site area*: The area between the incised portion of the wash near Tony Tank and a crescent-shaped bedrock ridge to the northeast, which includes the Pearthree (AZ Y:7:58) and Verbena (AZ Y:8:11) sites.

3. *Cutbank site area*: The area between the Brock's site and the arroyo headcut, which includes the Cutbank site (AZ Y:11:14 [ASM]).

Growler Bend site area. Although incision in the Growler Bend site area is quite deep, particularly where it dissects late Pleistocene surfaces, the walls are not vertical here as they are further upstream. Artifacts are exposed on young alluvial surfaces that probably are eroded remnants of the late Holocene, pre-arroyo floodplain. Tributary arroyo

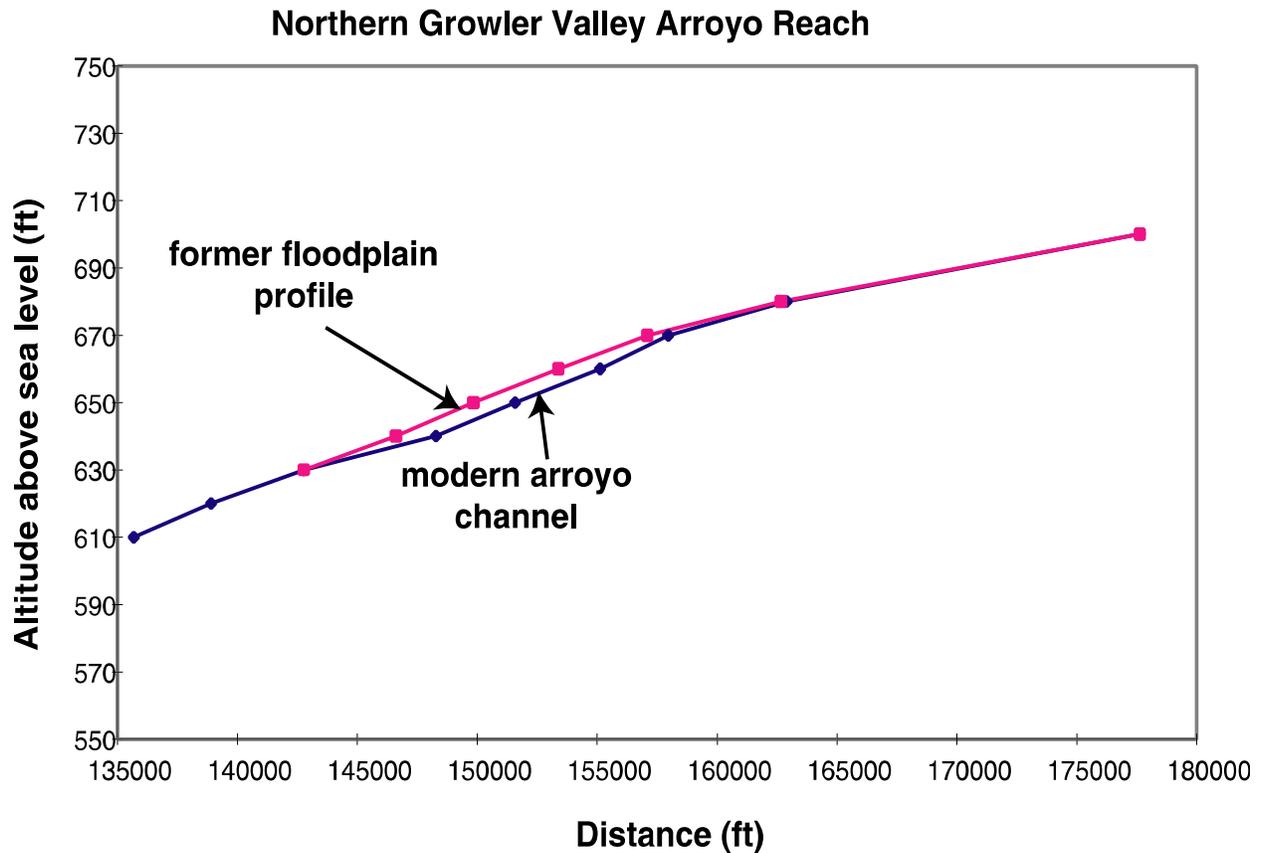


Figure 8. Longitudinal profiles of the Growler Bend - Tony Tank area. Profiles for the modern wash and the pre-arroyo floodplain are shown.

development in the floodplain is predominant on the southern side of the wash. Few cultural resources were found in these tributary drainages.

