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Soil Investigation for Nankoweap Area Grand Canyon, Arizona

prepared for

U.S. Bureau of Reclamation

Glen Canyon Environmental Studies

September 27, 1995

by

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GLEN CANYON ENVIRONMENTAL
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Introduction:

As part of the Glen Canyon Environmental Studies program, DAVIS^2 Consulting Earth Scientists has completed field mapping of soils associated with Quaternary deposits in the Nankoweap area. This work is part of the overall geomorphology study, as directed by Dr. Ivo Lucchitta, U.S. Geological Survey, Western Regional Geology, Flagstaff, Arizona.

This report is part of open file report (95###). Information in this report supports surficial geology mapping and geomorphology, in progress by Lucchitta and others, as part of the overall study. Portions of this study are incomplete, pending data from other contributors. There is enough data, however, to forward meaningful soil delineations and interpretations advancing considerable knowledge of Colorado River behavior over the past several thousand years, and how paleo-cultures flourished in this reach of the Canyon. Soil information contained in this report can be utilized by archeologists, biologists, engineers, geologists, land managers or pedologists to facilitate land use decisions or strategies for river management.

This document has not yet had the benefit of peer review and is subject to revision as data sets are completed. Soils have not been correlated with others in Arizona or the Southwest. Description and interpretations follow National Cooperative Soil Survey standards. Contemperary best management practices and vegetation strategies for soils described can be provided.

Environmental Setting:

The area of study is located from approximately river mile 51.8 below Lees Ferry, at the confluence of Little Nankoweap Creek and Nankoweap Creek to approximately river mile 56, where Kwagunt Creek joins the Colorado River. Nankoweap Creek was flowing to its mouth at the time of study. Bald eagles were fishing the clear water stream.

In the near proximity of Nankoweap Creek at least three discrete alluvial surfaces are preserved above the active flood plain which includes the frequently and occasionally flooded zones of the Colorado River. Deposits immediately above the active flood plain of the River, are sandy in composition, and were utilized by the paleo-Indians (Anasazi) for habitation and agricultural pursuits. Higher (older) terraces are stony and bouldery and form a prominent bench known as Nankoweap Bluff. The Bluff resides above the mouth of Nankoweap Creek at wash right, which is on the downstream, or river right side on the Colorado River. An analogous feature of similar composition and morphology, but of smaller dimensions, occupies the opposite, or wash left, side of Nankoweap Creek.

Soils associated with each of these depositional landforms follow a developmental pattern, showing increased secondary carbonate and clay development with increasing elevation and distance from the Colorado River. Vegetation associated with the soils consists of invading riparian species along the occasionally flooded

zone; a mesquite forest on the archeological platform; and desert communities dominated by cactus and Mormon tea above.

Procedures:

Access to this site was gained by boat, with a base camp approximately 880 meters downstream (river right) of Nankoweap Creek. The team of experts for this study includes Dr. Ivo Lucchitta, leader (USGS, Flagstaff), Dr. Jack Hillhouse, Branch Chief and paleomagnetics expert of Western Regional Geology (USGS, Menlo Park), Dr. Thomas Hanks, seismologist, (USGS, Menlo Park), Drs. Marc Caffee, and Robert Finkel, radionuclide chemists, Lawrence Livermore National Laboratory (LLNL), Ms. Marie Davis, geologist and soil scientist, DAVIS^2 and Mr. Sidney Davis, soil scientist DAVIS^2. Other members of the team include Mr. Chris Geanious, head boatman, and Mr. Steve Bledsoe, boatman (Oars, Inc.). This group was also joined by Ms. Helen Fairley, archeologist (NPS), for two days, to observe excavations in relative proximity to known archeological sites on the first trip in February, 1994. Mr. Christopher Coder (NPS) archeologist assisted on the second trip in February of 1995.

Soils were examined by use of hand excavated pits, to expose and enable detailed description and interpretation, utilizing standards of the National Cooperative Soil Survey, to a depth of at least one meter. Pedogenic secondary carbonate development follows Gile (1981) modified by Machette (1985). Where feasible, soils were examined utilizing natural features, such as erosional escarpments.

Where charcoal was identified, discrete samples were collected and analyzed for age determination by radiocarbon techniques (^{14}C) at LLNL. Boulders and gravels were sampled for radionuclide chemical dating (^{10}Be- ^{26}Al) techniques by LLNL on surfaces above the archeological platform. Soil horizon samples were collected and analyzed at the University of California, Davis (UCD), Soil Morphology Laboratory, by Dr. Randy Southard, for particle size distribution, total carbonate, and soluble cations related to salinity and agricultural suitability. Paleomagnetic sampling was analyzed by Dr. Hillhouse, who collected insitu cemented carbonaceous materials from the base of soil pits and deposits. Charcoal-rich horizon samples were collected and delivered to palynologists Jim Hasbargen and Susan Smith, University of Northern Arizona (NAU) for pollen and plant material identification.

Findings:

HOLOCENE DEPOSITS

SOILS THAT ARE FREQUENTLY AND OCCASIONALLY FLOODED

Soils associated with the frequently flooded and occasionally flooded terraces are coarse grained and display no visible sign of soil profile development in the way of accumulated secondary carbonate, segregated lime, or detectable illuvial clay

accumulations. Backwater eddy environments, concave features associated with river slack water and over bank inundation from fluctuating flows display finer texture due to their depositional regime - these areas did not acquire appreciable clay as a consequence of pedogenesis.

Sand deposits as a result of the 1983 flood are preserved in the camp area, on river right, down stream of Nankoweap Creek, on the occasionally flooded terrace. These soils are characterized as light brown or strong brown coarse sand to approximately one meter depth. This coarse sand material abruptly buries dark brown medium sand to a depth of over 140 cm. Arrowweed (Tessaria sericea) and tamarisk (Tamarix chinensis) are invading this deposit. Even though facultative hydrophytic species thrive, soils lack hydric indicators (low chroma color mottling) and are other than jurisdictional wetlands. These excessively drained and undeveloped soils are common to the active flood plain deposits, and range in relative amounts of coarse fragments - cobblestones, stones and boulder size materials. Some beaches are relatively free of coarse fragments, while others are dominated by stoniness.

