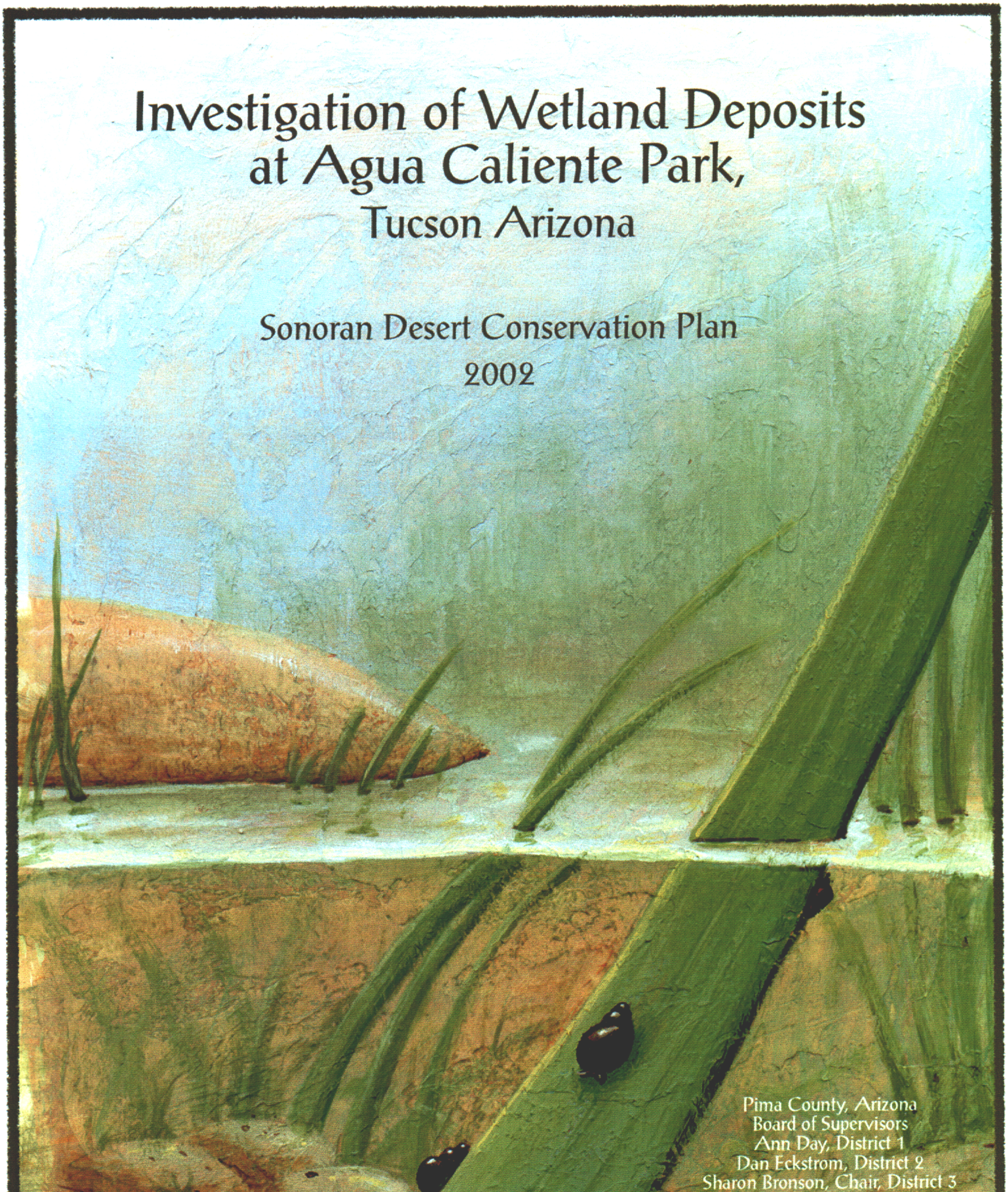
Investigation of Wetland Deposits at Agua Caliente Park,

Tucson Arizona

Sonoran Desert Conservation Plan

2002



MEMORANDUM

Date: July 29, 2002

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: **Agua Caliente Wetlands Study**