Aerial photographs from 1953, 1978, and 1986 show little change in this area. Toward the western portion of this reach, the 1978 channel appears slightly narrower and more well-defined than the same portion of the channel in 1953. The morphology and position of the alluvial fan at the downstream end of the arroyo changed very little between 1953 and 1985.

This area deserves the same degree of attention as was focused on the Cutbank site. Although in situ features have not been discovered here, the artifacts found include many diagnostic ceramics and pieces of shell. Because the walls of the channel are not vertical, facing the sides would prove more difficult; therefore, facing should be supplemented with test trenches or test pits. Testing should focus on preserved portions of the former floodplain where archaeological resources are found. Geologic mapping and additional study of arroyo development could prove

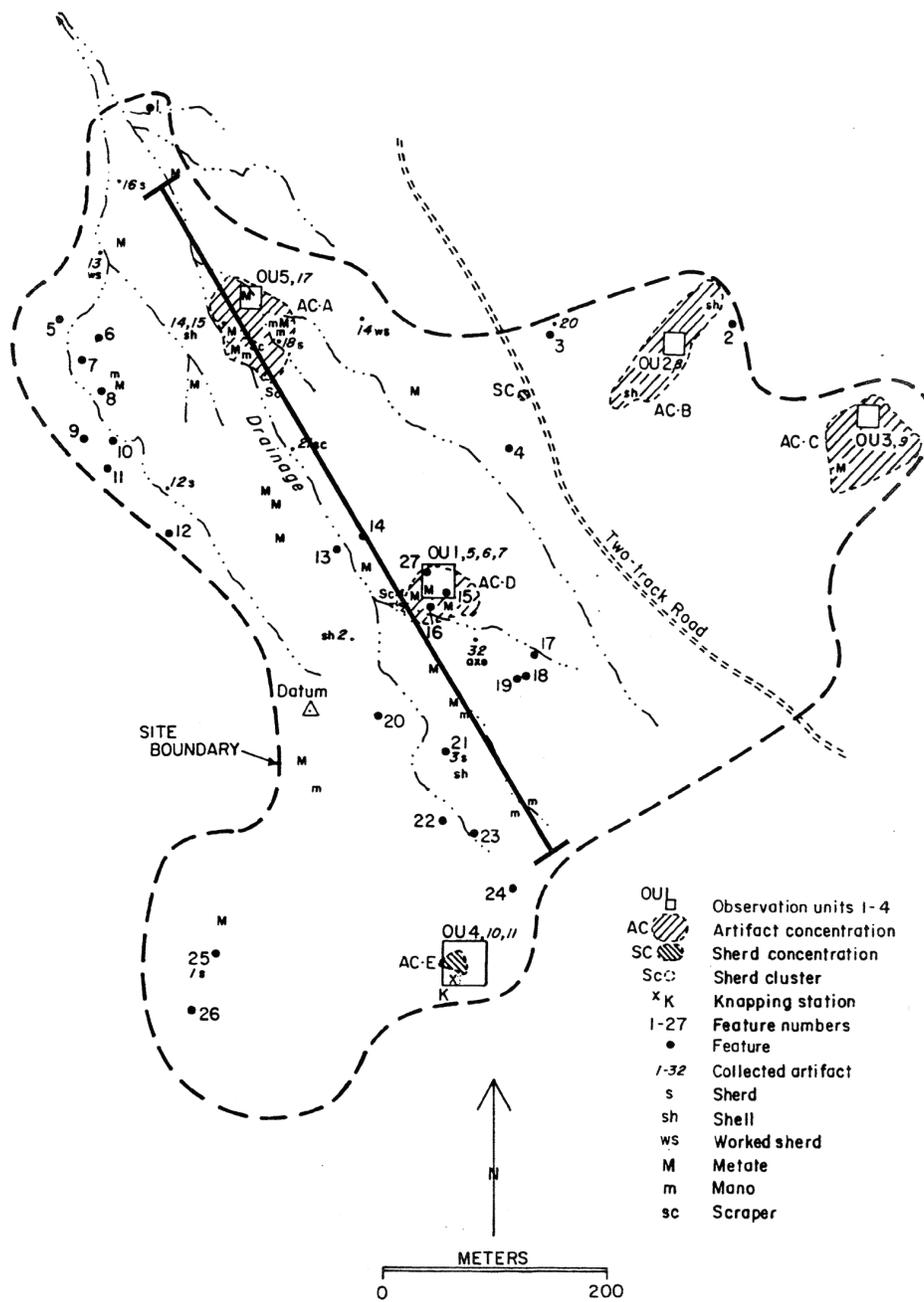


Figure 9. Map of the Cutbank site. The approximate plane of the longitudinal section displayed in Figure 11 is shown by the dark line. Modified from Slaughter and others (2000).