Backwater eddy areas typically display facultative and obligate vegetation, in conjunction with reduced soil colors ($\leq$ 2 chroma, Munsell), indicative of prolonged saturation. These are emergent marshes. Soil colors in the upper 25 cm display mottling (redoximorphic depletion) of low chroma-high value, indicative of reducing conditions (Pedon 94008), criteria for Hydric soils, as defined by the Army Corps of Engineers (1987). Marsh vegetation consists of species of Typha, Equisetum, Salix, and Eleocharis, as dominant (greater than 50 percent of the canopy). These are obligate or facultative hydrophytic plants found in the national wetland plant lists (U.S. Fish and Wildlife Service, 1988). Marshes possess all three parameters of jurisdictional wetlands: dominant hydrophytic plants; hydric soils; and, hydrology. Several wetlands occur along the frequently flooded border of the river from Nankoweap to Kwagant Creeks, mapped as Unit 104. Marshes worthy of mention reside just upstream of the Nankoweap camp site and upstream of the mouth of Kwagunt Creek, both on river right. They are perhaps artifacts of fluctuating flows caused by intermittent releases at Glen Canyon Dam. These areas are relatively small in spacial extent, but nevertheless display three parameters of hydrophytic vegetation, hydric soils and wetland hydrology - criterion for jurisdictional wetlands as regulated under Section 404 of the Clean Water Act.

ARCHEOLOGICAL PLATFORM

Soils associated with the Archeological Platform are deep, weakly developed and somewhat excessively drained. These soils can be characterized as having a thin dark reddish brown loamy fine sand topsoil, approximately 5 cm thick over a strong brown loamy fine sand or gravelly loamy fine sand subsoil, abruptly underlain at 43 cm by a buried surface of dark reddish brown fine sandy loam, crowded with 2mm and smaller black flecks of charcoal. Rimming some charcoal nodules are indications of vitrification, or a reddening of clay minerals caused by firing. Occasional soft masses of secondary carbonate (Stage I development) or salt precipitate also appear

in association with this and other charcoal rich bands, at depth. Beneath this first buried layer, from 53 cm, are sediments of strong brown loamy fine sand or very fine sandy loam to 94 cm, where yet another buried surface laden with charcoal resides, beneath an abrupt, smooth boundary. Fluvial materials below are slightly finer textured, consisting of alternating lamination of strong brown very fine sandy loam or loamy very fine sand, to a depth of approximately 172 cm, where another buried surface resides (Pedon 94007).

Selected soil horizons were sampled for soluble cations, to include electrical conductivity (EC), exchangeable sodium, and exchangeable sodium percentage (ESP). These are tests to ascertain suitability of soils for agricultural pursuits for field crops, such as corn, beans, cotton or squash, crops known to be utilized by Anasazi in other areas of the Southwest. Sodium is particularly troublesome to most cultivated crops, and is also an indicator of irrigation application, especially where soils of fresh depositional terraces in the near proximity otherwise contain low salinity levels. These tests show that the upper buried charcoal horizon is suitable to sustain most agricultural crops in a range less than 4 mmhos/cm^2. However, the buried soil between 91 and 101 cm has very high EC (31.5 mmhos/cm^2) and ESP (73.4). Tolerances for most field crops are: EC 4 to 10 ; ESP < 10 (Nelson, 1992; Reisenauer, et. al. 1983). The lowest horizon sampled also has elevated salinity levels: EC 12 and ESP 21.

An area between Nankoweap Creek and Little Nankoweap Creek display similar multiple buried surfaces, charcoal bands at varying depths. Cotton pollen is identified in soil samples collected from this site at approximately 55 to 60cm, while corn pollen is identified between 100 to 110 cm. ^{14}C dates of 1,390± 90 and 1,280± 60 Yr. B.P., respectively, (Basketmaker III culture ?) are obtained from charcoal materials from these buried surfaces (Figure 1). Burial of these charcoal surfaces by the river floods also supports that the Colorado River was in an aggradational or depositional regime at the time of Anasazi occupation. Downcutting since that time is approximately 5.0 meters (the difference between the top of the archeological platform and present river elevation).

The horizontal bands of organic-rich materials and charcoal are interpreted to be agricultural fields associated with paleo-Indian farming practices. Burning of natural vegetation in preparation for planting, and then habitual crop stubble burning (perhaps for many generations) is the likely mechanism for the relatively thick and prominent charcoal bands. Granaries at Nankoweap confirm seed storage by early human cultures. Presence of the charcoal bands in association with crop pollen supports cultivation of the specific fields found as inclusions within Soil Map Units 110, 112 and 113. Elevated salts associated with the charcoal bands imply application of irrigation water. Presence of cotton and corn pollen at Little Nankoweap also supports that not only grain crops were being produced, but fiber materials as well.

Unit 112 represents a surface similar to Unit 110, except eolian deposits are burying underlying fluvial deposits, producing very hummocky microtopography. Presumably soils similar to Unit 110 were exposed and farmable at the time the river

was aggrading; ground that would have been available to cultural practices, all the way down to and including the mouth of Kwagant Creek. Inspection of aerial photography and reconnaissance reveals that greater amounts of eolian sand resides on river left in the study area. Coppice dunes could have been forming at the time of Anasazi occupation, however one charcoal sample collected (Coder, archeological site No. C952) from a hearth among sand dunes near the mouth of Nankoweap Creek, at the toe of Nankoweap Bluff, yields a ^{14}C date of 280±60 yr. B.P. This date does not substantiate the age of the dunes, but suggests that at this particular locale they were well in tact by late 1600 - early 1700 AD. Very large dunes are mapped as Unit 106. Some are stabilizing with vegetation, other are transitional and unvegetated.

Vegetation on the archeological platform is dominated by Honey mesquite (Prosopis glandulosa). Unit 110 supports a very lush mesquite forest, with mature trees commonly growing stump whorls of as many as six trunks, each 20 cm diameter at breast height. A thick carpet of annual grasses occupies the understory. Mesquite are common to units 112 and 113 also, but tree diameters are typically smaller, stands thinner.

Surfaces associated with the side creeks (Little Nankoweap, Nankoweap and Kwagant) nest with main stem deposits. Sand deposits associated with the river and archeological platform are not present as part of the alluvial packages produced by the creeks. Alluvial packages present along the creeks and at the mouths of washes are typically a result of high energy delivery - debris flows, stranded by subsequent incision. Active washes are nearly void of vegetation, except where desert plants of Prickly pear (Opuntia phaeacantha), Mormon tea (Ephedra fasciculata, E. nevadensis) and sparse annual grasses are establishing on the occasionally flooded areas. On terrace level 3 and higher, desert plants are more abundant but fail to achieve productivity of the better agricultural units (110, 112, 113) mainly due to a lack of water holding capacity.

Pleistocene Surfaces:

INTERMEDIATE FAN TERRACES

Intermediate terrace remnants are of very small distribution at Nankoweap and poorly preserved, nearly reduced to lag gravel. For this reason soils on these deposits were not studied in detail. Shallow probing mid-way up Nankoweap Bluff confirms secondary carbonate accumulations as 1 to 2mm rinds beneath gravels in the upper 50 cm (Stage II carbonate development) on Unit 114.

