Surficial Geology and Geoarchaeology of the Daniels Wash Area in Northern Growler Valley, Barry M. Goldwater Air Force Range, Southwestern Arizona

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INTRODUCTION

This report summarizes geomorphologic investigations and surficial geologic mapping conducted on part of the Barry M. Goldwater Air Force Range (BMGR) in southwestern Arizona in 1997 and 1998. These investigations were done in support of two extensive archaeological surveys in northern Growler Valley, in the west-central part of this vast desert reserve (Ahlstrom and Lyon, 2000; Tucker, 2000; see Figure 1). The map and survey area are about 30 km west-northwest of Ajo, and about 60 km southwest of Gila Bend. 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. The general implications of the geomorphology and surficial geology for the potential for finding archaeological sites and features is considered in Part 2. The possibility that prehistoric inhabitants or seasonal visitors to this area diverted flow for agricultural purposes is explored in Part 3.

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 pleasant company. In particular, we thank Jerry Lyon, Heidi Roberts, and Dave Tucker, 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 Rick Ahlstrom of SWCA, who provided useful insights into the archaeology of this part of the world. Bruce Masse of Luke Air Force Base pointed out the curious berms along the north branch of Daniels Wash, which led to the investigations summarized in Part 3 of this report. Pete Corrao and Tim Orr assisted with production of the surficial geologic map.

Part 1. SURFICIAL GEOLOGY AND GEOMORPHOLOGY

By Philip A. Pearthree and Karen A. Demsey

Introduction

This part of the report summarizes the surficial geology and geomorphology of the Daniels Wash area in northern Growler Valley, in the central portion of the Barry M. Goldwater Air Force Range. The purpose of these investigations is to provide a general geologic and geomorphic framework for an archaeological survey of the Daniels Wash area that was conducted for the Air Force by SWCA, Inc, and Arcadis Geraghty and Miller. A 1:24,000-scale map showing the surficial geology of the survey area is included with this report (Plate 1). Interpretation of aerial photographs and preliminary geologic mapping was done primarily by K. Demsey, with field checking and final mapping by P. Pearthree. Andres Meglioli and Jeanne Klawon provided field assistance and feedback for the mapping process.

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 (Bryan, 1925). 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, was subsequently mapped in somewhat more detail (Gray and others, 1988). The generalized surficial geology of the Ajo sheet was mapped by Morrison (1983) at 1:250,000-scale. Bull (1991) developed a conceptual framework for understanding the impacts of climatic changes on arid region fluvial systems of the lower Colorado River region.

General Geology and Geomorphology

Growler Valley is 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 in the northern Growler Mountains consist of silicic to mafic volcanic rocks and some associated volcaniclastic sediments of Oligocene to middle Miocene age (Gray and others, 1988). Several bedrock hills or ridges that rise above the piedmonts of Growler

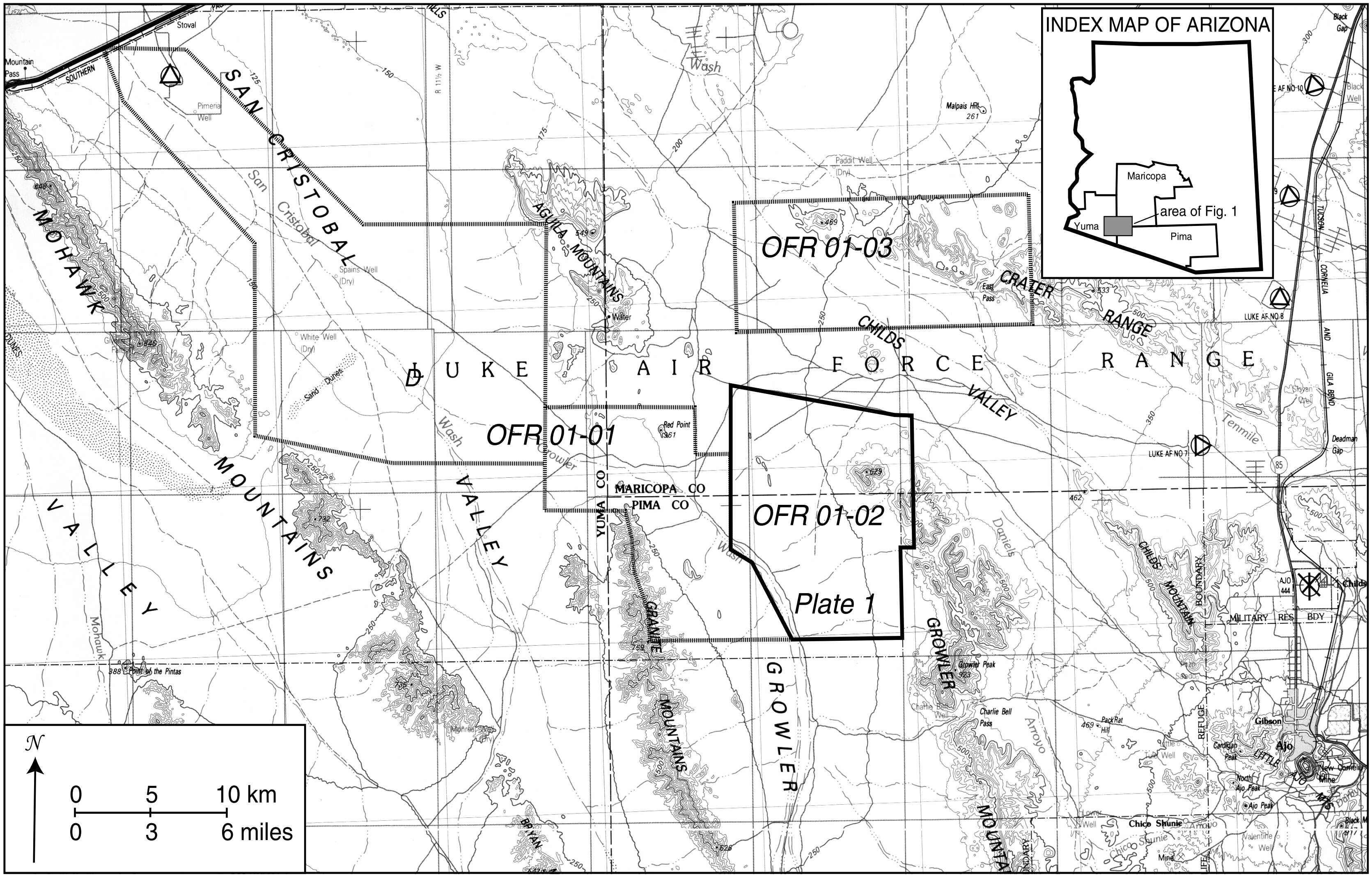

Figure 1. Location of the map area in the Barry M. Goldwater Air Force Range is outlined by the solid line. Adjacent areas where surficial geology has been mapped at 1:24,000-scale are outlined by dotted lines; letters and numbers refer to Arizona Geological Survey Open-File Reports that contain the maps.

Valley are mapped as Tertiary basalt. Undisturbed, exposed surfaces of these volcanic rocks are coated with very dark rock varnish.

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.

The geomorphology and surficial geology of this part of Arizona may be grouped into three main elements:

(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, 1925). 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 floodplains and alluvial fans 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