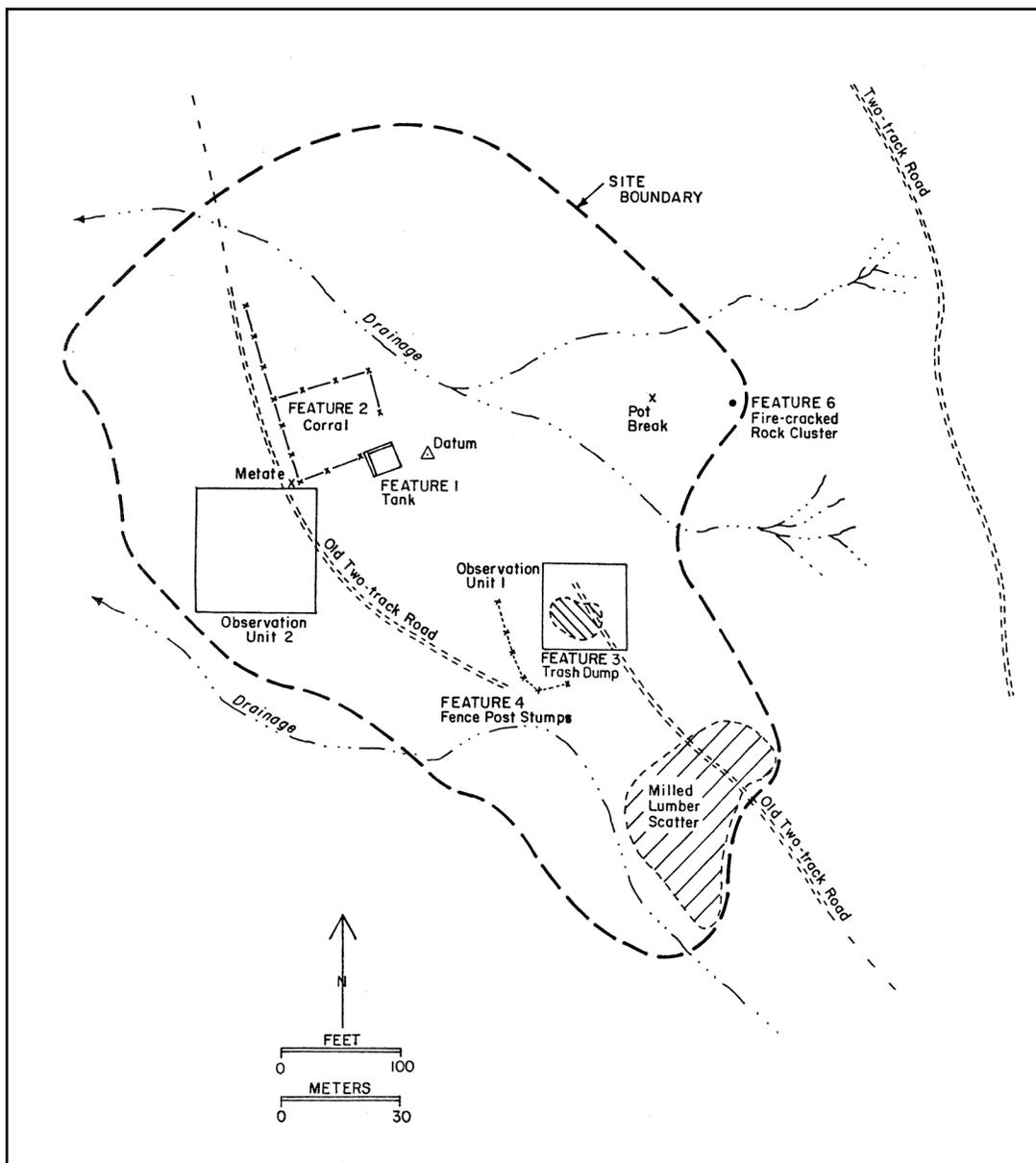


Figure 10. Map of the Tony Tank site. Southeast of feature 4, the drainage indicated is a tributary arroyo that follows the old two-track road. Modified from Slaughter and others (2000).

useful in assessing the contemporaneity of archaeological resources within this area and their relationship to the cultural resources found at the Cutbank, Verbena, and Pearthree sites.

Verbena site area. The Verbena and Pearthree sites are located along Daniels Wash northeast of Growler Wash between Tony Tank and a crescent-shaped bedrock ridge that rises above the piedmont. Daniels Wash is a major drainage that swings around the north end Growler Mountains and joins Growler Wash in the vicinity of Tony Tank (Figure 1; Plates 1 and 3). As Daniels Wash rounds the north end of the Growler Mountains, it changes from a fairly narrow, braided channel system into a very broad distributary drainage network that is associated with a large alluvial fan complex. This alluvial fan complex contains multiple distributary channels and widespread Holocene and late Pleistocene deposits. The two largest channels of the Daniels Wash distributary system diverge to the north and south of the crescent-shaped bedrock ridge. Downslope from this ridge, the channels become smaller and eventually are disappear in the broader floodplain. Based on their fresh appearance on aerial photos and abundant evidence of recent flooding, both channels convey significant amounts of water during floods and broad portions of the piedmont are inundated during floods. The Verbena site is located just downslope from the ridge, and the Pearthree site is located along the northern margin of the southern branch of Daniels Wash.

The Pearthree site stretches most of the distance between the Verbena and Cutbank sites along on the fringe of the floodplain of the southern branch of Daniels Wash near its contact with slightly higher, slightly older, mixed alluvial and eolian deposits to the north. The floodplain area is covered by late Holocene deposits, and is most likely inundated by shallow water in large floods. This area has probably experienced some, but not much, aggradation of fine-grained sediment since the time of prehistoric occupation. The area to the north consists primarily of mixed alluvial and eolian deposits of Holocene