OLDER FAN TERRACES

Nankoweap Bluff displays a two tiered profile: soils derived from materials of coarse angular stone and gravel composition; abruptly overlying a soil formed on gravel and stone materials which are water rounded. Both soils have developed to advanced Stage II carbonate, with the lower position (64 cm below the surface) soil

displaying the most development, in terms of higher clay and carbonate content (Pedon 94006).

Clasts in the upper soil are typical debris flow materials, angular, and locally derived, consisting of dominatly Redwall, Kaibab and Supai, with minor contributions from the Tapeats and Chuar Formations. The buried soil is derived from rounded river gravel, but highly developed in terms of clay content in the matrix. Parent materials consist of Redwall, Kaibab, and Supai, as well as occasional far traveled gravel clasts of volcanic porphyry (Henry Mountains ?). The boundary separating these soils is abrupt and wavy, indicative of debris flow burial of a pre-existing river channel. This feature is common to both sides of Nankoweap Creek, at similar geomorphic position.

The upper soil can be characterized as having a reddish brown stony sandy loam to approximately 10 cm where clay increases and segregated lime appears as common medium soft masses and common medium concretions, with 1 - 2mm laminae on the undersides of angular gravels and stones to approximately 64 cm. The above abruptly buries a variegated dark red and light red very gravelly (water rounded) clay loam, with many medium soft masses of segregated lime to a depth of 117 cm (termination of pit). Two advanced Stage II carbonate soils are identified here, one burying the other. ^{10}Be - ^{26}Al dating on boulders on the surface are pending. Based upon relative carbonate development these soils are analogous to ones in the Comanche and Tanner area, which have achieved Stage III carbonate, and occupy at least geomorphic level 5.

There are no other older alluvial terraces preserved in this portion of the Canyon as there are further downstream in the Palisades / Unkar or Granite Park areas. Upstream in Nankoweap Creek there are well preserved sets of terraces that likely correlate with ones seen in this study area. Those are not a part of this study.

Following are Soil Mapping Unit Descriptions which define the Soil Mapping Units, as shown on the accompanying Soil Maps for the Nankoweap - Kwagant area of Grand Canyon.

Soil Mapping Unit Descriptions:

Frequently and Occasionally Flooded Units

100 **Modern Beaches, frequently flooded.** These deep and somewhat poorly drained sandy soils reside immediately adjacent to the active river channel. Because the river flow fluctuates from dam releases, these materials are in constant transition. As a result, little vegetation flourishes other than patchy hydrophytic species. Being near the river and because the entire profile is subject to irregular inundation, temperature (at 50 cm depth) is estimated to be more moderate than just a few feet away, and the regime is considered to be Mesic. These areas are highly desirable for recreation, good for landing boats with smooth access to higher ground. This unit is broadly defined as Sandy, mixed, mesic, Oxyaquic Udifluvents.

101 **Stony or Bouldery Beaches, frequently flooded.** This unit is essentially the same as 100, except it is dominated by cobblestones, stones and boulders, typical of high energy deposition. These soils are deep and irregularly subject to inundation, from storm runoff and dam releases. These areas are less desirable for recreational purposes due to surface roughness. Vegetation is transitional, because of fluctuating river flow, but hydrophytic plant species invade intermittently. These soils are broadly defined as Sandy-skeletal, mixed, mesic, Oxyaquic Udiflufents.

102 **Loamy Alluvium, frequently flooded.** These are deep and somewhat poorly drained soils of medium texture. They typically support hydrophytic vegetation, as water holding capacity is greater than the sandier units (100 and 101). These are commonly associated with backwater eddies, where finer grained material coalesce as a result of quiet water deposition. They are not a common feature, or extensively mapped along the active flood plain. These are defined as Loamy, mixed, mesic, Oxyaquic Udifluvents.

103 **Active Washes, frequently flooded.** These are coarse grained and stony soils, varying in depths from only a few centimeters to over a meter in thickness, associated with the active side canyon creeks and ephemeral drainage channels. The drainage features typically are void of vegetation and only run water during high intensity storms, or for a relatively short duration at Spring snow melt. At anytime during intense thunder storms these drainages can flash flood, capable of delivering debris flows to their mouth. These are defined as Loamy-skeletal, mixed, hyperthermic, Torriorthents.

104 **Wetlands and Emergent Marshes.** These soils are moderately deep to deep and somewhat poorly drained, supporting obligate and facultative hydrophytic vegetation. They are medium to fine textured, associated with near shore back eddy or return current hydrology environments, or depressional features that receive

overbank flooding as a result of fluctuating river flows. Marshes are nearly level with slightly concave topography. They can be characterized as having a thick brown or strong brown clay loam (near clay) topsoil to 30 cm, over a mottled dark brown reduced (redoximorphic depletions) and saturated clay loam subsoil. Typical vegetation includes cattail (Typha, sp.) and bullrush (Eleocharis, sp.) near the center of the unit, and around the perimeter, vegetation of willow (Salix, sp.), sedge (Carex, sp.) and horsetail (Equisetum, sp.) occupy the transition zone to upland terrain. These areas provide high value habitat for vertebrates, such as beaver, and a wide variety of migratory and resident waterfowl. Because they display a dominance of hydrophytic vegetation, hydric soils, and are inundated on a regular interval, they qualify as Jurisdictional Wetlands, as regulated under Section 404 of the Clean Water Act. Wetlands can be found, upstream of Nankoweap camp, on river right; upstream of the mouth of Kwagant, river right and intermittently along the river in between. The typical pedon for unit 104 is near camp (Pedon 94008). These soils classify as Fine-loamy, mixed, mesic, Typic Endoaquepts.

105 **Terrace Escarpments, very steep and transitional.** These are shallow very gravelly textured materials comprised of colluvium (scree slopes) from eroding, higher elevation alluvial deposits. They typically support little, if any, vegetation and mantle bedrock. They may carry from high cliffs down into the water, but generally they reside above flood level.

106 **Sand Dunes.** These are shallow to very deep eolian derived soils that mantle gravel bars on occasionally flooded terraces, and low terraces just above the 100 year flood plan. They also represent climbing or falling sand sheets, where prevailing wind velocity slackens. They form downwind of fresh alluvial sand deposits in and along the active river channel. Dunes within the 100 year flood plain exhibit sparse vegetation, but are being invaded by expanding riparian growth. Above the 100 year flood plain, on geomorphic Level 3, dunes are somewhat more stabilized by vegetation, such as Mesquite (Prosopis, sp.) and cheat grass (Bromus tectorum). Available water holding capacity is low, permeability is very rapid, and water erosion is negligible. Although these areas are gaining material, they are susceptible to destabilization by forces of wind, sand blasting and winnowing. These soils are classified as Mixed, hyperthermic, Typic Torripsamments.