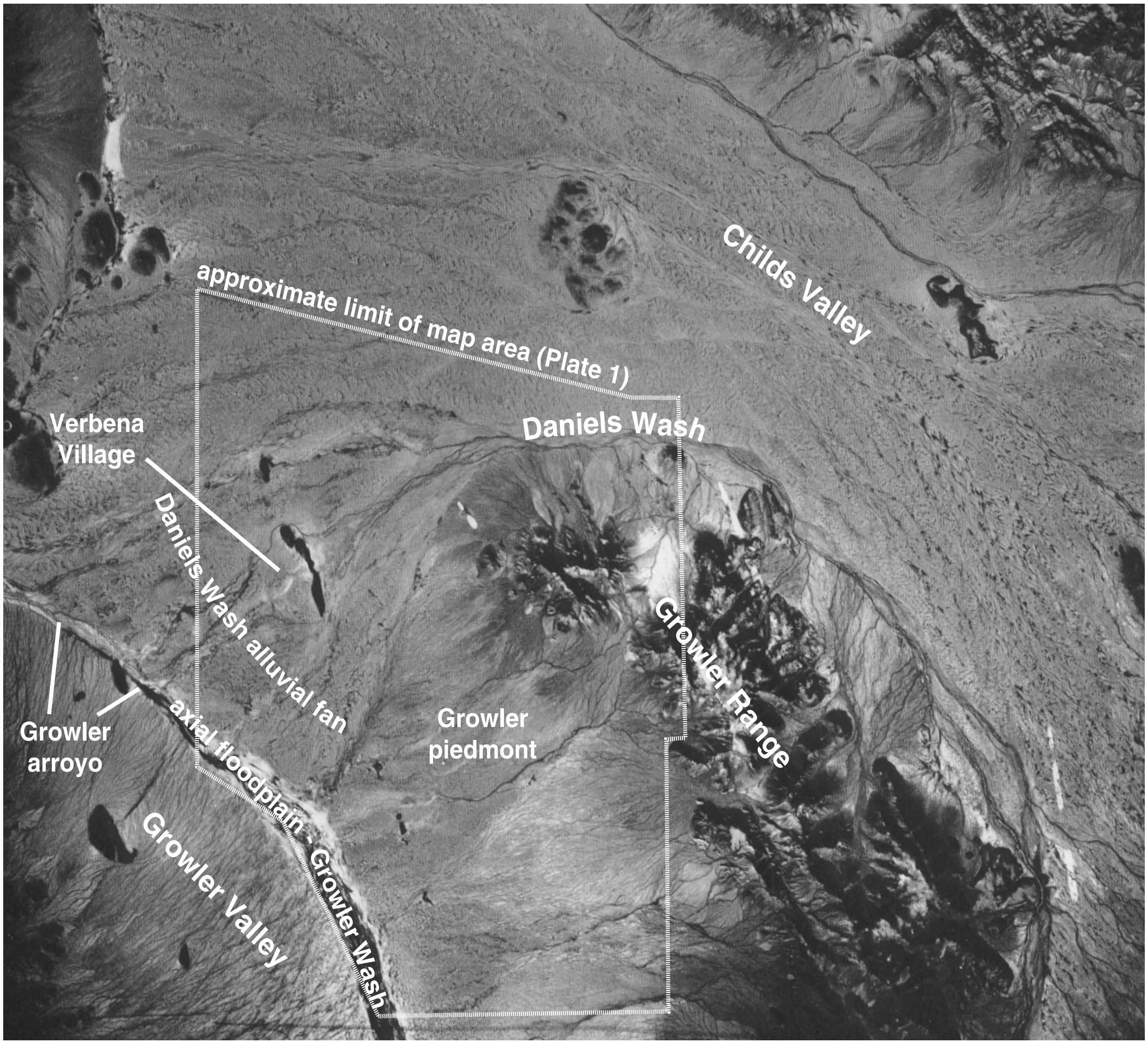

Figure 2. High-altitude aerial photograph (~1:150,000-scale) of the study area. The major landscape elements are labeled, as are some specific localities in the area. The extent of Plate 1 is outlined by the dotted line.

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. Locally, alluvial fans exist along these washes where floodplains are very wide and increase in width substantially downstream. Eolian reworking of floodplain and fan surfaces is common, especially in areas that have not been flooded recently.

(3) Very wide piedmonts with minimal topographic relief. Piedmonts are the broad plains that slope gently from the mountains to the axial washes. They 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.

The archaeological survey covered the northern flanks of the Growler Mountains and much of the Daniels Wash alluvial fan system. Although the area covered by the survey and this map is fairly small, it includes each of these three landscape units (Figure 2). The map area covers the northwesternmost part of the Growler Mountains and its surrounding piedmonts, which are covered by Quaternary alluvial deposits of various ages. In addition, the map includes part of a large alluvial fan complex deposited by Daniels Wash and a very small part of the floodplain of Growler Wash.

Mapping Techniques and Ground Control

We employed standard surficial geologic mapping techniques to produce geologic maps of the project area. We developed a 1:24,000-scale surficial geologic map of the project area. Mapping was based primarily on interpretation of approximately 1:24,000-scale color photographs flown in 1985 that were supplied by the Air Force. Extensive field surveys were conducted to verify geologic relations in the map area.

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 deposited by larger washes consists of channels, low floodplain terraces, and broad alluvial fans. 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 criterial described below. Deposits in the third category were subdivided based on 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. The 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 (troughlike 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 been isolated from substantial fluvial deposition or reworking for hundreds of thousands of years. These surfaces are characterized by strongly developed soils with clay- and calcium-carbonate-rich horizons, well-developed tributary stream networks that are entrenched 1 to 10 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 (Plate 1) are classified by by source of emplacement and inferred age. Deposits are divided by age into late Holocene (H2; less than about 2 ka; the abbreviation **ka** stands for thousands of years before present), early to middle Holocene (H1; about 2 to 10 ka), late Pleistocene (10 to 150 ka), middle Pleistocene (150 to 750 ka), and early Pleistocene (750 ka to 2 Ma; the abbreviation **Ma** stands for millions of years before present). Piedmont alluvial deposits have the letter (**a**) attached to the unit labels other than age (**Qy2**, for example). Deposits associated with major axial drainages have the letter (**r**) added to the age designation (**Qy2r**, for example). Many areas in this valley are covered by mixed alluvium 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 (**Qyre**, for example). As was noted above, ages of all of these deposits are roughly estimated by correlation with other similar areas, because no useful constraints have been developed for most of the deposits in these valleys. Age estimates given here 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.**

<u>**Piedmont Alluvial Deposits**</u>

Piedmont alluvial deposits are derived from the Growler Mountains. The lithologic composition of clasts reflects local source lithologies.

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 **Qy2** surfaces. **Qy1** deposits are probably correlative with unit Q3b and possibly unit Q3a of Bull (1991), which are middle to early Holocene in age.

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 that 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.

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 units Q2b and Q2a of Bull (1991), which are 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 fragments derived from petrocalcic soil horizons litter **Qo** surfaces. Tributary drainage networks are strongly developed and moderately to deeply entrenched; areas between channels are 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 of Bull (1991), which is of early Pleistocene age.

QTs – early Quaternary to late Tertiary deposits (1 to 10 Ma)

Deeply dissected, weakly to moderately consolidated relict alluvial fan deposits adjacent to the Growler Mountains. The surfaces associated with this unit are narrow ridge lines and hillslopes. Soil development is weak to moderate, as the highest depositional surfaces on top of these deposits have been completely removed by erosion.

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 uncertainy in the boundaries shown on these maps.

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 surface 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 (unit Ql) 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.

Deposits of Daniels Wash

Deposits of Daniels Wash are derived from a large source area and typically contain diverse clast lithologies.

Qy2r - late Holocene stream deposits (< 1 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.

Qy1r - 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)**.

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 **Qy1r**.

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

Mixed intermediate river terraces and young eolian deposits. **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 Geology

Tv – Tertiary volcanic rock, including basalt, andesite, rhyolite, and volcanic conglomerate.

Age Range	Lower Colorado River chronosequence (Bull, 1991)	Growler chronosequence (this report)
historical (< 100 yr)	Q4	Qy2r
late Holocene (0-2 ka)	Q3c	Qy2, He, Qy1r
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	Qo

Table 2. Tentative correlation table for deposits of the lower Colorado River Valley and the northern Growler Valley. 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 the Daniels Wash area in northern Growler Valley reflect the complex interaction between piedmont tributary streams, 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 in this region typically are dominated by alluvial deposition, whereas piedmonts on the eastern sides of the valleys have a strong eolian component. 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 comprise about 40 percent of the study 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 piedmonts are covered primarily by finer-grained Holocene alluvial deposits, with 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 geologic map, may not be subject to flooding in the modern environment. Distinctly alluvial landforms dominate the upper piedmonts, but in the southwestern part of the map area these alluvial landforms gradually fade out downslope as the eolian imprint becomes stronger. Drainage networks also become indistinct as evidence of eolian activity increases. In lower piedmont areas, areas covered by solely alluvial deposits are limited.

Landforms associated with the major axial washes of this region consist of channels, floodplains, low terraces, and large alluvial fans of Holocene or late Pleistocene age. Fluvial landforms associated with Daniels Wash in Growler Valley are very broad and are fan-shaped. Thus, they are best characterized as large alluvial fans. Complex active distributary drainage networks associated with Holocene deposits range up to 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 Daniels Wash have a significant eolian overprint.

Part 2. GENERAL GEOARCHAEOLOGY OF THE DANIELS WASH AREA
By Philip A. Pearthree

Surficial geologic mapping outlines the geologic and geomorphic framework of the Daniels Wash area and provides a context in which to consider the archaeological sites found there. The ages of the various surficial geologic units in the project area have implications for the potential for discovery of surface and subsurface archaeological features. In addition, the character of the surficial geologic units and their spatial distribution may help explain the distribution of the archaeological features and sites that have been identified in this project, because features appear to be concentrated in specific geomorphic settings.

Potential Artifact and Site Distributions on Surficial Geologic Units

The age and character of the various surficial geologic units in the project area have implications for the potential for discovery of archaeological features. On piedmont alluvial deposits of late Pleistocene age or older (units **Ql**, **Qm**, and **Qo**), artifacts will almost certainly be found only on the surface unless features were excavated into these surfaces. These Pleistocene alluvial surfaces have moderate to well-developed gravel pavements that are fairly coarse near the mountains. If these pavements contain rock types such as fine-grained volcanic rocks that are suitable for the manufacture of stone tools, then they might be sites for stone tool acquisition. Pleistocene deposits in the middle and lower piedmonts have finer-grained pavements that generally do not have large gravel clasts that would be suitable for working. In the broad piedmont and alluvial-fan areas covered by mixed late Pleistocene alluvium and Holocene eolian deposits (units **Qle** and **Qlre**), artifacts might be buried by small dunes, but it is probably more likely that they would be exposed on the dunes or on intervening gravel pavements. Because Daniels Wash is a fairly large drainage, gravel pavements associated with Pleistocene deposits of Daniels Wash (unit **Qlre**) include some cobbles consisting of a variety of rock types. The larger cobbles of suitable rock types may have provided a potential resource for stone tool acquisition.