Background

The Riparian Element of the Sonoran Desert Conservation Plan involves restoration efforts. Pima County has undertaken successful projects such as the Bingham Riparian Restoration, the Pantano Jungle Restoration, and the restoration of the Cienega Creek Natural Preserve. One of a number of current restoration projects under consideration is the Agua Caliente Restoration, which has the potential for re-creating habitat for native fish and frogs. The attached study entitled *Investigation of Wetland Deposits at Agua Caliente Park* was conducted by Jeff Pigati, a paleoecologist at the University of Arizona Desert Laboratory at Tumamoc Hill, to determine where the Agua Caliente wetlands formerly occurred.

Results

Scientists can determine the past locations of an abandoned wetland, particularly the outflow channels, because they are marked by the geologic deposits that are unique to wetland systems. In essence, wetland deposits act as recorders of hydrologic change. Wetlands are home to unique plants and animals, including vegetation and certain mollusks that can be used as indicators of wetland conditions.

This study found that Hydrobiid spring snails formerly inhabited the Agua Caliente wetlands. Hydrobiids are tiny snails that are unable to live on land. They prefer flowing water and are usually found in spring head pools and outflow channels associated with springs. They no longer live in the Agua Caliente spring or ponds, but their fossils were used by paleoecologist Jeff Pigati as a tool for determining the location of past outflow channels.

In general, it appears the wetlands were located where ponds and modern channels are located. There is no evidence for spring flows having gone across the presently dry northwestern portions of the park.

The study uncovered evidence of a former outflow channel associated with the spring at Agua Caliente Park below one pond. The former outflow channel migrated between this area and an area south of the park boundary across Roger Road.

Although it is clear that these deposits are not the result of historical anthropogenic influence, we cannot be certain that the deposits were not at least influenced in some way by prehistoric inhabitants of the area.

The wetland deposits appear to be no more than a few thousand years in age, which covers the same general period of time as nearby prehistoric settlements.

The area between two of the ponds also probably contained wetlands. However, this area has been so extensively modified by historical actions that it is difficult to determine if this deposit was related to a natural meander of the outflow channel between the spring orifice and the area west of one pond or a result of anthropogenic activity.

Conclusion

Introducing a fascinating mix of science and paleontology to the Sonoran Desert Conservation Plan study series, the *Investigation of Wetland Deposits at Agua Caliente Park* enhances the discussions of the feasibility of restoring flow paths at Agua Caliente to a more natural state by providing information which allows us to better understand the wetland system that existed before periods of intervention.

Attachment

Investigation of wetland deposits at Agua Caliente Park, Tucson, Arizona

May 1, 2002

Jeffrey S. Pigati

FIGURES:

Investigation of wetland deposits at Agua Caliente Park, Tucson, Arizona

INTRODUCTION

Today, the Sonoran Desert receives ~30-50 cm of annual precipitation in the low elevation (<1000 m ASL) valley floors. Over the past few decades, a growing demand for water, particularly ground water, by agriculture, mining, industry, and an ever-increasing population has significantly lowered the water table in many of these valleys. For example, between the 1940s and 1995, groundwater levels declined over 50 m near Green Valley/Sahuarita, more than 60 m in parts of the Central Wellfield and over 30 m in the Southside Wellfield in the Tucson basin, and 50 m in the southern Avra Valley (Gelt et al., 2000). Stretches of rivers that used to flow perennially, such as the Santa Cruz River near Tucson, now only flow briefly following seasonal precipitation events. Cottonwood trees (*Populus* sp.) and other hydrophilic vegetation that formerly lined the perennial rivers have largely vanished. Surface water and riparian habitats are now scarce throughout much of Sonoran Desert lowlands, and humans have extensively modified many springs and wetlands.

One of the primary tasks of geomorphologists is to determine the conditions of the landscape prior to significant anthropogenic (human) influence. Pre-historic inhabitants of the Sonoran Desert have long modified the landscape through construction of canals, for example, for agriculture and other purposes. Evidence of historical modification of the landscape is abundant, including mining activities, agriculture, and building of canals, roadways, and urban areas just to name a few.