107 **Very Gravelly Alluvium, occasionally flooded.** These soils are moderately deep to deep, composed of extremely coarse grained materials, and occupy a position immediately adjacent to active washes. They are well or somewhat excessively drained. Water holding capacity is low. They are susceptible to intermittent flooding, scour and redeposition as a result of periodic flash floods, or stream realignment at peak flow. Stones and boulders comprise up to 40 percent of the matrix, gravels approximately 50 percent, with the balance less than 2mm size. Of the fine earth fraction, nearly half is silt and clay (Supai materials ?). Because they are transitional in nature, and very young, these soils have acquired few diagnostic features, and they support little in the way of vegetation, other than a few scattered pioneering

annual species. These soils classify as Loamy-skeletal, mixed, hyperthermic, Typic Torriorthents.

108 **Loamy Alluvial Land, occasionally flooded.** These soils are typically deep and and well or moderately well drained, and commonly support facultative hydrophytic species of arrow weed, tamarisk, willow and horse tail. Available water holding capacity is moderate and this is reflective of the vegetation it supports, in that the vegetation canopy is generally thicker than coarser grained soils found at similar geomorphic position. These soils classify as Fine-loamy, mixed, hyperthermic, Oxyaquic Torrifluvents.

109 **Stony or Bouldery Shores and Bars, occasionally flooded.** These are deep and moderately well drained soils that occupy the majority of the occasionally flooded portion of the mapping area. They are very stony and typically have a fluctuating water table that in places can reach to with 50 cm of the natural ground surface. These soils support mostly hydrophytic vegetation, tamarisk, willow and arrow weed; much of the younger riparian vegetation along the river corridor resides here. Old drift wood lines commonly define the upper boundary of this unit, which is coincidentally at the toe of the mesquite vegetation line. This soil classifies as Sandy-skeletal, mixed, hyperthermic, Oxyaquic Ustifluvents).

Archeological Platform - Soils developed on Holocene materials above the current active flood plain.

At the time of paleoindian occupation, the River system was aggrading, as evidenced by buried soils (charcoal layers supported by ^{14}C dates) and habitation sites containing artifacts - tools and pottery chards. Since about 1650 AD the River has downcut approximately 5 meters.

110 **Lands of High Agricultural Potential.** These soils are deep or very deep and well to somewhat excessively drained, with moderately high to high saturated hydraulic conductivity. They are composed mainly of stratified very fine sand, fine sand and loamy fine sand with surface slopes in the 0 to 2 percent range, above the active flood plain. This unit hosts a high number of archeological sites in this reach of the Canyon, and has high agricultural potential (U.S.D.A. Class II), except where excess salts have accumulated. Vegetation consists of Honey mesquite (Prosopis glandulosa), erodium, sp., brassica, sp. and bromus tectorum. Soils of this unit are represented as a complex of Loamy, mixed, hyperthermic, Typic Haplocalcids (or Haplocambids) and Sandy, mixed, hyperthermic, Typic Torriorthents. There are inclusions of sodic soils in this unit and occasional coppice dunes.

111 **Very Stony Debris Flow Land.** These soils are typically very deep, very stony and gravelly, with moderate amounts of silt and clay in the fine earth fraction (< 2mm), mainly derived from the Supai Group. They form at surface level three, above the active flood plain, adjacent to the active washes, on alluvial fan deposits.

They nest with the archeological platform (Units 110, 112, 113) near the mouths of the drains and side canyons.

Discrete packages of debris flows, marked by highly contrasting textural differences (mostly gravel / stone sizes) across abrupt smooth boundaries are visible in vertical walls of the fans cut by active drains. Secondary carbonate development as fine soft masses (Stage I) is evident in the 50 to 100 cm depth range, similar to what is seen in other units associated with this geomorphic surface.

These units are generally too stony to advance sustainable agriculture, although linear stone patterns on this fan unit at Little Nankoweap may be related to paleoindian irrigation diversion structures (?). Mesquite grows where eolian materials bury the unit, otherwise vegetation is sparser than other soils in this stratigraphic position, because of low available water holding capacity due to high coarse fragment content. Other plants include prickly pear, beaver tail and Mormon tea. These soils classify as Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids.

112 **Hummocky Land, Moderate Agricultural Potential.** This unit comprises a complex of sand dunes (eolian materials) burying dominately water lain (alluvial) sand deposits. The resultant is very uneven topography ranging from nearly level to as much as 20 percent slope. Eolian materials commonly bury archeological sites on all stretches of the river where this unit is mapped. In some places Anasazi habitation sites appear to have been on or between existing dunes. The dunes are dominately fine sand of varying depth and would place as other than prime farm ground (U.S.D.A. Class III). Low water holding capacity and varying slopes decreases farming opportunities on the dunes. The substratum, the alluvial platform beneath the dunes, is similar to Unit 110, with high land capability for agricultural pursuits (U.S.D.A. Class II).

Textures are stratified very fine sand, fine sand and loamy fine sand. Each of these soils are excessively or somewhat excessively drained. Dunes have less available water holding capacity than the alluvium it buries. Mesquite flourishes in shallow dunes above the alluvium; it is not clear if the trees emerged from the eolian sand or if the sand blew in around them after germination. Mesquite grows in both the dunes and the water lain materials, but tree diameter is observed to be larger in the soils with the finer textured materials and higher water holding capacity. Other vegetation associated with this unit includes sand verbena (Abronia elliptica), globe mallow (Sphaeralcea ambigum), filaree (Erodium, sp.), prickly pear (Opuntia, polyacantha), beaver tail (O. basilaris), and cheat grass (Bromus tectorum) . Overall this unit is inferior to Unit 110 in terms of arable land, but potential for agriculture in isolated places nonetheless there. This unit classifies as a complex of Torripsamments and Haplocalcids. Typical pedons in units 106 and 110 are representative of these soils.

113 **Stratified Alluvial Lands of Low Agricultural Potential.** These soils are very deep, excessively drained and consist of stratified sandy alluvium, eolian sand and colluvial gravel. These soils have less water holding capacity than the 110 unit, but if intensively managed can sustain crops of corn, beans, cotton or squash under an

irrigation regime (U.S.D.A Class III). These soils have a relatively smooth surface, in the 2 to 5 percent slope range. There are inclusions of Units 112 and 106 within Unit 113. Unit 113 is defined as a complex of Haplocalcids - Torripsamments - Haplocambids.