Channels, floodplains, terraces and alluvial fans of Holocene age may have surface or subsurface artifacts associated with them. The channels, floodplains, and active alluvial fan areas associated with Daniels Wash generally are covered with late Holocene to modern sediment (unit **Qy2r**). It is likely that sizable, infrequent floods result in the inundation of most of these floodplains and much of the alluvial fan area, depositing sediment and reworking young surfaces. 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 and alluvial fan areas that are somewhat removed from active channels (unit **Qy1r**) have not been subject to much or any recent flooding, so any archaeological features are more likely to be exposed in these areas. Older Holocene alluvial surfaces with a substantial eolian overprint (unit **Qyre**) might have artifacts exposed on the alluvial surfaces or buried beneath eolian deposits. On the piedmonts of the Growler Mountains, deposition on some young fans and terraces (some areas included in unit

Qy2) certainly post-dates the prehistoric occupation of this area. It is likely, however, that in most **Qy2** areas minimal deposition has occurred in the past 1,000 years or so. Therefore, artifacts might be found on the **Qy2** surfaces or they might be buried beneath them. Artifacts are most likely to be found on older Holocene alluvial surfaces (unit **Qy1**) and not beneath them.

Geomorphic Setting and Archaeological Site Distribution

In this section we consider the geomorphic and geologic settings in which archaeological sites and features were found. Comparison of distribution of surface archaeological sites and features found in the survey area with the distribution of surficial geologic units indicates a preference for certain geomorphic settings. Nearly all of the sites and features identified are either associated with the Daniels Wash alluvial fan or are found on the upper portions of piedmonts and lower hillslopes of the Growler Mountains (see Plate 1). Very few sites or features were discovered in middle and lower piedmont areas, which are covered almost entirely by relatively fine-grained Holocene deposits (units **Qy2** and **Qy1**).

Upper Piedmont and Hillslope Setting

Many archaeological features and small sites found in this study are located on the upper portions of piedmonts around the Growler Mountains and the lower hillslopes of the mountains. Upper piedmont areas are covered almost entirely by Pleistocene alluvial fan remnants. Middle Pleistocene surfaces (unit **Qm**) are the most extensive surface type on the upper piedmonts around the northern Growler Mountains, but late Pleistocene (unit **Ql**) and early Pleistocene (unit **Qo**) alluvial fan surfaces are also common. The adjacent mountain hillslopes consist of exposed bedrock and colluvium derived from the bedrock (unit **Tv**), with colluvium being much more extensive than exposed bedrock. Young alluvial surfaces (units **Qy2** and **Qy1**) cover very little of the upper piedmonts, but are widespread in middle and lower piedmont areas.

About 50 percent of all of the upper piedmont features and sites are located on **Qm** surfaces; the remaining 50 percent of the sites are fairly evenly distributed between the other map units. The relatively large number of sites on **Qm** surfaces may be explained in part by the large areal extent of these surfaces on the upper piedmont. Of all the alluvial surfaces, however, the **Qm** surfaces typically have the greatest density of coarse gravel clasts on them. **Qm** surfaces would have been obvious candidates for the procurement of stone tools if favorable lithologies are included in the surface gravel. Early (**Qo**) and late (**Ql**) Pleistocene alluvial surfaces are also typically mantled by gravel lags, although their surface gravel cover typically is less well developed (**Ql**) or less well preserved (**Qo**). Some of the higher Pleistocene alluvial fan surfaces, such as the high Qo fan remnant at the pass near the eastern edge of the study area (T. 10 S., R. 9 E., Sec. 36 [unsurveyed]), may have been occupied because of the vantage points they provided. As was noted above, younger surfaces (**Qy2** and **Qy1**) are quite limited on the upper piedmonts. Where they exist, however, they typically have larger vegetation associated with them. The shelter and potential firewood provided by this larger vegetation may have made the younger surfaces favorable areas for campsites.

Daniels Wash Alluvial Fan

Numerous sites were documented in the portion of the Daniels Wash alluvial fan that was covered by the archaeological survey. In addition to the sites discovered in this survey, the major Verbena Village site (Olszewski and others, 1996) and other sites to the west (Slaughter and others, 2000) are located on the Daniels Wash alluvial fan. Daniels Wash forms a large alluvial fan complex as it rounds the northern end of the Growler Mountains and flows westward toward Growler Wash (see Plate 1). The drainage system associated with this alluvial fan complex is distributary, meaning that flow diverges downstream from a single channel into multiple channels and eventually into broad areas of sheetflooding with a few small, discontinuous channels. The total width of the active flow system of Daniels Wash increases from about 300 m at the northeastern edge of the map area to about 5 km at the west edge of the map area. Included within the distributary flow system are very young alluvial surfaces that are part of the modern distributary drainage system and are subject to flooding, erosion and deposition (unit **Qy2r**), areas that are peripheral to the modern drainage system and rarely flooded (**Qy1r**), and areas that are isolated from the modern drainage system and have not been subject to substantial flooding for thousands of years (**Qyre**) to 10,000 years or more (**Qlre**). In addition, there is an elongate ridge of volcanic rock that trends perpendicular to the flow direction of Daniels Wash. Thus, local environments within the Daniels Wash alluvial fan vary substantially in terms of drainage characteristics, water availability, soil and surface characteristics, and vegetation.

In the southeastern part of Daniels Wash alluvial fan, sites exist primarily on relatively older surficial geologic units, including **Qy1r**, **Qyre**, and **Qlre** (Plate 1; Figure 3). Although this area is included within the Daniels Wash alluvial fan, the limited extent of very young deposits (**Qy2r**) there indicates that it receives little distributary flow from Daniels Wash in the modern regime. Surface drainage is generally poorly defined, with small, intermittent channels and extensive, low-relief areas that are subject to sheetflow from local runoff or occasionally from Daniels Wash. There is a strong eolian overprint on the alluvial deposits in much of this area (**Qyre** and **Qlre**). Surface drainage is especially poorly defined on these mixed eolian/alluvial units because the axes of the low dunes typically trend northwest - southeast, which is perpendicular to the overall surface slope. In these areas, accumulation of fine sediment (silt and clay) indicates that runoff tends to pond upslope of the dunes. Some of these ponded areas support fairly large and abundant stands of bunch grass, which may have been utilized by prehistoric inhabitants of the area.

Archeological sites have also been found in the more active portion of the Daniels Wash alluvial fan system both upslope and downslope from the low basalt ridge (Figure 3). Because these areas are within the most active part of the alluvial fan system, they receive significant flow during floods. Surfaces in this area consist mostly of broad very young (**Qy2r**) and fairly young (Qy1r) alluvial surfaces. Sites were discovered on both **Qy2r** and **Qy1r** surfaces, but the most extensive sites, including most of Verbena Village, are located on **Qy1r** surfaces. Possible irrigation features exist along the north channel of the Daniels Wash in the vicinity of Verbena Village (see below), and features may be discovered along other channels upon closer examination. In addition, maize pollen was detected in subsurface deposits associated with the south branch of Daniels Wash near Verbena Village (Ahlstrom and Holloway, 2000). Flow in the Daniels Wash channels may have been contained by the means of low earthen berms and directed to low-relief areas of sheetflooding, which were cultivated. It is not clear whether flow in Daniels Wash was more regular at that time, or whether these irrigation features and cultivated areas exploited occasional flows of the sort that characterize the modern flow regime. These preliminary data strongly suggest that active alluvial fan area of Daniels Wash was exploited for agricultural purposes in association with occupation of the Verbena Village site and other sites in this area.

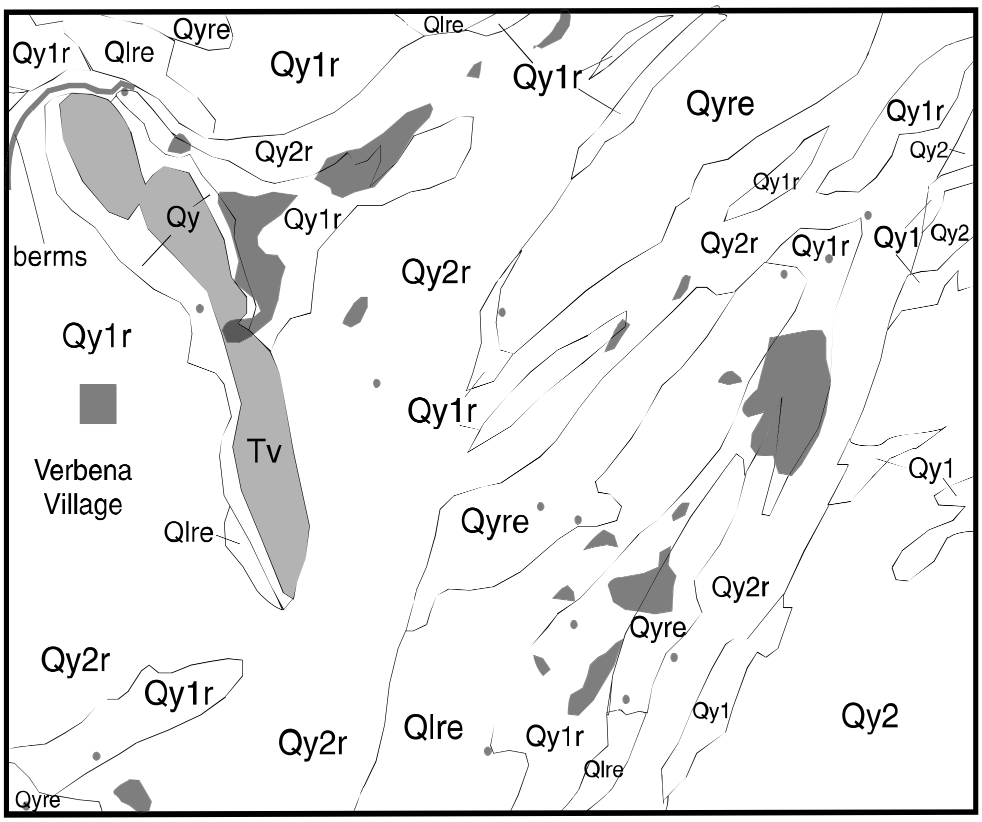

Figure 3. A portion of the surficial geologic map (Plate 1) covering part of the Daniels Wash alluvial fan. Geologic map units are described in Part 1 of this report. Archaeological sites are depicted with black polygons. Most of the sites were found on middle to early Holocene surfaces (units Qy1r and Qyre) in proximity to the more recently active parts of the Daniels Wash fluvial system (unit Qy2r). Few sites were discovered on unit Qy2r, probably because much of this area has been reworked by fluvial activity in the past 1000 years.