age, with a few isolated late Pleistocene alluvial surfaces (Plate 3). Lower portions of this northern area may be inundated during large floods, but the Pleistocene surfaces and the eolian dunes most likely have not been flooded for a long time. Artifacts were found on the floodplain and along the edge of the floodplain. This area is currently sparsely vegetated, with scattered creosote, annuals, and occasional clumps of mesquite and palo verde trees. The channels of Daniels Wash are small and discontinuous, and are about 200 m south of the site. Vegetation associated with these channels is somewhat larger and more dense, and includes mesquite and ironwood trees. The geologic setting of the southern margin of the floodplain is a very similar to the northern margin, but a reconnaissance, informal survey of the southern margin did not reveal any artifacts.

The current environment of the Pearthree site does not appear to be very attractive for human occupation or use. Vegetation is sparse, trees are uncommon, and there is no obvious water supply. We speculate that this area was significantly more inviting when prehistoric people were using this area. Several factors could have facilitated this, including a regional climate with somewhat more effective moisture. We think it is likely that the channels of the southern branch of Daniels Wash closely followed the northern margin of the floodplain during the time of human occupation, resulting in the presence of substantially more and larger vegetation in the area where artifacts have been found.

Cutbank site area. The Cutbank site area was studied most intensively during fieldwork (Figure 9). The channel of Growler Wash curves around a volcanic hill here. Several distributary drainages associated with Daniels Wash enter Growler Wash from the northeast, bringing with them relatively large discharges during floods. The arroyo is deeply incised in this area with walls up to 2 m in height and near vertical faces. Extensive tributary arroyos that have developed in the area appear to follow old roads, particularly in the area surrounding Tony Tank (see Figure 9). Numerous artifacts and features were discovered in the Cutbank site area. Many of the features were exposed in the walls of the arroyo or left exposed on eroded floodplain surfaces produced during large floods.