There are several methods that can be used to determine what the landscape may have been like prior to human modification. Computer models, direct measurement of various landscape parameters, and chemical or isotopic investigations have all been used for such investigations. However, the most practical method for many ecosystems, and the one chosen for this study, is direct geologic research – i.e. mapping, digging, describing, measuring, and sampling.

SITE DESCRIPTION

Agua Caliente Park is located in the foothills of the Santa Catalina Mountains just east of Tucson (32°16.87 N, 110°43.72 W; 835 m ASL). The park lies just southeast of Agua Caliente Wash, one of several ephemeral streams in the Tucson Basin.

The park is currently home to a perennial spring (Fig. 1), as well as a series of canals and still water ponds largely created over the last century. The spring lies on a contact between Upper Oligocene to Lower Miocene granitic gneiss (highly metamorphosed granite), which is exposed at the east boundary of the park, and overlying alluvium of the Late Tertiary Rillito formation. Water originally emanated from at least two springs, one with emerging cold water and one with hot water. However, early landowners dynamited the spring in hopes of increasing the discharge, and the explosion merged the two springs into one. The surviving spring now maintains a constant temperature of 30.4°C (87°F). The flow rate is quite variable, and has ranged from ~40 to 170 gallons per minute (gpm) between 1982 and 2001 (PAG, unpublished data; Tucson Water, 1983; Lloyd et al., 1989).

Figure 1 (a): Active spring at Agua Caliente Park.

Figure 1 (b): Spring and outflow channel. Note absence of vegetation adjacent to flow. Park personnel actively clear this area.

The spring also fed a wetland system that has been extensively modified over the past century, and probably longer. Three earthen dams have been created, one prior to 1941 (the date of the oldest available aerial photograph) and two since then. Spring discharge water enters Pond 1 about 150 m downstream of the spring (Fig. 2a, b). Additional canals have been constructed throughout the park to channel the outflow between ponds (Fig. 2c). Five dry ponds are also present at the park.

In addition to the historical modification, it is quite likely that Hohokam inhabitants of the park area manipulated the water emanating from the original springs for at least the last ~3500 years. There is evidence of channel modification to convey stormwater runoff and quite possibly spring flows during Hohokam periods at nearby Gibbon Springs (Slaughter and Roberts, 1996), and therefore we would expect a similar use of flowing water at the Agua Caliente site. As part of a feasibility study aimed at identifying alternatives to the current situation at Agua Caliente Park, including possible restoration of flow paths to a more natural state, it is imperative to better understand the Agua Caliente wetland system prior to historic intervention, and ideally before pre-historic intervention.

WETLAND DEPOSITS

Stratigraphy, chemistry

The primary goal of this study is to determine the extent of wetlands and location of outflow channels prior to human modification of the landscape. Wetlands form where the water table intersects the ground surface, resulting in the formation of seeps, flowing springs, and wet meadows. Although often fairly small in scale, wetlands are important ecological refuges for a


Figure 2 (a): Pond 3


Figure 2 (b): Earthen dam associated with Pond 3.

Figure 2 (c): Canal connecting Ponds 1 and 2.

variety of wildlife and fauna, particularly those dependent on a continual water supply in an otherwise arid climate.

In addition to the abundant biological and ecological life that can be sustained in these unique areas, a characteristic set of geologic deposits, consisting of chemical precipitates, organic material, and detrital material (collectively termed "wetland deposits") is typically found in association with wetlands. The nature and appearance of wetland deposits can be highly variable, and is determined by the chemistry of the emerging spring water (Fig. 3a). Emerging ground water with a high dissolved silica content can form siliceous deposits that contain microscopic silica-shelled organisms called "diatomites". For example, wetland deposits consisting chiefly of diatomites are found in the Atacama Desert of northern Chile (Fig. 3b). Ground water with abundant dissolved carbonate species can result in the formation of a "marl", or fine-grained carbonate-bearing mud (Fig. 3c). Marls often contain microscopic carbonate-shelled organisms called "ostracodes", which are common in wetland deposits in the San Pedro Valley of southern Arizona. If ground water is not saturated with respect to either silica or carbonate, the result may be deposition of detrital material, such as aeolian silts and clays that are trapped by vegetation supported by the shallow water table (Fig. 3d). The latter type of deposit is present here at Agua Caliente Park.