Part 3. GEOARCHAEOLOGY OF POSSIBLE IRRIGATION FEATURES NEAR VERBENA VILLAGE

By Jeanne E. Klawon and Philip A. Pearthree

Introduction

During the course of field mapping, we investigated a series of unusual channel features that exist along a branch of Daniels Wash in the northwestern part of the map area near the Verbena Village archaeological site (Figure 4). In this area, the channel along the north branch of Daniels Wash is curvilinear in plan view, its width and depth are fairly uniform, and it is lined by low berms of variable height (Figure 5). Relict distributary channels have been isolated from flow in the present channel configuration, apparently because of the existence of the low berms along the main channel. In its present configuration, flow is collected by this branch of Daniels Wash upstream of a basalt ridge, conveyed about a kilometer downstream without significant divergent flow, and delivered to an area of broad sheet flooding that is covered by fine sediment. In this section we document the physical characteristics of these features and their position in the landscape, and explore the possibility that they are of anthropogenic origin.

Daniels Wash is a large drainage that heads in the Growler Mountains southwest of Ajo, Arizona, and drains the east flank of the Growler Mountains as it flows northwest through Childs Valley. As the wash rounds the northern end of the Growler Mountains, it turns west-southwest into Growler Valley and splits into several channels. The primary flow path of Daniels Wash bifurcates into two channels that pass immediately to the north and south of a NW-SE-trending low basalt ridge, informally named “Peanut Hill”. Downslope from Peanut Hill, both branches become distributary flow systems composed of multiple small channels that diverge downstream and broad areas that are subject to sheet flooding (Figure 4; Plate 1). Because of the broad width of the distributary system, flow from Daniels Wash joins Growler Wash over a reach of several kilometers.

This study concentrates on the northern branch of Daniels Wash in the vicinity of Peanut Hill (Figure 6). The channel system in this area consists of tributary, confined, and distributary reaches. Along the tributary reach east (upstream) of Peanut Hill, smaller channels feed into the main channel and flow is increasingly concentrated downstream. The confined reach begins just upslope of Peanut Hill and continues downstream for about 750 m. In this reach, the single channel is well defined and continuous, there is minimal input from tributary streams, and the channel banks are lined by vegetation and sediment berms of varying height that apparently contain nearly all of flood flows. Many relict distributary channels along this reach have been cut off from recent flow events. The active distributary system exists downslope of Peanut Hill at the lower end of the confined reach. This distributary reach is characterized by small channels and broad areas with minimal relief that are covered by young, fine-grained deposits.

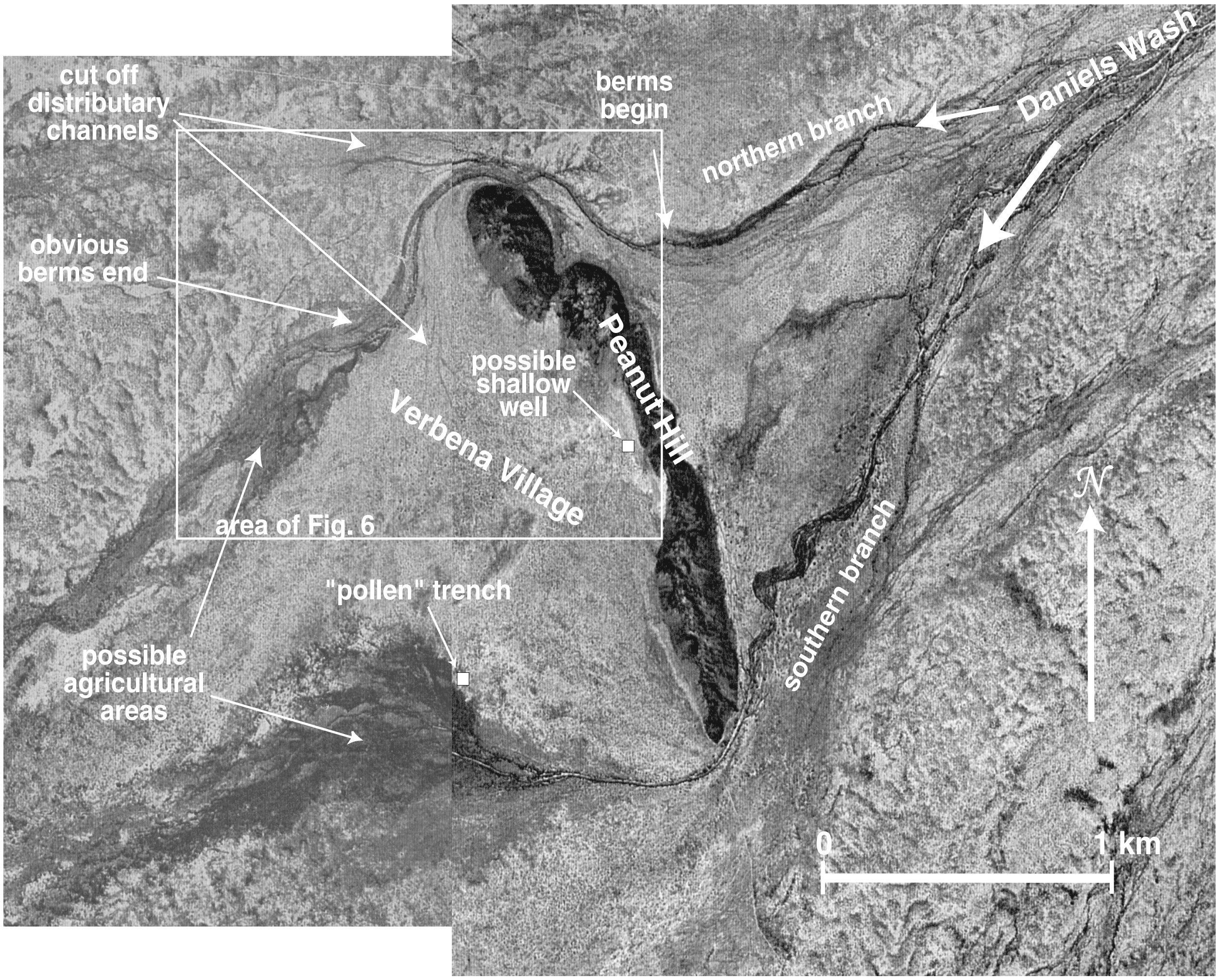

Figure 4. Large-scale aerial photo of the Verbena Village site showing the major geomorphic and archaeological features discussed in the text. The distributary channel system in this part of Daniels Wash bifurcates around Peanut Hill. Flow in the modern system is concentrated into relatively narrow channels as it rounds both the north and south ends of Peanut Hill. This concentration of flow may be the result of anthropogenic alterations to the natural system.