Historical activity in the area has created some unusual features and caused some modification to the arroyo. Two large berms of sediment built on either side of the channel near Brock's site appear to be the backdirt for removal of the vertical arroyo wall in order to build an access road across the channel to the site.

Soils and Sediments. Five soil profiles were drawn of the Cutbank site area. Two of these were located near features at opposite ends of the mapped area. Sediments in the mapped portion of the Tony Tank area are comprised of pale reddish brown fine-grained sands, silts and clays. Most of the sediments lie on flat, conformable contacts with the sediments below them. Occasional very small coarse sand or gravel channel deposits are present. These small channels are probably localized gullies and do not indicate past periods of large-scale channel incision analogous to the modern arroyo.

Soils exposed in this portion of the wash are weakly developed, which is consistent with the young age of the sediment. The best soil structure occurs within clay loams and may be a factor of sediment composition rather than soil formation. Occasional carbonate filaments in some sediments indicate that a somewhat significant period of time has elapsed (Gile 1975). Carbonates like these found in sediments in New Mexico and Arizona have given ages of between 1000 and 2000 years. The weak soil development present in the incised area around Tony Tank could support a light cover of desert grasses, shrubs, and trees. There are no indications that water ponded for long periods of time; however, it may have been present in wetter seasons.

Arroyo Incision. As was noted earlier, this area consisted of a mesquite thicket and an undissected floodplain covered with fine sediment early in this century. The arroyo is evident on the 1953 aerial photos, with the arroyo headcut located near the Brock site. By 1978, this headcut had progressed approximately 370 m upstream, past Tony Tank and into a grove of mesquite trees to the southeast. The rate of headcut progression during this 25 year period was approximately 14.5 m per year; however, headward erosion probably occurred during only a few large flow events.

Channelization of water in roads and wagon tracks during large floods probably facilitated the development of deeply incised arroyo system present today. It is clear from the 1953 photos that the mesquite thicket to the west of the volcanic outcrop was slightly denser and well-established than it is today. By 1978, a portion of this thicket has thinned near the center of the

arroyo. The fire which destroyed the remainder of the thicket occurred sometime after 1985, however, because the 1978 and 1985 aerial photographs show that at least some of the mesquite grove west of the volcanic outcrop was present after erosion of the main channel began. Burned stumps indicate that fire destroyed much of what remained at that time. Flotsam was found on the upstream side of these stumps and living vegetation indicating recent flooding of the area.

Geoarchaeological Mapping of the Cutbank Site

Geoarchaeological mapping and surveying of the Tony Tank arroyos were conducted in order to determine if there were any reasons to suggest that there might be stratigraphic differentiation between artifacts and features found in the Tony Tank area and to determine if the indications given in soil-geomorphic analysis that the area around Tony Tank were representative of more favorable climatic conditions in the past. Mapping was conducted by Freeman and Pearthree, with the assistance of Kirk Vincent of the Arizona Geological Survey. An electronic total station instrument borrowed from the University of Arizona Department of Geosciences was used to survey the area. Points near the centerline of the wash were surveyed in order to determine the current slope of the channel. Points on remnants of the floodplain were surveyed in order to try to determine the past slope of the drainage. Unfortunately, the floodplain surface has experienced some degradation, so the points do not precisely reflect the old slope. Artifacts and features were mapped and given classifications for the degree of confidence that the archaeological resources were *in situ*.

The map of survey points was projected to a single NW-SE trending line for purposes of plotting the longitudinal section (see Figure 11). This section is displayed in Figure 11. Floodplain shots are predominantly found furthest outside the centerline, as these appeared to be the least eroded portions of the floodplain. The floodplain in this area is denuded; however, which implies that it has undergone some erosion.