Soils on Pleistocene Age and Older Alluvium

114 **Gravelly Alluvium.** These soils can be described as deep, very coarse grained, moderately developed with moderately rapid permeability. They typically display desert pavement (without varnish) and are very stony. Surfaces are typically thin (3 to 5 mm) very or extremely stony brown loam, underlain abruptly by reddish brown to dark red very gravelly or stony sandy loam, with 1 to 2 mm secondary carbonate rinds lining the undersides of gravels or as soft masses in the matrix (Stage II carbonate development) to a depth of about 75 cm. Carbonates decrease, and the matrix becomes sandier to approximately 1 meter depth. Surface slopes are in the 8 to 15 percent range, and runoff is medium. These soils support Mormon tea, brittle bush, prickly pear and beaver tail. They classify as Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids.

116 **Very Gravelly Fan-Terraces.** These soils are deep, well drained and highly eroded, developed from stratified debris flow / eolian / alluvial gravel. They can be characterized as having an exposed subsoil in places, with desert pavement and varnish, usually with high amounts of secondary carbonate concretion scatter intermixed in the pavement. Textures are coarse throughout (very gravelly sandy loam) with gravel content (including lime concretions) in the range of 50 to 70 percent. Concretions in the upper 40 cm may be many and of large diameter, and the calcic horizons becomes weakly to moderately cemented below, to at least 1.0 meter depth. This soil is of a two tiered Stage II carbonate development. It is slowly permeable, and runoff is very high. Slopes are in the 8 to 15 percent range. These soils support a very sparse vegetation cover of brittlebush (Encelia farinosa), prickly pear, beaver tail, and perennial grasses. The typical pedon for this unit is located on Nankoweap Bluff (Pedon 94006). These soils classify as Loamy-skeletal, mixed, hyperthermic, Haplocalcids.

117 **Stony Flow Lands.** These soils are deep and well drained with a high amount of coarse fragments throughout, with a moderately fine grained subsoil matrix. They typically develop from debris flow materials of dominantly Redwall limestone or Cardenas basalt, that mantle older and high elevation river alluvial deposits. They have accumulated a high amount of secondary carbonate and are of Stage III carbonate development. The surface is stony, with highly developed desert pavement and varnish. Boulders and stone of limestone display chert relief of 2 to 5 cm, indicative of advanced weathering and accelerated erosion. Secondary carbonate comprises a high percentage of the desert pavement. These soils support a sparse (< 5 percent) canopy of brittle bush, Mormon tea (Ephedra fasciculata), prickly pear and beaver tail cactus. This unit is very limited in the mapping area - located across from Kwagant

Creek.

Representative Soil Profile Descriptions:

94006
2/28/94
Near Ruin - Nankoweap Bluff

A 0 to 5 cm, brown (7.5YR sandy loam, reddish brown (5YR 4/4) when moist; moderate fine granular to weak fin subangular structure; slightly hard, very friable, slightly sticky and slightly plastic common very fine and fine roots; common very fine and fine tubular pores; strongly effervescent; 20% gravel and 15% cobbles; clear smooth boundary.

Bk1 5 to 12 cm, light reddish brown (5YR 6/4) gravelly sandy loam, yellowish red (5YR 5/6) when moist; weak fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine tubular pores; violently effervescent, common medium lime occurs in concretions; 10% gravel, 25% cobbles; clear smooth boundary.

Bkt1 12 to 23 cm, pink (5 YR 7/4) gravelly sandy loam, light reddish brown (5YR 6/4) when moist; moderate fine to medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic common fine and medium roots; common fine tubular pores; few thin clay films on ped faces; violently effervescent, common medium lime occurs in concretions; 15% gravel 10% cobbles; gradual smooth boundary.

Bkt2 23 to 50 cm, pink (5YR 7/4) gravelly sandy loam, light reddish brown (5YR 6/4) when moist; moderate fine to medium subangular blocky to massive structure; slightly hard, friable, slightly hard, friable, slightly sticky and slightly plastic; common fine and medium roots; common fine tubular pores; few thin clay films on ped faces and lining pores; violently effervescent; 15% gravel, 10% cobbles; gradual smooth boundary.

Bk2 50 to 63 cm, light reddish brown (5YR 6/4) very gravelly sandy loam, yellowish red (5YR 4/6) when moist; massive; slightly hard very friable, nonsticky and nonplastic; few fine roots; common fine tubular pores; violently effervescent; 15% gravel and 10% cobbles; abrupt smooth boundary.

2Bkt1 63 to 94 cm, variegated yellowish red and pinkish gray (5YR 4/6 and 5YR 7/2) very gravelly clay loam, variegated dark red and light red (2.5YR 3/6 and 2.5YR 6/6); moderate medium angular blocky structure; hard, firm, sticky and plastic; few fine roots; common fine tubular pores; many thick clay films on ped faces and lining pores.

2 Bkt2 94 to 107 cm, yellowish red (5YR 5/6) very gravelly sandy loam,

yellowish red, (5YR 5/6) when moist; common medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; common fine tubular pores; few thin clay films on ped faces; violently effervescent; few fine lime occurs in soft masses; 20% gravel, 30% cobbles.

Soil Classification: Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids
Soil Hydrologic Group: B
Drainage Class: Well Drained
Permeability: Moderate
Runoff: Moderately rapid
Stoniness: Class 3
Vegetation: Mormon tea, Prickly pear, Fourwing saltbush, annual grasses.

Notes: Debris flow over buried soil in river gravel deposits. Angular gravels and stones bury water rounded cobbles and gravels below 64 cm. Two advanced stage II soils. Level 5. Secondary carbonate lines bottoms of clasts in Bkt horizons.

94007
3/1/94
Acheological platform

O 1/2 to 0 cm, mesquite leaves and twigs.

A 0 to 5 cm, light brown (7.5YR 6/4) loamy fine sand, dark reddish brown (5YR 3/4) when moist; strong fine granular structure; soft, loose, nonplastic and nonsticky; many very fine and fine roots; many very fine and fine tubular and interstitial pores; moderately alkaline; clear smooth boundary.

C1 5 to 15 cm, light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 4/4) when moist; weak medium granular structure; soft, very friable, nonplastic and nonsticky; many very fine and fine with common medium to coarse roots; common to many fine and medium tubular pores with few coarse tubular pores; moderately alkaline; clear smooth boundary.

C2 15 to 28 cm, light brown (7.5YR 6/4) gravelly loamy sand, brown (7.5YR 4/4) when moist; massive; slightly hard, very friable, nonplastic and nonsticky; many fine, medium and coarse roots; common to many fine, medium coarse tubular pores; moderately alkaline.