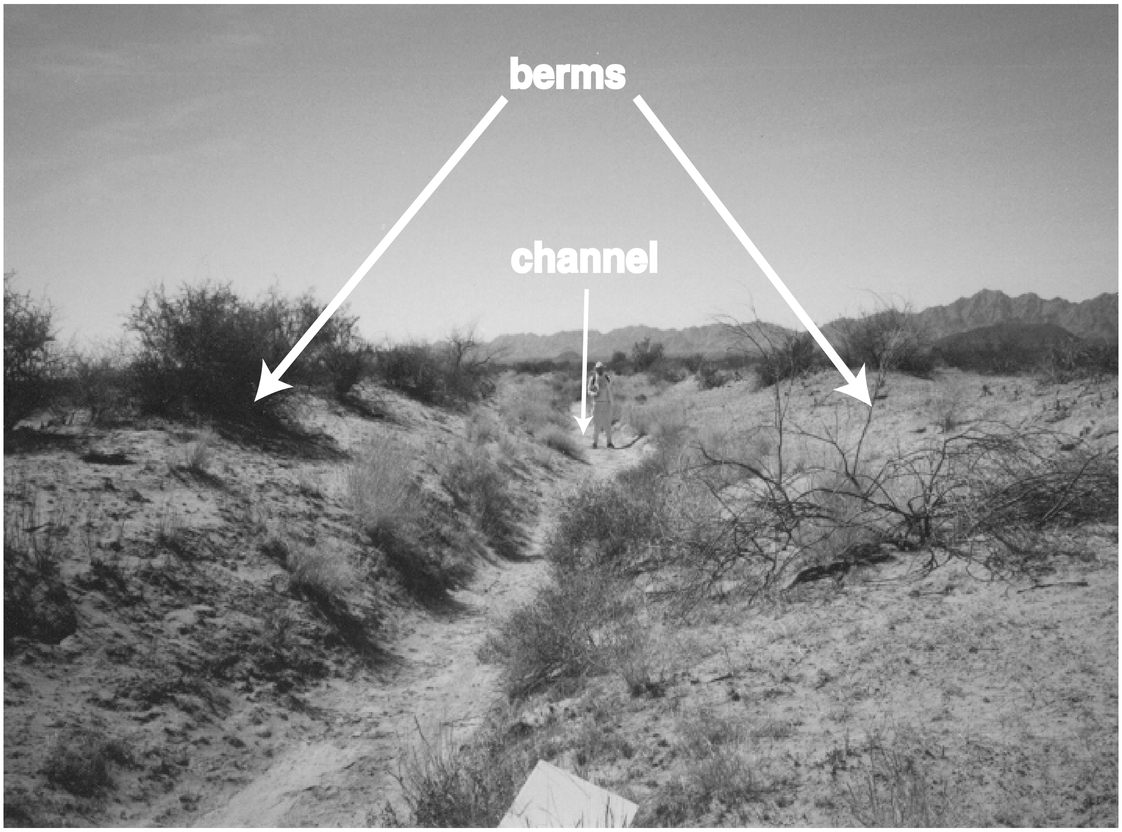

Figure 5. Photograph of the ditch and berms west of Peanut Hill, looking downstream. The channel is fairly uniform in cross-sectional shape, although hundreds of years have likely passed since the feature was constructed. The height of the lateral berms varies considerably; the highest mounds are associated with significant stands of vegetation. Substantially more vegetation lined this channel before the fire prior to a recent fire in this area.

Geomorphic Setting of the North Channel

In order to investigate this intriguing drainage system, we mapped the area in detail, focusing on geomorphic surfaces, channel configurations on these surfaces, other geomorphic features, and the characteristics of the berms along channel banks. The following geomorphic surfaces and features were described and mapped (see Figures 6 and 7):

Surficial Geologic Units

Late Holocene stream deposits (Qy2r)

Young deposits in stream channels and on floodplains and areas of overbank flow along Daniels Wash. Deposits generally consist of sand, silt, and clay, with local gravel concentrations. Vegetation typically is large creosote and low grass and shrubs, with local mesquite, ironwood, and palo verde concentrations. Variable surface color depends on vegetation density and soil

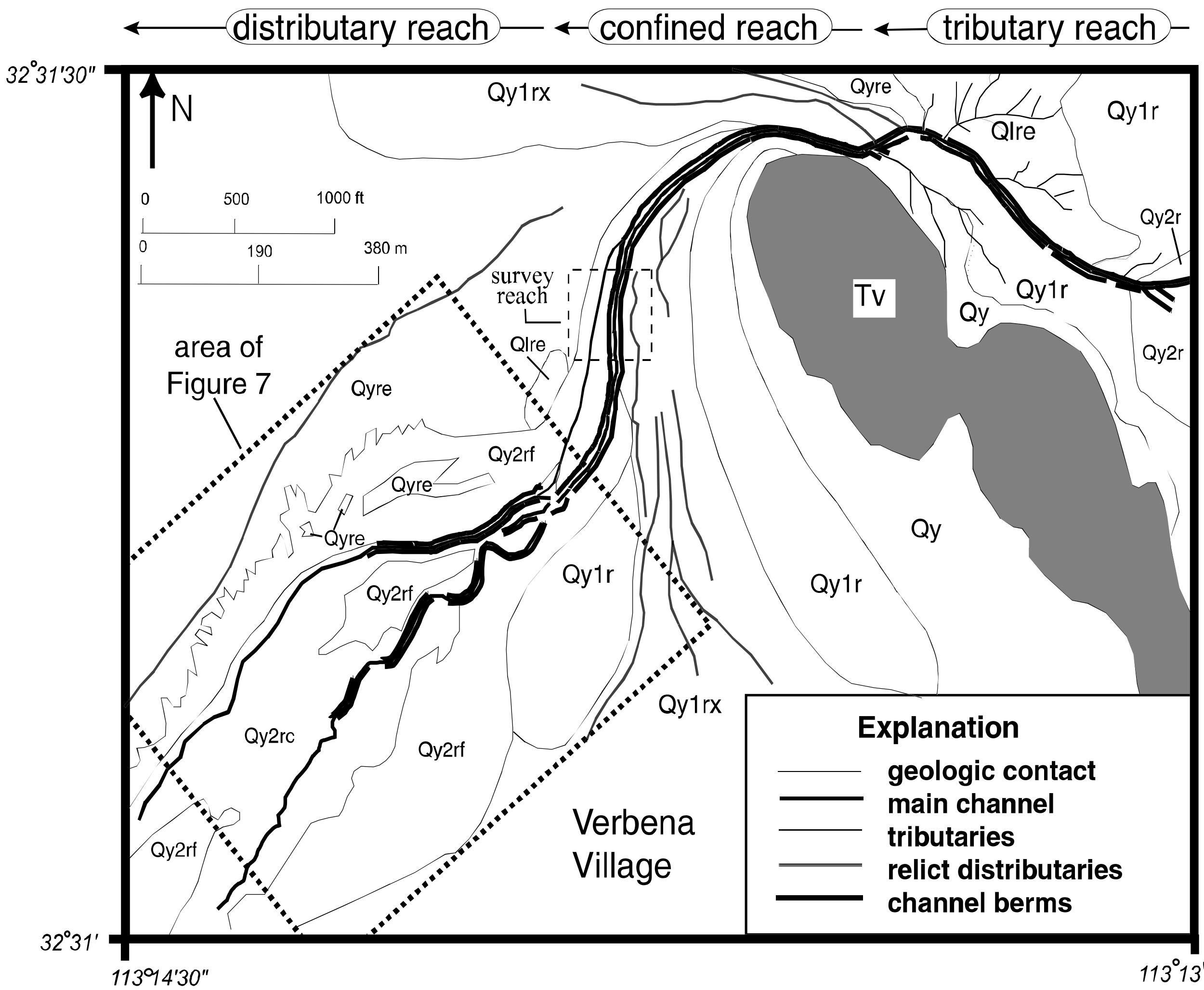

Figure 6. Geologic map of part of the northern branch of Daniels Wash, including the ditch and berms. Map units are described in the text. In the modern system, flow is confined as it rounds the north end of Peanut Hill. This area previously experienced unconfined distributary flow, as evidenced by the extensive young deposits and abandoned distributary channels.