We grouped artifacts into three categories based on our field assessment of the likelihood that they are in place. Artifacts that are most likely *in situ* were assigned to Class 1. This includes artifacts found buried within floodplain sediments and features that were found relatively intact (e.g., tight clusters of fire-cracked rock). Archaeological resources with moderate confidence of position were assigned to Class 2. These archaeological resources were usually clusters of artifacts and features that appeared to be resting on a similar plane and which may have moved only slightly out of position. We surveyed the highest archaeological resources within these clusters. Class 3 was used for archaeological resources that were significant but which displayed few characteristics that would suggest that they were found *in situ*. These resources were usually large pieces of ground stone found in the floor of the arroyo. They were mapped because there was little reason to suggest that the artifacts (because of their size) could have moved far from their original position. They could have dropped down as fine-grained material around them was eroded, or they may have slid down slopes during wet conditions. Care was taken to

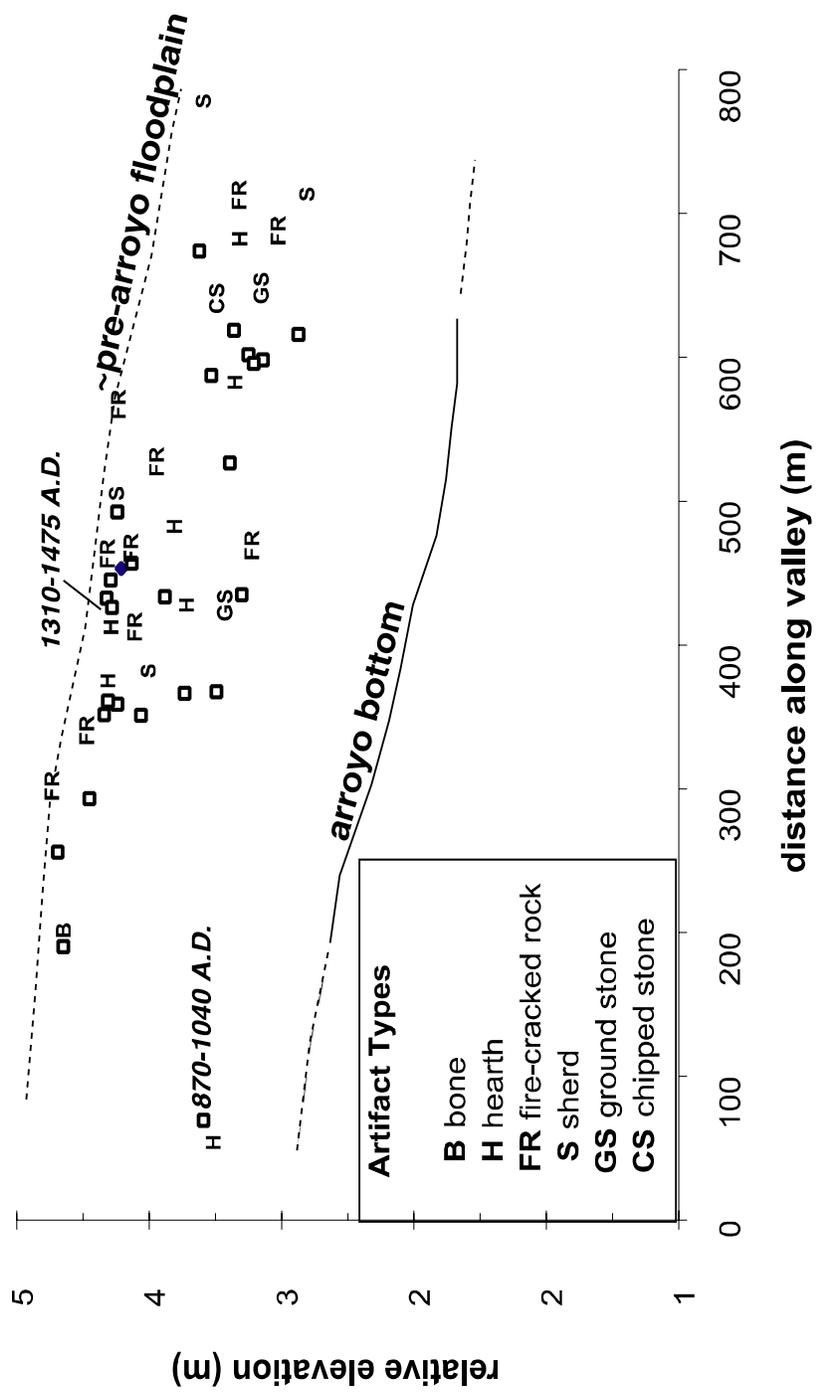


Figure 11. Longitudinal section along Tony Tank arroyo, Growler Valley. Data points were surveyed in various branches of the complex arroyo system, and were then projected onto a NW-SE-trending plane that is approximately parallel to the axis of the valley. This figure includes only artifacts that were considered likely to be in situ (Class 1).

examine the area around these artifacts, looking for possible holes from which they may have fallen.