C3 28 to 43 cm, light brown (7.5YR 6/4) gravelly loamy sand, dark reddish brown (5YR 3/4) when moist; massive; slightly hard, very friable, nonsticky and nonplastic; many fine, medium and coarse roots; common to many fine, medium and coarse pores; moderately alkaline; abrupt wavy boundary.

2Akb 43 to 53 cm, light brown (7.5YR 6/4) fine sandy loam, dark brown (7.5YR 3/4) when moist; weak very fine granular structure; soft, loose,

nonsticky and nonplastic; few fine, common medium and coarse roots; common to many fine medium and coarse pores; many fine lime occurs in soft masses, moderately alkaline; gradual smooth boundary.

2 Bk 53 to 91 cm, light brown (7/5YR 6/4) loamy fine sand, brown (7.5YR 4/4) when moist; massive; slightly hard, very friable, nonsticky and nonplastic; few fine and common medium and coarse roots; common to many fine medium and coarse pores; strongly alkaline; vitrification beneath charcoal; abrupt wavy boundary.

3Ab 91 to 97 cm, light brown (7.5YR 6/4) very fine sandy loam, brown (7.5YR 4/4) when moist; granular structure; soft, very friable, slightly sticky and slightly plastic; few fine and common medium and coarse roots; common to many fine, medium and coarse pores; no clay films, many medium lime occurs in soft masses; strongly alkaline; clear wavy boundary.

3Bkb 97 to 147 cm, light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 4/4) when moist; massive; soft, loose, nonsticky and nonplastic; few fine and common medium and coarse roots; common to many fine, medium and coarse pores; no clay films; strongly alkaline; clear wavy boundary.

3C 147 to 163 cm, light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 4/4) when moist; massive; soft, loose, nonsticky and nonplastic; few fine and common medium and coarse roots; common to many fine, medium and coarse pores; strongly alkaline; abrupt wavy boundary.

4Akb 163 to 170 cm, brown (7.5YR 5/4) very fine sandy loam, strong brown (7.5YR 4/6); soft, very friable, slightly sticky and slightly plastic; few fine and common medium and coarse roots; no clay films; many fine lime occurs in soft masses; strongly alkaline; clear irregular boundary.

4C 170 to 183, light brown (7.5YR 6/4) very fine sandy loam, brown (7.5YR 4/4) when moist; massive; soft, very friable, slightly sticky and slightly plastic; few fine, common medium and coarse roots; common to many fine, medium and coarse pores; no clay films; strongly alkaline.

Soil Classification: Fine-loamy, mixed, hyperthermic, Sodic Haplocambids
Soil Hydrologic Group: B
Drainage Class: Somewhat excessive
Permeability: Moderately rapid
Runoff: Slow
Stoniness: Class 0
Vegetation: Mesquite, Fourwing saltbush, annual grasses.

Notes: Charcoal layers show evidence of vitrification; soft masses of carbonate in buried A.

94008
3/1/94
Wetland - frequently flooded

A 0 to 5 cm, dark reddish brown (5YR 3/3) silty clay loam; moderate fine subangular blocky structure; soft, very friable, sticky and plastic; many very fine, fine and medium roots; many very fine, fine and medium tubular pores; moderately alkaline; clear smooth boundary.

AB 5 to 15 cm, dark reddish brown (5YR 3/3) silt loam mottled dark red (2.5YR 3/6); massive; soft, nonsticky and plastic; many very fine, fine and medium roots; many very fine, fine and medium tubular pores; moderately alkaline; clear smooth boundary.

Bg1 15 to 18 cm, dark grayish brown (10YR 4/2) silt loam mottled dark red (2.5YR 3/6); massive; soft, nonsticky and plastic; many very fine, fine and medium roots; many very fine, fine and medium tubular pores; moderately alkaline; clear smooth boundary.

Bg2 18 to 25 cm, dark grayish brown (10YR 4/2) silty clay loam, mottled dark gray and dark yellowish brown (5Y 4/1; 10YR 4/6); massive; soft, friable, sticky and plastic; many very fine, fine and medium roots; many very fine, fine and medium tubular pores.

Soil Classification: Fine-loamy, mixed, mesic, Typic Endoaquepts
Soil Hydrologic Group: D
Drainage Class: Very poorly
Permeability: Slow
Runoff: Ponded
Stoniness: Class 0
Vegetation: Typha, equisetum, salix, Cynodon dyctalon, eleocharis.

Notes: 9' east of 5YRHs stake in bottom of wetland; standing water at 5"; 10 °C at 15 cm.

95005 (Kwagunt - off map)
2/20/95
Fan Terrace UTM 12425483; 4012818

A 0 to 8 cm, pale brown (10YR 6/3) loamy sand, brown (10YR 4/3) when moist; weak fine granular structure; soft, loose, nonsticky and nonplastic; many very fine and fine roots; many very fine interstitial pores; moderately alkaline; 5% gravel; clear smooth boundary.

Bw1 8 to 25 cm, very pale brown (10YR 7/3) sandy loam, brown (7.5YR 5/4) when moist; massive; soft, loose, nonsticky and nonplastic; common very fine and fine with few medium roots; many very fine interstitial pores; moderately alkaline; gradual smooth boundary.

BC 25 to 38 cm, pale brown (10YR 6/3) loamy sand, yellowish brown (10YR

5/4) when moist; massive; soft, loose, nonsticky and nonplastic; common fine and medium roots; many very fine interstitial pores; moderately alkaline; gradual smooth boundary.

C 38 to 61 cm, light yellowish brown (10YR 6/4) loamy sand, dark brown (10YR 4/3) when moist; massive; soft, loose, nonsticky and nonplastic; many very fine interstitial pores; moderately alkaline; clear smooth boundary.

2Bk1 61 to 89 cm, variegated very pale brown (10YR 7/3) and white (10YR 8/2) loam, light yellowish brown (10YR 6/4) when moist; strong coarse subangular blocky structure; hard, friable, slightly sticky and slightly plastic; common very fine and fine tubular pores; moderately alkaline, segregated lime occurs as many large irregular masses; gradual smooth boundary.

2Bk2 89 to 102 cm, light yellowish brown (10YR 6/4) loamy sand, brown (10YR 4/3) when moist; single grain; soft, loose, nonsticky and nonplastic; many very fine and fine interstitial pores; moderately alkaline, lime occurs as common medium concretions.

Soil Classification: Fine-loamy, mixed, hyperthermic, Typic Haplocalcid
Soil Hydrologic Group: B
Drainage Class: Well drained
Permeability: Moderate
Runoff: Moderately slow
Stoniness: Class 0
Vegetation: Prickly pear, annual grasses.