Subtle changes in the hydrology of an aquifer may alter the location of the spring, outflow channel, or wetland. Over long periods of time (centuries to millennia), these changes may result from tilting of the basin through tectonic processes, changes in the amount of precipitation an area receives, or other related processes. Changes can also be made by humans, such as building canals to divert the outwash flow. We can determine the past locations of an abandoned wetland, particularly the outflow channels, because they are marked by the geologic deposits that are unique to wetland systems. In essence, wetland deposits act as recorders of hydrologic change. For example, wetland deposits higher up on the landscape than today document higher water table conditions in the past.

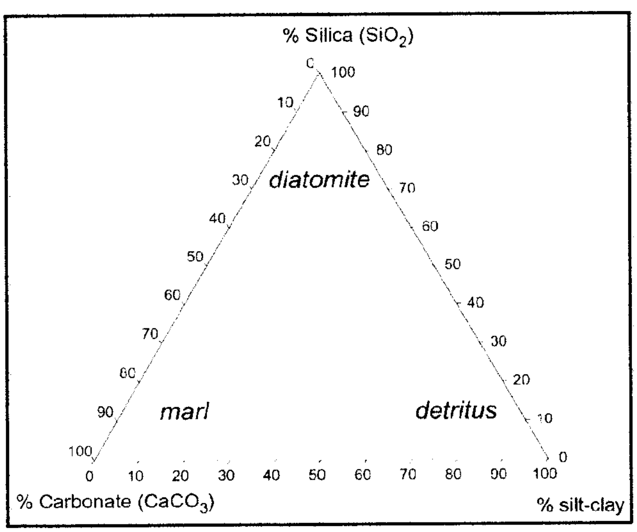


Figure 3(a): Relationship between chemistry of emerging ground water and type of wetland deposit (Quade, unpublished).

Figure 3(c): Carbonaceous wetland deposits from the San Pedro Valley, Arizona.

Figure 3(b): Siliceous wetland deposits from the Atacama Desert, northern Chile.

Figure 3(d): Detrital wetland deposits from Agua Caliente Park, Tucson, Arizona.

Macrofossils

The variable chemistry and appearance of wetland deposits, and their similarity with pluvial lake deposits has led to much confusion and misinterpretation as to their origin. Fortunately wetlands are home to unique flora and fauna, including phreatophytic vegetation and certain taxa mollusks and ostracodes that can be used as indicators of wetland conditions.

Phreatophytic vegetation are comprised of plants that can only survive in arid climates in areas where ground water is near the surface, such as near or downstream of a spring. Phreatophytes common to southern Arizona include salt grass (*Distichlis spicata*) and saltbush (*Atriplex canescens*). If the water table drops, either naturally or as a result of anthropogenic processes, these plants are unable to adjust to the dry conditions and quickly die off. Remains of these plants are often, but not always, found embedded in wetland deposits as thin, organic rich layers.

Similarly, certain types of mollusks (snails) are also particularly adapted for living in wetlands. Terrestrial snails, including minute varieties such as *Succinediae* and *Pupillidae*, are common in wetland areas because of the continually moist ground conditions. These snails can be found in abundance in wetlands with constant flow conditions because of the general absence of flood conditions, which would wipe out their habitat and even the snails themselves. Likewise, some aquatic snails, such as *Physidae* and *Planorbidae*, are common in wetlands, as well as ponds and small lakes. We can use mollusk and ostracode assemblages recovered from wetland deposits to obtain information pertaining to past flow conditions (i.e. seeps vs. flowing springs; perennial vs seasonal flow), as well as to delineate the extent of former wetlands and outflow channels.