In situ artifacts found in this survey are concentrated in the upper 1 m or so of the Cutbank deposits and are rare in the lower portions of the deposits (Figure 11). Class 1 artifacts were found throughout the upper 1 m of the section; the only one Class 1 feature found in the lower 1 m of the section is located near the headcut of the arroyo. This feature (Feature 22) was sampled and should be radiocarbon dated as well as examined for macrobotanical remains, because it appears to be distinctly lower in the section than any other clearly *in situ* feature and may represent the oldest evidence of prehistoric occupation in the area. Class 2 artifacts have a similar distribution, but there are more Class 2 artifacts in lower topographic positions. We believe that this most likely indicates that these lower artifacts are not *in situ*. Although *in situ* artifacts appear to be almost entirely in the upper part of the section, the lower parts of most arroyo banks are mantled by spoil resulting from the mass-wasting of the arroyo walls. Thus, the amount and quality of exposure of the upper part of the section is generally much greater than the lower part of the section.

Growler Wash at the Cutbank site has changed quite remarkably since the prehistoric occupation of the area. The stratigraphy exposed in this area and the radiocarbon dates obtained as part of this survey indicate that the wash was aggrading throughout the period of prehistoric occupation. Channels were probably small and discontinuous, and no arroyo existed. The sedimentology of the deposits exposed in the arroyo walls imply shallow water depths and fairly low flow velocities. Fine-grained deposits predominate and small gravelly lenses of channel deposits indicate that channels were much shallower than the modern arroyo. It is likely that the area supported an extensive mesquite thicket, suggesting that the water table was fairly shallow. Surface water coming from Growler Wash and tributary drainages to the northeast likely ponded around the volcanic outcrop, which served also as a source of good lithic raw materials. Other nearby high- to medium-density site areas probably represent the extension of these groups downstream to additional areas which might have been local sources of foods.

Exposures of archaeological resources and sediment, combined with several radiocarbon dates obtained for this study, reveal an interesting history of deposition and erosion at the Cutbank site. *In situ* archaeological resources were found in the upper 1.5 m of the arroyo stratigraphy; the highest artifacts are on or very near the pre-arroyo floodplain surface. A radiocarbon date obtained from charcoal in the stratigraphically lowest clearly *in situ* feature in the arroyo, feature number 22, has a 2σ calibrated age of 875-1040 A.D. Radiocarbon dates obtained from features near the western edge of the floodplain at depths of 50 cm and 25 cm (features 11 and 10) have calibrated ages of 985-1180 A.D. and 1245-1325 or 1340-1390 A.D., respectively. A radiocarbon date obtained from charcoal in one of the stratigraphically highest *in situ* features, feature number 15, has a 2σ calibrated age of 1310-1355 or 1385-1475 A.D. These dates imply that this area was utilized for at least 400 years, during which time 1 to 1.5 m of sediment accumulated. Evidently, very little aggradation occurred in the 500 years following Hohokam occupation, between about 1400 and 1900 A.D. It is possible that small channels developed and conveyed flow more efficiently through this area after 1400 A.D., resulting in minimal deposition. It is also possible that human activities such as erection of low berms or

dams may have caused floodplain aggradation during the time of Hohokam utilization of this area.

The geoarchaeological evidence is consistent with relatively low intensity occupation of this area over a long period of time. *In situ* artifacts distributed throughout the upper part of the exposed sections suggest that occupation of the area occurred over a relatively long period of time while this area was aggrading. The area likely experienced low-density occupation over a 500+ year time period. However, further study of the stratigraphy in the arroyo and the relationship of artifacts and features to that stratigraphy is necessary to determine if there are not significant hiatuses in deposition within the arroyo which might indicate occupations during distinct temporal (and possibly environmental) periods.