Notes: Stage II carbonate. Weak cementation below 24". Level 4.

95002
2/21/95
Above camp

A 0 to 3 cm, pale brown (10YR 6/3) loamy sand, brown (10YR 4/3) when moist; weak fine granular structure; soft, loose, nonsticky and nonplastic; many fine common and moderately thick roots; many fine interstitial pores; moderately alkaline; clear smooth boundary.

Bk 3 to 33 cm, light brown (7.5YR 6/4) loamy sand, brown (7.5YR 4/4) when moist; massive; soft, very friable, nonsticky and nonplastic; common fine and medium roots; common fine and medium interstitial pores; moderately alkaline, few fine lime occurs in soft masses; gradual smooth boundary.

C133 to 56 cm, pale brown (10YR 6/3) loamy sand, dark yellowish brown (10YR 4/4) when moist; soft, very friable, nonsticky and nonplastic; common fine roots; common fine interstitial pores; moderately alkaline; gradual smooth boundary.

C256 to 109 cm, very pale brown (10YR 7/3) loamy sand, dark yellowish brown

(10YR 4/4) when moist; single grain; soft, very friable, nonsticky and nonplastic; few fine roots; common fine interstitial pores; moderately alkaline; gradual smooth boundary.

Soil Classification: Sandy, mixed, hyperthermic, Typic Haplocambids
Soil Hydrologic Group: A
Drainage Class: Excessive
Permeability: Rapid
Runoff: Slow
Stoniness: Class 0
Vegetation: Prickly pear, Fourwing saltbush, annual grasses.

95003
2/22/95
Archeological platform between Little Nankoweap and Nankoweap Creeks.

A 0 to 8 cm, brown (10YR 5/3) fine sandy loam, dark brown (10YR 3/3) when moist; moderate fine granular structure; soft, loose, nonsticky and nonplastic; many very fine and fine with few medium roots; many very fine and fine interstitial pores; moderately alkaline; clear smooth boundary.

C 8 to 15 cm, light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 4/4) when moist; massive; soft, very friable, nonsticky and nonplastic; many fine and medium with few coarse roots; many very fine and fine interstitial pores; moderately alkaline; abrupt smooth boundary.

2Ab 15 to 23 cm, grayish brown (10YR 5/2) and brown (7.5YR 5/4) fine sandy loam, Variegated very dark grayish brown (10YR 3/2) and brown (7/5YR 4/4) when moist; fine sandy loam; massive; soft, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial; pores; strongly alkaline; charcoal; gradual wavy boundary.

2Ac 23 to 33 cm, reddish yellow (7.5YR 6/6) fine sandy loam, strong brown (7/5YR 5/6) when moist; massive, soft, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; strongly alkaline; gradual smooth boundary.

2C 33 to 53 cm, reddish yellow (5YR 6/8) loamy sand, yellowish red (5YR 5/8) when moist; loamy sand; massive; soft, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; strongly alkaline; abrupt smooth boundary.

3Akb 53 to 61 cm, brown (7.5YR 5/2 and 7.5YR 5/4) sandy loam, variegated dark brown (7.5YR 3/2) and brown (7/5YR 4/4) when moist; massive; soft, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; lime occurs as

many fine soft masses, strongly alkaline; charcoal, cotton pollen*; clear smooth boundary.

3Bkb 61 to 99 cm, yellowish red (5YR 4/6) loamy fine sand, yellowish red (5YR 4/6) when moist; massive; soft, very friable, nonsticky an nonplastic; few fine roots; many very fine and fine interstitial pores; lime occurs as common small masses; abrupt smooth boundary.

4Akb 99 to 107 cm, light brown (7.5YR 6/4) loamy sand, dark brown (7/5YR 4/4) when moist; massive; soft, very friable nonsticky and nonplastic, few fine roots; many very fine and fine interstitial pores; moderately alkaline, common fine lime occurs in small masses; charcoal, corn pollen*; 5 percent gravel.

Soil Classification: Fine-loamy, mixed, hyperthermic, Typic Haplocambids
(Haplocalcids ?)
Soil Hydrologic Group: B
Drainage Class: Somewhat excessive
Permeability: Moderately rapid
Runoff: Slow
Stoniness: Class 0
Vegetation: Prosopis glandulosa; brassica, sp.; erodium, sp.; bromus tectorum.

Notes: Three buried soils. Charcoal in each. Lush vegetation, common threads of $CaCO_3$ in pores just below 61 cm.
* As reported by Hasbargen and Smith, palynologists, University of Northern Arizona.

95004
2/22/95
Beach - 1983 Flood Sand

C 0 to 95 cm, light brown (10YR 5/4) coarse sand, brown (7.5YR 5/4) when moist; single grain, soft, loose, nonsticky and nonplastic; common very fine and fine roots; many very fine and fine interstitial pores; abrupt smooth boundary.

2Ab 95 to 100 cm, brown (7.5YR 5/4) sand, brown (7.5YR 4/4) when moist; massive; soft loose, nonsticky and nonplastic; common very fine and fine roots; many very fine and fine interstitial pores; gradual smooth boundary.

2C 100 to 140 cm, pale brown (10YR 6/3) sand, dark yellowish brown (10YR 4/4) when moist; single grain; soft, loose, nonsticky and nonplastic.

Soil Classification: Mixed, meic, Typic Torripsamments
Soil Hydrologic Group: A
Drainage Class: Excessive
Permeability: Very rapid
Runoff: Slow
Stoniness: Class 0

Vegetation: Tessaria sericea; Tamarix chinesis.