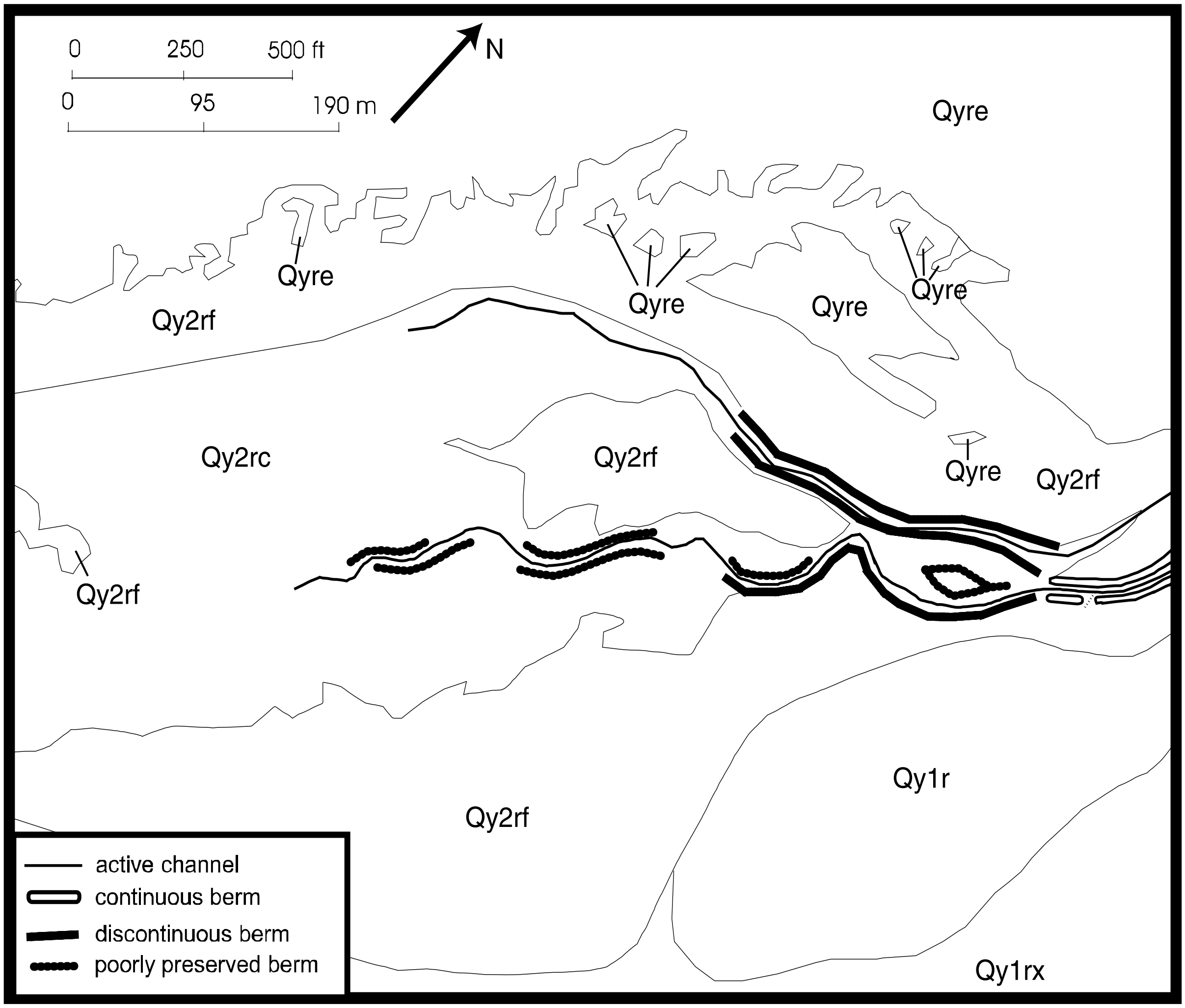

Figure 7. Detailed surficial geologic map of modern distributary area on the northern branch of Daniels Wash. In this area, possible berms are very low and problematic. We hypothesize, however, that this is the primary area where flow was diverted for floodwater farming.

moisture content, with dark brown color along channels and where vegetated, light brown where more sparsely vegetated. Many eolian features have been streamlined by fairly recent flood flow. In most of the map area, unit Qy2r is subdivided into the three units described next.

Active channel and overbank deposits, inundated fairly frequently (H2rc). Sand, silt, clay, and gravel found in areas that are inundated during large flow events. Low relief gravel bars contain poorly sorted, subrounded to subangular gravel and finer sediments, and appear light gray in color. Adjacent channels are less than 1 m below gravel bars and typically contain fine gravel, sand, and silt. Overbank areas are slightly higher than channels, are covered by sand, silt, and clay, and are brown in color. No pavement development or rock varnish is evident. A few riparian trees (ironwood, palo verde, and mesquite) are present, especially near the active channels, although recent fires have left much of the vegetation as standing snags. As this unit includes active channels and low-relief areas adjacent to them, it may be inundated fairly frequently.

Late Holocene alluvial-fan deposits, likely inundated in large flows (H2rf). Gently southwest sloping surface present in the distributary reach of Daniels Wash that exhibits accumulations of fluvial sand and silt with minor evidence of eolian activity in the form of semi-circular coppice dunes. No pavement development is evident on the surface, and the surface soil horizon is fairly loose. This surface is spatially removed from and somewhat higher than the active channels, suggesting that it is only be inundated by large flows on Daniels Wash.

Late Holocene stream deposits, isolated from Daniels Wash by berms (H2rx). This unit is characterized by subtle ridge and swale topography, in which relict channels occupy semi-linear swales generally trending north-south. Channels are best seen from aerial photos and exhibit no evidence of recent flows. Low "ridges" have no evidence of pavement development; erosion of the ridges along with eolian reworking of surficial materials has diminished their distinctiveness on the landscape. Vegetation is sparse and dominantly creosote. These surfaces apparently are not inundated by large flows on Daniels Wash.

Older Holocene stream deposits (Qy1r)
Undissected to weakly dissected terraces and alluvial fans that are isolated from active flow derived from Daniels Wash. Alluvial surfaces typically are less than 1 m above adjacent washes, and have some small, poorly defined channels. Surfaces may be partially covered by residual gravel deposits composed of pebbles and few cobbles of mixed lithologies 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 are less than 0.5 m above adjacent surfaces with gravel lags. Surface color is light brown. These surfaces are not inundated by large flows on Daniels Wash.

Older Holocene stream deposits and eolian deposits (Qyre)
Mixed Holocene stream 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, with desert shrubs concentrated in dunes and along small channels. The strong overprint of eolian activity on fluvial deposits implies that these areas have not been subject to substantial flooding for thousands of years; thus, the alluvium in these areas is older than **Qy1r**.

Late Pleistocene stream deposits and Holocene eolian deposits (Qlre)
Mixed older river terrace deposits and young eolian deposits. In this map area, Qlre landforms are terraces along Daniels Wash. Surfaces are smooth and flat, 1 to 2 m above the active channel; they have weak to moderate pebble to cobble pavements composed of mixed lithologies reflecting the large source area drained by Daniels Wash. Rock varnish on surface clasts is weak. This unit includes varying amounts of low coppice dunes composed of fine-grained, bioturbated sediment. Creosote bushes exist on the dunes, otherwise vegetation is very sparse. Surface color is light gray on photos due to weakly varnished gravel pavements. These surfaces are not inundated by floods on Daniels Wash.

Holocene piedmont deposits (Qy)
Active or recently active alluvial-fan and lowermost hillslope deposits derived from Peanut Hill. Deposits are very poorly sorted, consisting of silt and clay to small boulders. Gravel clasts are angular to subangular, reflecting the short transport distance from adjacent hillslope sources. Vegetation is generally sparse, with low desert shrubs and annuals; vegetation density is higher with larger shrubs along and near channels. Eolian landforms are evident locally. 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.

Bedrock (Rv)
Fine-grained volcanic rocks, probably basalt. Undisturbed, exposed bedrock surfaces are covered with very dark rock varnish. Fresh rock surfaces are gray.

Geomorphic Features

Active Channels
The active channels convey the deepest, highest velocity flow during floods on Daniels Wash. The main channel is well defined and has fairly uniform width and depth in the tributary and confined reaches. Along these reaches, the main channel contains almost all of the flow during floods with the exception of small breaches in the channel banks where some flow escapes. The main channel divides into several small, much less distinct channels at the upper end of the distributary reach. Sediment load in the channel is mainly fine to coarse sand. Mud drapes the channel sides in some locations, presumably from low flow events, and is also deposited in channel splays where velocity decreases enough to allow the fines to settle out. Knickpoints found in some reaches indicate active trenching of the channel bottom. Channel banks are lined with denser and larger vegetation than surrounding surfaces, although recent fire has destroyed much of this vegetation.

Relict Channels

Relict channels are recognized as wide, shallow swales in the topography. On aerial photographs, they are linear, branching features that diverge from the main channel and appear darker than the surrounding landscape. They are present downstream of the basalt knob on both the north and south sides of the channel. The relict channels conveyed flow due west from the end of Peanut Hill and also in a more southerly direction than the active channel. Links between the relict distributary channels and the active channel appear to be blocked by the berms along the main channel.

Berms

Berms are linear mounds composed of very fine sand, silt, and clay along the banks of the active channel. The berms begin at the transition between the tributary and confined channel reaches just upstream of Peanut Hill and continue downstream into the upper part of the distributary reach. They range in height from about 1 to 3 m above the bottom of the active channel. Their lateral continuity varies from continuous and regular to discontinuous and poorly preserved (Figure 8). Generally, they are highest in areas of preferred sediment accumulation, such as around concentrations of vegetation on the channel banks. They line the channel most continuously in the vicinity of Peanut Hill. They are somewhat lower and less well preserved downstream from the ridge, but nonetheless are quite evident throughout the confined reach. Berm size and preservation decrease dramatically at the transition between the confined and distributary reaches, but low, berm-like features continue for several hundred meters into the distributary reach.

Possible Anthropogenic Modification of Daniels Wash

Unusual characteristics of fluvial features on geomorphic surfaces in the study area suggest that the northern branch of Daniels Wash may have been modified from a previous, natural channel configuration. We assert this possibility based on the following observations:

(1) The channel berms have little resemblance to natural levees in this region, which are formed as floods deposit overbank sediments. Natural levees gradually decrease in particle size and height with distance from channel banks (Walker and Cant, 1984), whereas the berms are very high compared to immediately adjacent overbank areas and disappear abruptly away from the channel (Figure 9). Crown (1984) discusses a similar feature in the vicinity of Queen Creek which she calls a "raised 'levee'". She notes that the ridge may be man-made, built from the dredging of the canal. With a height of approximately 0.7 to 1.0 m above the ground surface, this ridge is comparable to the berms along Daniels Wash;

(2) Although the channel berms vary substantially in height, they are remarkably continuous along both banks of the confined reach of Daniels Wash. With the exception of a couple of breached areas, the berms apparently contain flows even during flood events. We believe that the higher berms developed as a result of the establishment of vegetation along the berms, which served to trap eolian sediment. Berms with little or no vegetation are typically 1 m above the channel bottom. These areas may approximate the original form of the berms, although they could have undergone some erosional lowering.

(3) The gradually sloping confined reach is formed mainly in unconsolidated, late Holocene alluvium that imposes no obvious controls on channel form. In this reach, Daniels Wash has a uniform, curvilinear planview shape and gradually varying channel width and depth. Relict channels, which diverge from the main channel and are now isolated from the active channel by the berms mentioned above, demonstrate that a distributary channel network existed along the confined reach in the past. The confinement of Daniels Wash results in the effective delivery of water to the modern distributary reach with minimal divergent flow. The modern distributary reach is a candidate area for floodwater farming because flows are shallow and spread widely, and sediment is fine-grained.