Site Preservation

Archaeological sites in the Growler Wash area appear to be relatively well-preserved. Although the artifacts and features have been exposed by large flood events, this appears to do minimal damage. Lighter artifacts and plant materials within some features will be entrained in the sediment load being transported by these events and redeposited downstream; however, larger artifacts and features are found near their original positions. The best locations to find artifacts and features *in situ* are where they are only partially exposed and the remainder of the feature is preserved beneath the surface. The two best places within the project area are associated with eolian deposits, where archaeological features and artifacts are preserved under low coppice dunes, and in the Tony Tank area, where features are partially exposed in arroyo walls. The latter also provides large exposures that can be studied for stratigraphic relationships between artifacts and features.

Environmental Conditions in the Past

Indications that environmental conditions were slightly more favorable in the past are represented in the density of archaeological sites found in portions of the Growler Wash area. These localized areas probably offered slightly better water accessibility over the long term. There may have been well-known sources of reliable water and plant materials utilized by short-term occupations over a long period of time. No prehistoric wells have yet been found in the incised portion of the wash, so it is not clear what water sources may have been available to prehistoric people. Additional archaeological survey or testing should keep a keen eye out for such features.

Fine-grained deposits that predominate in the Tony Tank area indicate that water spread widely in this area, facilitating stream aggradation. As noted above, it is possible that human activities also fostered deposition in this area. During the 500 years following Hohokam occupation of this area, minimal deposition occurred. Development of the modern arroyo began sometime during the early 1900's. A thick clay bank in the present headcut area indicates that water may have occasionally ponded in this area. The presence of a rhyolitic outcrop nearby. This outcrop might act as a barrier to subsurface flow that may keep groundwater close to the surface in this area.

Summary and Recommendations

Although today the Growler and San Cristobal Valleys are virtually uninhabitable, there is some indication that the environment was more favorable in the past. Archaeological sites in the Growler and San Cristobal Valleys seem to reflect limited activities and short term visits to specific resource areas over many years. Archaeological sites may have been located where groundwater was relatively close to the surface, where water pooled from heavier rains, and where vegetation was more dense. Areas where additional resources such as lithic raw material or protective cover were available, were probably favored.

Geoarchaeological assessment of the discovered survey sites suggests that high dunes may have provided protective cover from sun and wind, and plant resources that would provide firewood and forageable plant foods. Partial exposure of cultural resources at the base of these dunes provide indications of where subsurface cultural resources may be found *in situ*.

Bedrock hills that protrude into the valley, like in the Tony Tank area, may cause groundwater to rise closer to the surface or may cause water from drainages entering the area to pool during wetter seasons. Plant resources are more likely to grow in these area, providing a source for firewood, plant foods, and protective cover. Lithic resources in the area may have made this portion of the Growler Valley a favorable locale for short-term seasonal activities. Exposures of archaeological features and artifacts provide cultural resources that may be sampled in abundant geologic exposures.

Additional geologic and archaeological research is necessary to determine what the nature of the prehistoric occupation was like in the Growler Wash area, the intensity of that occupation, and timing. The following recommendations are made with reference to the project areas defined in the text above:

- (1) We recommend that additional archaeological survey focus in areas where high dunes are located and in the area surrounding the large cluster of sites near Tony Tank. Archaeological testing is recommended in these areas as well. Archaeological testing in these areas is reasonably likely to produce *in situ* artifacts and features.
- (2) Additional geoarchaeological research is necessary to determine the context of archaeological features and artifacts in the Tony Tank area. A detailed topographic map should be produced in conjunction with archaeological excavation and survey and a detailed assessment of the sedimentology and stratigraphy of the arroyo walls. Photogrammetry or detailed field surveying may be appropriate methods for developing a detailed topographic map of the Tony Tank area.
- (3) Additional intensive geologic examination of the deposits exposed in the arroyo walls can provide a stratigraphic framework for additional archaeological research in the area and can provide a better understanding of the environment present during site occupation. Radiocarbon dates on selected archaeological features will be necessary to aid in establishing a geochronological framework for the archaeological resources found in the area.

(4) If the Stoval area is examined further, we recommend that additional topographic mapping be conducted in conjunction with archaeological survey and excavation. Additionally, further examination of archival records (GLO surveying notes, geologic field notes) may provide useful geoarchaeological data for evaluating the area.

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