A particularly useful mollusk taxa, *Hydrobiidae*, commonly known as "spring snails", prefers flowing water and are usually found in the spring pool and outflow channels associated with springs (Fig. 4). Hydrobiids are minute (<1-2 mm) snails that are hermaphroditic, gill-breathing members of Order Prosobranchia, one of the two great molluscan orders (Hershler and Sada, 1987). Their breathing mechanism excludes the possibility of living on land, and their presence in active springs, particularly near the outflow channel, allows their use as a diagnostic tool for determining the location of past outflow channels.

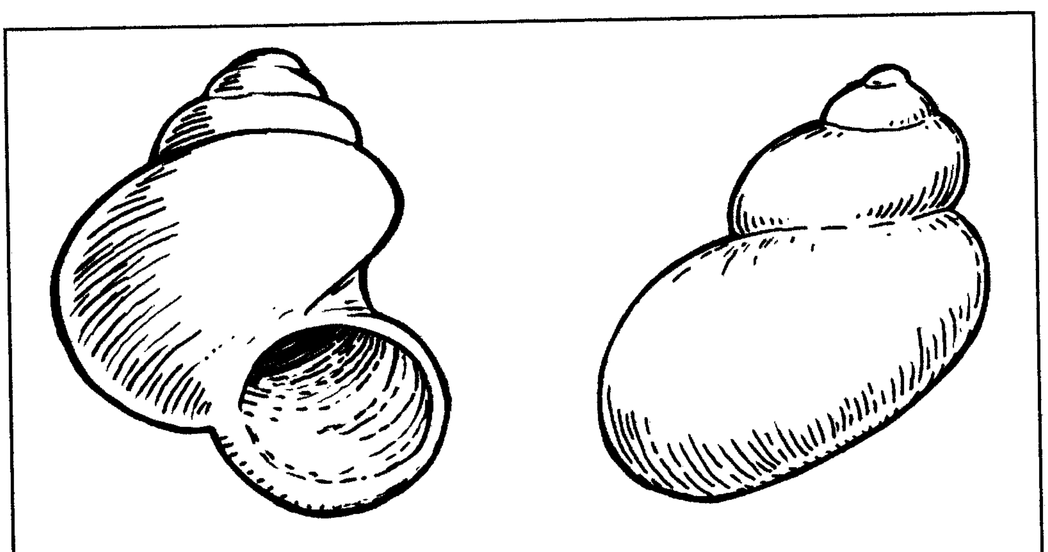


Figure 4: Diagram of *Hydrobiidae* shells recovered from wetland deposits at Agua Caliente Park. This taxa is diagnostic of perennial flowing water and was used here to determine the location of the former outflow channel.

Chronology of wetland deposits

The age of wetland deposits, and therefore the timing of the high water table conditions, can often be determined by radiocarbon (^{14}C) dating. Upon death, vegetation near active wetlands decays and contributes an abundant source of carbon to the host soils. There are two basic types of soil carbon (referred to as "organic matter") that result. Disseminated organic matter (DOM) consists of plants and other sources of organic carbon that have decayed beyond the point of recognition, and have become incorporated in the soil matrix itself. DOM accumulates over time and may include carbon derived from long dead plants to recently decayed organic matter. Although DOM is found in nearly all wetland stratigraphic sequences, including the Agua Caliente deposits, it is generally not applicable for ^{14}C dating because it provides only an integrated age, which can be older, younger, or the same as the average age of the deposit, depending on the rate of decay through time. Reworked older carbon and addition of secondary humic acids by infiltrating ground water further complicate the interpretation of ^{14}C ages obtained from DOM.

Organic macrofossils on the other hand, can be used for ^{14}C dating. Organic macrofossils include the remains of organic material (plants, leaves, seeds, carbonized wood) that can either be identified or have preserved some or all of the original physical structure. Carbon contained in an organic macrofossil can be isolated from surrounding DOM through chemical pretreatment techniques that involve a series of acid-base-acid treatments (Rech et al., 2002).