(4) Berms exhibit variable heights and moderate to poor preservation, suggesting that they are of considerable antiquity. Two small, hand-dug trenches were excavated into berms along the confined reach; however, we found no artifacts and could not discern any clear sedimentologic or stratigraphic evidence of human activity. Military operations, active within the past several decades, maintain numerous crude roads that utilize low points in the berms to cross the channel. This suggests that the variations in berm height existed prior to military activity. If eolian deposition is primarily responsible for the variable berm heights that exist along the confined reach, then it is likely that these features have been developing for a substantial period of time.

We speculate that Hohokam people may have altered the north branch of Daniels Wash so that flow became concentrated into a curvilinear, semi-incised reach and was delivered to an area downstream where Ak Chin farming may have been done. The Hohokam may have observed intermittent, sizable discharges in Daniels Wash, and determined to use that flow as effectively as possible to increase their food supply and thereby chance of survival in a land with limited resources. In order to direct water where they wanted to use it, they may have exploited the natural tendency for concentration of flow into a single channel just upstream from Peanut Hill. They efficiently conveyed flow to an area where it could be exploited by "dredging" one of the existing distributary channels and piling sediment along the banks. This engineering effort cut off other drainage paths, and directed flow to an agricultural area where water was allowed to spread widely.

Pollen analyses of sediment collected from a shallow pit excavated on the north side of the southern branch of Daniels arroyo indicate the presence of corn pollen (*Zea mays*) at two distinct stratigraphic levels (Ahlstrom and Holloway, 2000). Although found only in low abundances, the mere presence of the pollen strongly suggests that some agricultural activity was conducted in this area as corn pollen is large and tends to drop very close to its source. There are also low, berm-like features on the southern branch suggesting that flow was diverted to particular areas on the fan, including the area of the excavation where corn pollen was found. These features are much more subtle and less well preserved than on the northern branch. This is likely due to the fact that much more water flows down the southern branch during floods in the modern regime, as evidenced by the much larger channel that exists where the southern branch rounds Peanut Hill.

Given the climate of this region, what water resources would be available for agriculture and survival? As we can know little about precipitation events that would have provided the water resources to grow crops, this question may ultimately be unanswerable. Currently, this arid, very hot region appears inhospitable to humans and agricultural activity seems unlikely. Daniels Wash is ephemeral, flowing only in response to precipitation events. We know little about the depth to ground water in this immediate area. It is likely, however, that the bedrock ridge trending perpendicular to the piedmont slope serves to impede the flow of groundwater in alluvium from the Growler Mountains westward to Growler Wash in the middle of the valley. This may force ground water near the surface in the study area. There is no evidence of dramatic climate changes in this region during the Holocene, although the long-term trend has been toward increasing aridity (Thompson and others, 1993). Winter rains and stream flow may be especially important in evaluating past ground water levels in this region, because winter stream flow typically is of longer duration and losses to evaporation are notably less. There is evidence for relatively abundant and intense El Nino activity during the period of about 1000 to 1200 AD (Ely and others, 1993). Historical El Nino activity has been associated with higher than average winter precipitation and streamflow in the Southwest (Cayan and Webb, 1992). If the El Nino activity 800 to 1000 years ago caused a prolonged period of increased winter precipitation and streamflow, the water table might have been closer to the surface than it is today. There is archaeological evidence that suggests that water may have been quite near the land surface during the occupation of Verbena Village.

HYDRAULIC RECONSTRUCTIONS

In the above section, we postulate that Daniels Wash was modified to capture and direct flow to a potential farming area. We surveyed a portion of the confined reach in order to evaluate the capacity of the channel. Through hydraulic reconstructions we were able to compare and contrast our study reach to canals studied in the Phoenix basin.

Reach description

The reach chosen for hydraulic analyses is located southwest of the bedrock outcrop, about 200 m upstream of the modern distributary area of Daniels Wash where flow begins to spread laterally into a broad, low-relief area potential farming area (Figure 8). The channel has a sandy bed with uniform slope and fairly uniform dimensions. Vegetation is very sparse within the channel and moderate on the channel sides, although abundant evidence of burned plant remains suggests that recent fires have diminished the density and vitality of existing plants. The reach is relatively straight; berms are well preserved, although variable in height along the channel banks.

Methods

We determined width-depth ratios by measuring the top width of the channel level with the top of the lowest berm; maximum depth was measured by extending a line perpendicular from the top width to the deepest portion of the channel. We calculated bankfull cross sectional area and wetted perimeter using the top width of each cross section as the upper limit for the channel.

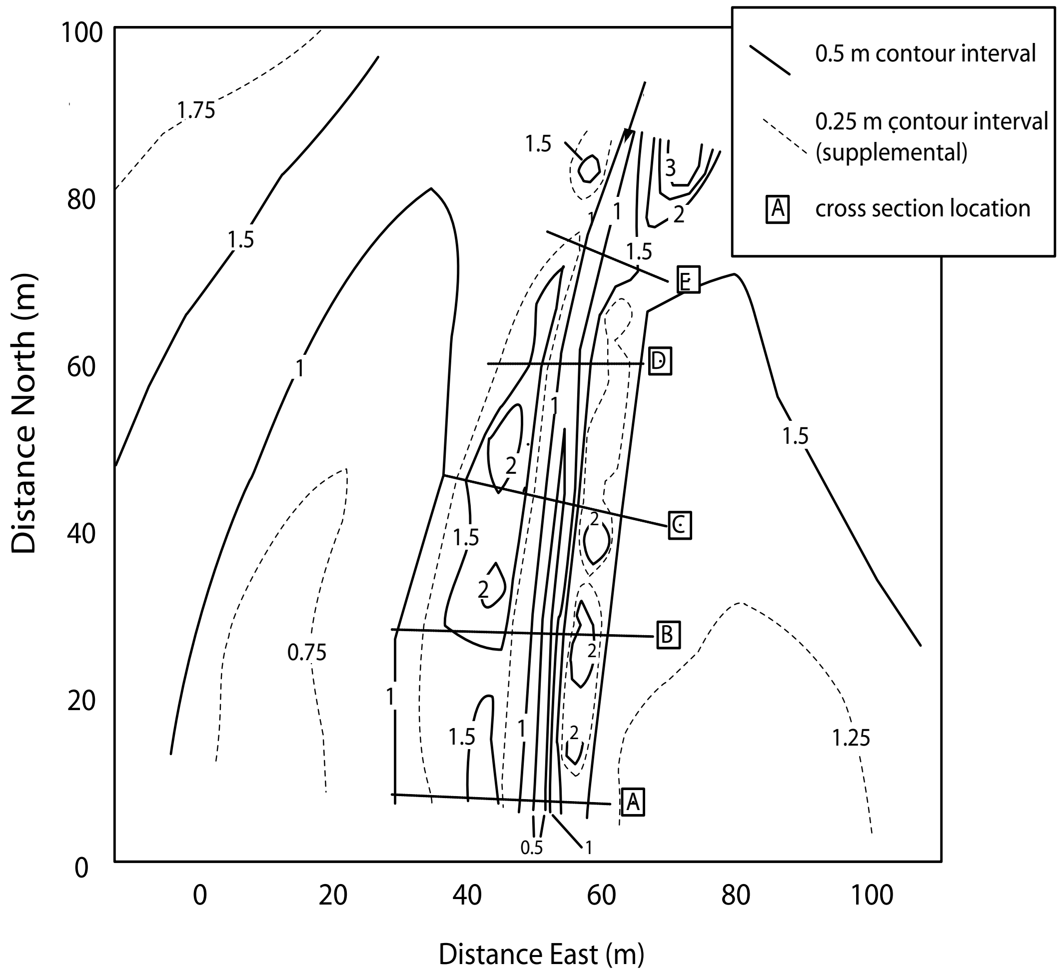

Figure 8. Topographic map of the hydraulic reconstruction site, located several hundred meters downslope from Peanut Hill.

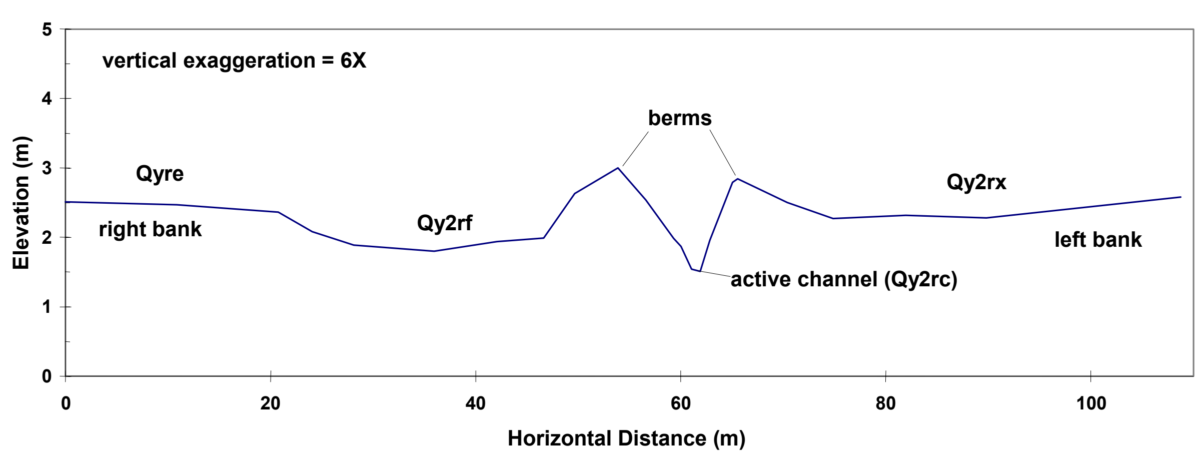

Figure 9. An extended topographic section at the location of cross section C in Figure 8, view upstream. Surficial geologic units Qy2rc, Qy2rf, Qy2rx, and Qyre are discussed in the text.