Table No. 1 Laboratory Analyses - Selected Nankoweap Soils

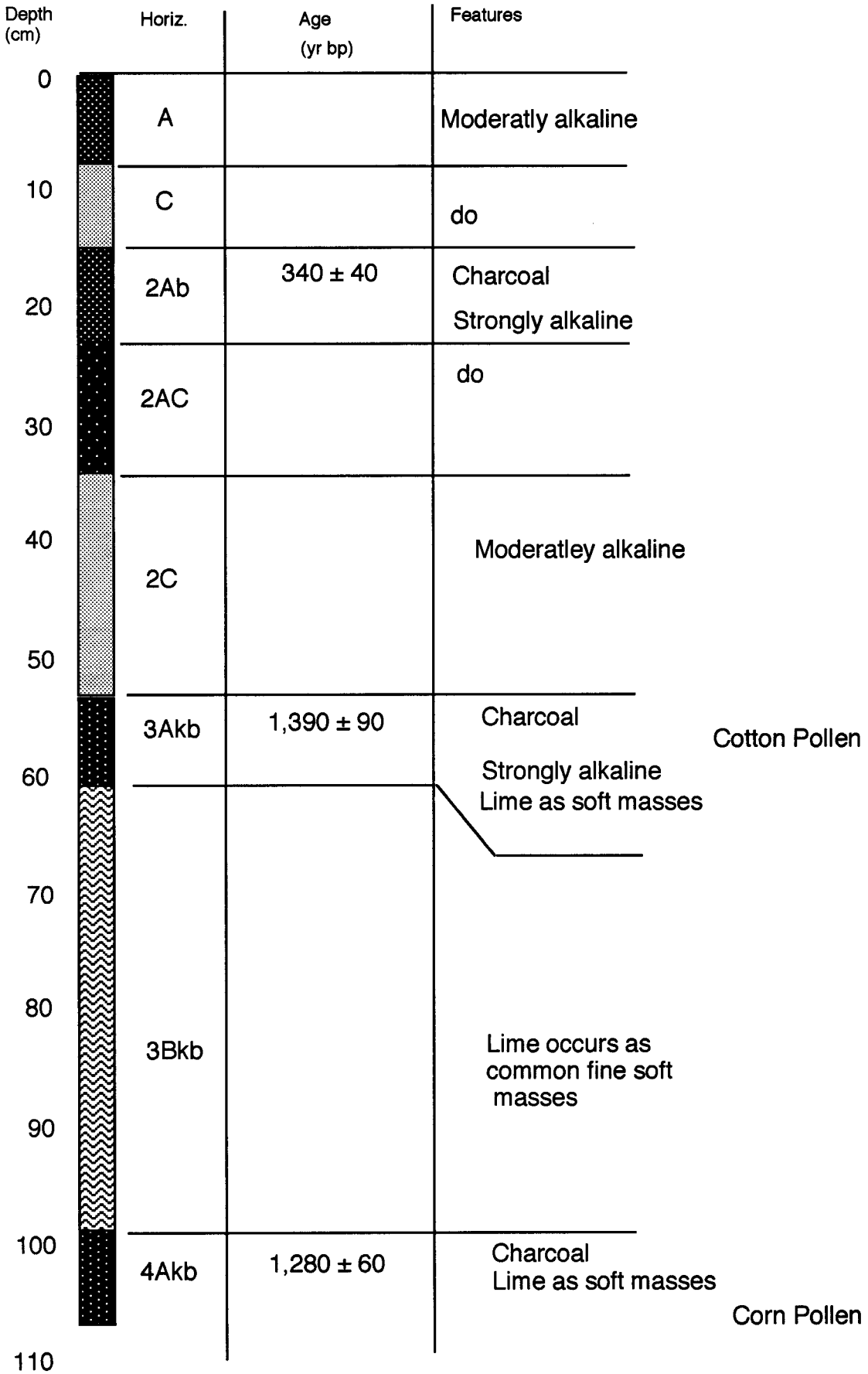
DEPTH (cm)	SAND	SILT	CLAY	VCS	CS	MS	FS	VFS	GRAVEL*	CaCO3	Fe (d)	Al (d)
	%											
Nankoweap Bluff												
94006												
0-5	71.05	24.32	4.63	3.01	1.75	2.9	24.95	38.44	22.31	9.18	0.45	0.02
5-13	64.4	21.86	13.74	1.98	1.98	4.25	31.26	24.93	12.14	11.75	0.54	0.02
13-23	66.22	19.07	14.7	3.93	2.52	6.93	37.61	15.23	10.35	19.64	0.45	0.01
23-51	69.63	19.02	11.35	5.97	4.08	8.11	39.04	12.44	15.46	21.84	0.38	0.01
51-63	69.99	19.54	10.47	6.26	5.78	8.87	34.58	14.5	29.51	21.54	0.28	0.01
63-94	49.19	24.39	26.42	4.35	3.06	4.61	28.2	8.98	22.47	27.91	0.62	0.02
94-107	71.34	14.16	14.5	5.96	7.66	13.71	32.1	11.92	22.13	22.81	0.53	0.01
Archeological Platform												
94007	(Partial data)											
0-5	63.31	32.43	4.25	0.24	1.00	1.06	16.55	44.46	0	9.8	0.42	0.01
15-28	68.08	28.07	3.85	0.68	0.77	0.88	17.35	48.39	1.88	11.28	0.4	0.01
43-53	61.64	32.94	5.42	0.41	0.59	0.88	15.09	44.67	0.18	13.03	0.4	0.01
53-91	78.27	18.86	3.06	0.21	0.36	1.13	23.09	53.48	0.41	9.86	0.34	0.01
91-97	71.17	23.36	5.47	0.15	0.47	1.26	22.28	47.02	0.79	15.29	0.36	0.01
147-163	73.1	23.53	3.37	0.05	0.12	0.39	16.04	56.5	0	10.84	0.35	0.01

*washed untreated gravel

SAMPLE	Depth (cm)	pH	O.C. %	N %	EXTRACTABLE CATIONS, by NH40 Ac Ca	Mg	Na	K	CEC NH_4OAc pH 7.0	CEC NaOAc pH 8.2
					meq/100g					
94007	0-5	7.52	2.79	0.13	39.66	2.83	0.13	0.82	7.7	6.96
	15-28	8.18	2.13	0.06	42.88	2.17	0.19	1.02	5.64	5.06
	43-53	8.36	2.89	0.09	50.9	3.31	0.17	2.3	7.83	7.36
	53-91	8.84	1.64	0.03	39.73	3.09	0.15	1.05	4.23	3.14
	91-97	9.07	2.44	0.03	33.52	11.33	5.4	2.9	4.0	2.76
	147-163	8.52	1.59	0.02	43.74	5.43	1.43	2.03	3.81	2.97

SAMPLE	DEPTH (cm)	SOLUBLE CATIONS, by Sat Paste Ca	Mg	Na	K	EC ds/m	SAT %	EXCH. Na meq/100g	ESP
		meq/l							
94007	0-5	6.44	3.95	0.33	1.74	1.43	41.69	0.12	1.67
	15-28	5	2.88	0.57	4	1.29	33.19	0.17	3.38
	43-53	3.15	1.56	0.89	5.62	1.22	37.88	0.14	1.85
	53-91	1.3	1.07	0.53	2.38	0.54	30.78	0.13	4.26
	91-97	24.98	205.59	113.04	47.18	31.5	30.1	2	72.37
	147-163	28.35	59.62	27.72	19.23	12.6	29.52	0.91	20.59

Little Nankoweap Soil Profile - Depth, Horizon, Age and Features of Interest



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Notes: ^{14}C dates by M. Caffee and R.Finkel; Palynology by J. Hasbargen

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