Carbon-bearing shells may also be used for ^{14}C dating, with a few caveats. Aquatic organisms, such as ostracodes and many types of mollusks, should be avoided for dating in situations in which the host water is significantly depleted in terms of ^{14}C. In other words, the carbon source of the shell carbonate was not in equilibrium with the atmosphere during the time of shell formation. For example, water emanating from the Agua Caliente spring is significantly depleted in ^{14}C. The "percent modern carbon" of water sampled in June 2000 was 0.472 (C. Eastoe, unpublished data); meaning that any organism that obtains its carbon from this water source would also start with a ^{14}C inventory of 0.472. Such as situation would result in ^{14}C ages that are ~6000 years too old! Aquatic organisms at Agua Caliente, including the shells of Hydrobiids, should therefore be excluded from consideration for ^{14}C dating.

Similarly, many types of land snails should be avoided for radiocarbon dating because they are known to ingest and incorporate limestone or other sources of old carbon during shell formation (e.g. Goodfriend and Stipp, 1983). Thus they would also yield ^{14}C ages that are anomalously old. Recently, some minute land snails, including *Pupilla* sp., *Euconulus fulvus*, and *Succineidae*, have been found to yield reliable radiocarbon ages (Brennan and Quade, 1997; Pigati *et al.*, forthcoming). Unfortunately, these taxa were not found in the wetland deposits at Agua Caliente Park.

AGUA CALIENTE PARK STUDY RESULTS

Surficial geologic deposits

Surficial geologic deposits were characterized as alluvial ("A"), fluvial ("F"), or wetland ("W") in origin (Fig. 5). Alluvial deposits consist of poorly sorted, angular to subangular, sand to pebble size clasts that are deposited as part of a shallow alluvial fan that dominates the area in and around Agua Caliente Park. Alluvial clasts are silica-rich, consisting primarily of granite gneiss from the nearby Santa Catalina Mountains. Most of the park surface is covered by these alluvial clasts.