Paleodischarges were estimated using the Manning equation,

$$\text{Velocity (V)} = \frac{R^{.67}S^{.5}}{n} \qquad (1)$$

where

R = hydraulic radius (cross sectional area/wetted perimeter), measured for each cross section

S = channel slope (0.002), within and slightly upstream of the channel reach

n = roughness coefficient (0.035), for flow in sandy bed channels (Bedient and Huber, 1992)

To calculate discharge, the cross sectional area is multiplied by the velocity, where:

$$Q=AV \qquad (2)$$

To compute the area of land which can be irrigated with the given discharge, we used equation (3) developed by Ackerly (1991) from historic canals in the Phoenix basin, where:

$$\text{Irrigated acres} = 86.39\ (Q) + 1.39; \quad (r=0.88)$$

Other estimates based on water volume per irrigated acre in the modern Phoenix basin are used for comparison (Busch and others, 1976; Haury, 1976).

Results and Discussion

Width-depth ratios are within the range measured by Huckleberry (1987) for the Las Acequias-Los Muertos canal system (Table 3). The small variability within the ratios at Daniels Wash demonstrates that although the size of the channel varies among cross sections, its shape is very uniform. This uniformity and similarity of ratios with canals in the Phoenix basin supports the hypothesis for channel modification.

Velocity measurements range from 0.49 to 0.98 m/s, which is a relatively slow flow. These velocity values, however, may be the upper limit of stability for a sandy bed channel with relatively uncohesive banks, and are also suitable velocities for preventing vegetative growth and seeds from settling in the channel (Zimmerman, 1966). Overall channel slope is approximately 0.0038 and locally may be as great as 0.0080. Velocities for other reaches, then, may be considerably higher.

Maximum discharge values for the five cross sections vary from 0.67 to 7.38 m^3s^{-1}. This discharge estimate is similar to estimates for Phoenix canals such as those at the head of the

					Wetted	Hydraulic		Maximum		Potential Irrigable Land	
	Top Width	Depth	Width/Depth	Area	Perimeter	Radius	Velocity	Discharge	Ackerly, 1991	Busch, et.al.,1976	Haury, 1976
Cross Section	(m)	(m)	Ratio	(m^2)	(m)	(m)	(m/s)	(m^3s^{-1})	(acres)*	(acres)**	(acres)**
1	10.5	1.26	8.33	6.5	11.8	0.55	0.86	5.57	17,084	9,176	7,865
2	11	1.45	7.59	7.55	11.26	0.67	0.98	7.38	22,636	12,158	10,421
3	10.5	1.33	7.89	6.7	14.09	0.48	0.78	5.20	15,957	8,570	7,346
4	8.5	1.07	7.94	4.1	8.67	0.47	0.77	3.17	9,729	5,225	4,479
5	5.25	0.66	7.95	1.35	5.58	0.24	0.49	0.67	2,046	1,098	941

*Ackerly, 1991 uses the equation Irrigated acres=86.39(Discharge)+1.39 (r=.88) based on analysis and regression of historic canal data

**Busch, et.al., 1976 estimate based on modern canals, using 1.5L/s/ha; Haury's (1976) estimate is also based on modern canals, but uses a range of 1-1.75 L/s/ha;

this study calculates the upper limit of the range, using 1.75 L/s/ha.

Table 3. Summary of hydraulic data for the possible irrigation features near Verbena Village. Clearly, the potential irrigable land estimates are based on flow through the ditch during much of the year. It is likely, however, that the ditch was intended to divert water for Ak Chin floodwater farming during infrequent flow events.

Scottsdale Canal system, in which Howard and Huckleberry (1991) and Huckleberry (1995) estimated potential discharges ranging from 0.8 m^3s^{-1} to 12.9 m^3s^{-1}.

A number of other assumptions and limitations must also be noted for any hydraulic reconstruction. The Manning equation assumes steady, uniform flow with low sediment concentrations. Although the study reach conforms well to optimum conditions for use of the Manning equation, the amount of scour and/or deposition in the channel since the time of postulated use is unknown. There is no evidence of dramatic downcutting (i.e., no arroyo has developed here), but locally the channel gradient or the channel width and depth may have changed since the time of postulated use. In defining channel dimensions for flow computation, the berm with the lowest elevation is assumed to more accurately represent the original height of the feature, exhibiting only minor degradation in the chosen reach; high berms are assumed to have accumulated additional sediment by eolian processes.

Potential irrigated acres, using the relations developed by Ackerly (1991), Busch and others (1976), and Haury (1976), range from 941 to 22,636 acres. This is a considerable range of values among the three relations. The variability may be explained by the difference in modern and historical water use, such that modern irrigation methods use less water per acre than historical methods.

Within each equation, the variability may be explained by the difference in channel dimensions at each cross section. A maximum discharge of 7.4 m^3s^{-1} at cross section two was selected in order to compute an upper limit to irrigable area (22,636 based on historical data; 11,290 averaged from modern relations). It is not impossible for this discharge to be routed through the channel; however, at the smallest cross section, velocities would have to reach 5.47 m/s holding other variables constant in order to accommodate the flow volume. Both acreage estimates are unreasonably large and demonstrate that potential irrigable land can certainly be overestimated. Other studies have reported on the overestimation of discharge and corresponding irrigable land (Ackerly, 1991; Howard and Huckleberry, 1991). Ackerly (1991) states that his relation is limited by variations in agricultural practices of farmers along the canals studied, and variations in diversions both seasonally and during discrete runoff events. However, we also realize that these estimates are based on a network of canals which deliver water daily to farmed land miles from the actual water source. Potential irrigable land in the vicinity of Daniels Wash must therefore be of smaller size, considering that flow is intermittent in this region, channel flow may never reach the maximum discharges calculated and does not have a canal system to distribute water to distant plots of land.

When considering relations that estimate potential irrigable land, Huckleberry (1995) states that reconstructions using historical data should be the best estimate, as historical, rather than modern, methods are more similar to the Hohokam methods of irrigation. It is for this reason that we prefer to use a value of 941 acres from the Ackerly (1991) relation as a conservative estimate of potential irrigable land. This area is still approximately twice the size of the study area itself and from our viewpoint would serve as a maximum, if not an overestimation, of irrigable land.

We have not determined to what extent we can apply Phoenix canal morphology to a ditch-like channel. Although climates are similar, canals in the greater Phoenix area were assumed to carry flow perenially, while flow in Daniels Wash is currently ephemeral. Implications of the differences are unknown; however, we do know that the features themselves are markedly similar and therefore would respond alike to hydrologic phenomena. Despite the limitations of the data, discharge reconstructions define the maximum extent to which a modified channel and adjacent land could be utilized for irrigated farming.

Summary

We have described a series of unusual fluvial features and associated geomorphic surfaces found along Daniels Wash west of the Growler Mountains. Fluvial features include active channels, relict channels isolated from the present flow regime, and sandy berms which line channel banks, while geomorphic surfaces are mapped in more detail but are comparable to map units described in the larger project area. Our observations of the fluvial features associated with Daniels Wash in the vicinity of Peanut Hill have led us to postulate that this channel system has been modified to efficiently collect water, contain it in a single channel, and deliver it to an area of sheet flow that was farmed. This irrigation system was developed by exploiting the natural concentration of flow around a bedrock ridge. An existing distributary channel may have been selected to convey water to the appropriate area, while other channels of the previous distributary network were cut off from flow. We make this conclusion based on dissimilarities of the berms with natural levees, their continuous nature along channel banks, confinement of the reach in unconsolidated alluvium, and the apparent antiquity of the berms. Although present precipitation and resultant flow is minimal in this region, evidence of abundant and intense El Nino activity 800-1000 years ago may have increased winter precipitation, such that streamflow events were greater in magnitude and more frequent; in addition, it may have allowed for shallow groundwater resources in areas near the low basalt ridge.

Through hydraulic reconstructions, we note that maximum discharge using present channel configuration and height of berms is approximately 7 m^3s^{-1}; the preferred potential irrigable land estimate is 941 acres, a conservative value based on historical irrigation methods. This acreage is approximately twice the size of the entire study area, and in our opinion constitutes the maximum area which could have been farmed using flow from Daniels Wash. Channel slope, width-depth ratios, and hydraulic reconstructions are similar to canals studied in the Phoenix basin and support the conclusions drawn by this study.

Time constraints allowed us to study only one branch of Daniels wash; brief reconnaissance surveys of other sites in this area revealed similar unusual features. Future work should address these areas, with special attention given to the southern branch of Daniels Wash near the bedrock ridge, as corn pollen from a trench site described within this report suggests that the area has been cultivated.

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