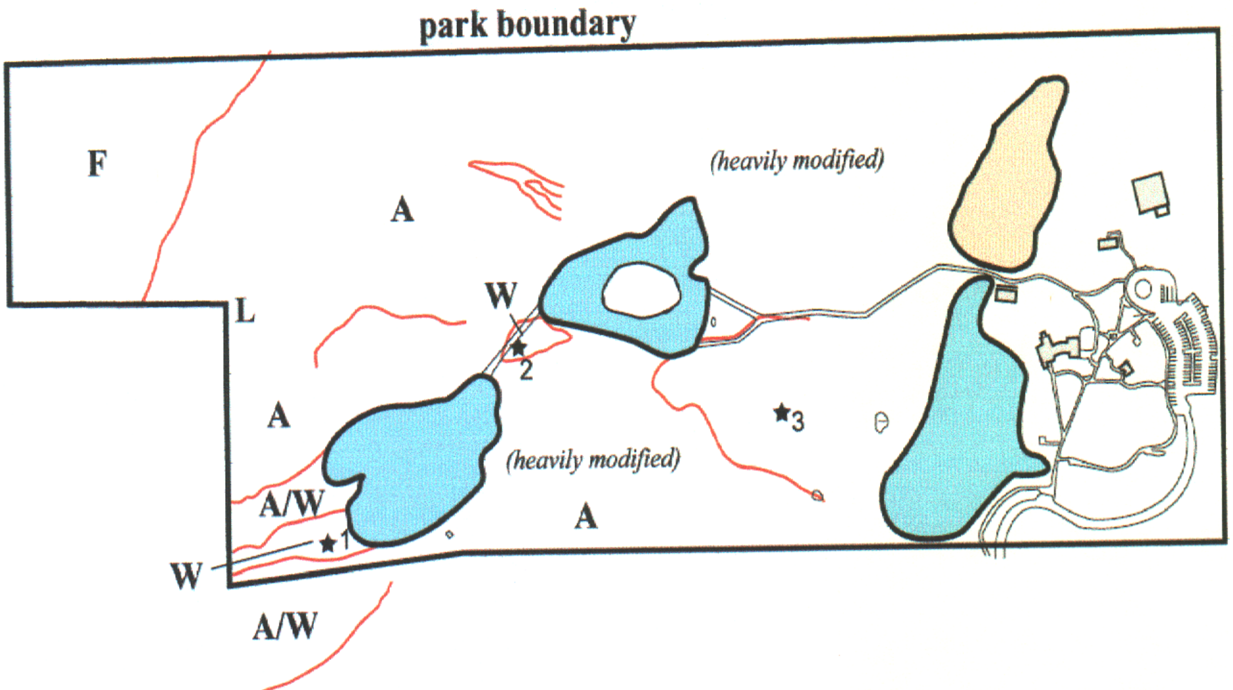


Figure 5: Surficial geologic map of Agua Caliente Park. Letters in **bold** refer to geologic deposits:
w-wetland, **a**-alluvial, **f**-fluvial, **l**-limestone, **a/w**-interbedded alluvial and wetland deposits. Solid lines demarcate boundaries between geologic units.

There is evidence of desert pavement development in the undisturbed parts of the park, particularly north of Pond 3. Desert pavements are flat geomorphic surfaces capped by interlocking grains, such that a clear and continuous surface can be identified. They form as a result of aeolian material that slowly accumulates through time. In extremely arid climates where vegetation is minimal, desert pavements are capped by a hard, thin (2-3 cm) layer of interlocked alluvial clasts underlain by ~8-10 cm of aeolian silt, which itself is underlain by additional alluvial material. At Agua Caliente Park, the abundant vegetation serves to constantly disturb the pavement surface, resulting in a top layer that is not interlocked. However the layer of aeolian silt is easily accessible, and is typically 5-10 cm thick in the area north of Pond 3.

In addition to the silicate clasts, alluvial deposits near the western boundary of the park also contain local limestone clasts, including several large (~1 meter in diameter) limestone boulders (marked "L" on Fig. 5). The appearance of the boulders suggests they are not related to pedogenic (soil formation) processes. These boulders may have been brought down from a small outcrop of limestone to the east during a large flood, although this is purely speculative.

Fluvial deposits are the result of direct deposition by a river or stream, and here are limited to the northwest corner of the park near Agua Caliente Wash. Fluvial deposits consist of well-sorted, well-rounded clasts that vary in size depending on their proximity to the wash (clast size increases closer to the river). A small tributary arroyo just north of Pond 2 (also marked on Fig. 5) consists chiefly of reworked alluvial material, and therefore does not warrant an "F" designation.

Wetland deposits are limited to the southwest corner of the park, west of Pond 3, and a small area between Ponds 2 and 3. The only evidence of a former outflow channel is located west of Pond 3. The surface sediment in this area contains abundant shells of *Hydrobiidae*, the small aquatic mollusk described above. Adjacent wetland deposits, similar in appearance to the outflow channel but lacking fossil shells, are present north and south of the former outwash channel and are interbedded with alluvial deposits. These areas are marked "A/W". These wetland deposits, including the former outflow channel, continue beyond the park boundaries to the west and may reach Agua Caliente Wash.

A shallow (30-40 cm) man-made canal is present near the boundary between the former outflow channel and the A/W unit to the north. The canal is cut through the wetland deposits, indicating the deposits are older than the canal. Unfortunately, material suitable for ^{14}C dating was not found in the wetland deposits or canal, so we cannot determine if the canal is historic or pre-historic in age.

Sediment exposed at the surface between Ponds 2 and 3 is similar to wetland deposits west of Pond 3, but there is no evidence of mollusk shells. It is difficult to determine how the creation of the artificial ponds and adjacent hiking trails may have impacted this area.

Wetland stratigraphy

Natural exposures via arroyo cutting are generally not available at Agua Caliente Park. Therefore, three soil pits were dug by hand to allow access to the subsurface stratigraphy of the wetland deposits and sediment associated with the phreatophytic vegetation. Soil pit (SP) 1 was located in the shell-rich outwash area west of Pond 3 to allow description and sampling of the deposit; SP2 was located between Ponds 2 and 3 to determine the origin of the apparent wetland deposits; and SP3 was located in the phreatophyte zone west of Pond 1 to characterize the associated sediment. Detailed stratigraphic descriptions are included as Figure 6. A brief summary and interpretation of the deposits is presented here.

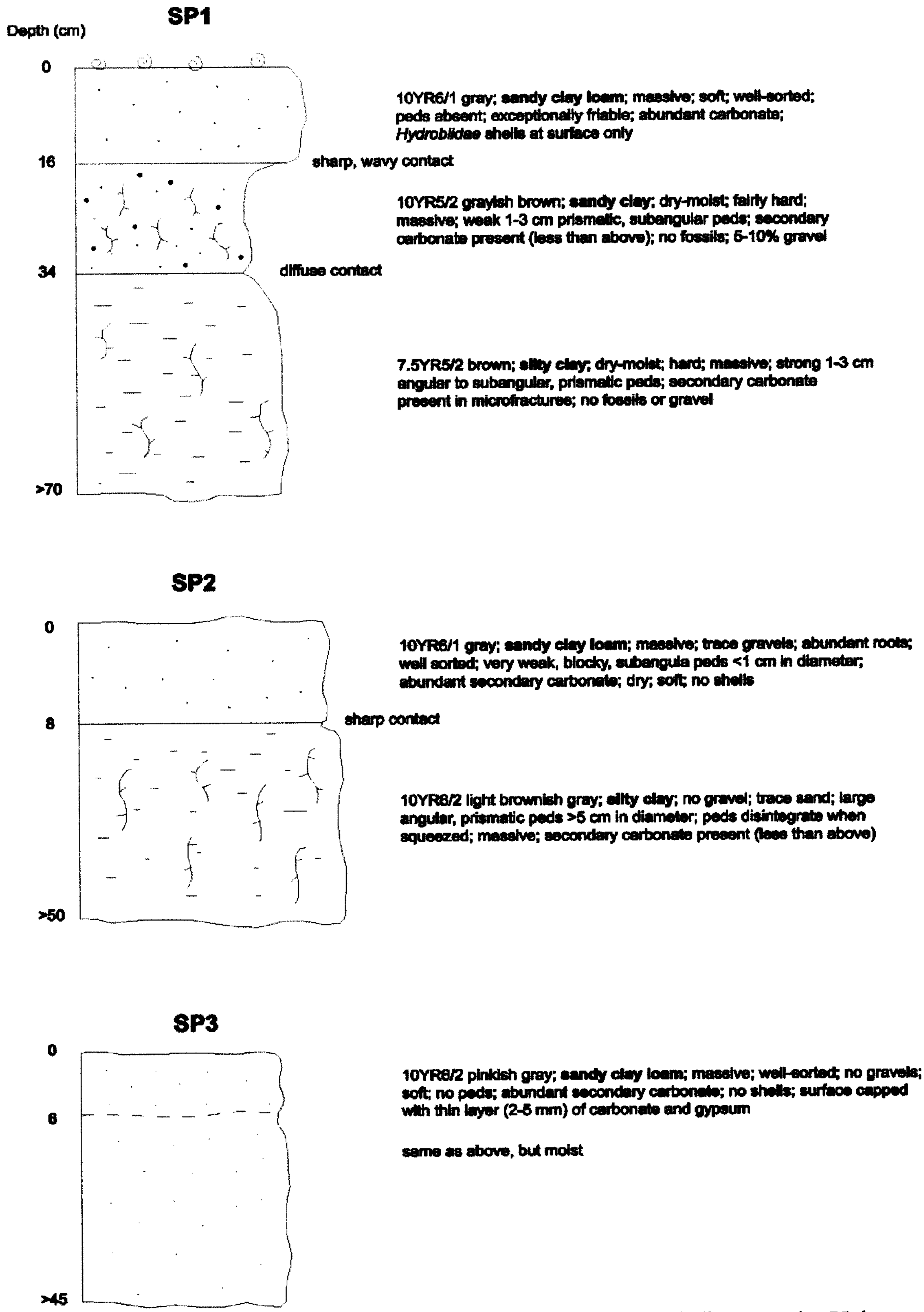


Figure 6: Detailed stratigraphic descriptions of sections at Agua Caliente Park. Unit designation is described in text.

Unit A

Unit A is a massive, well-sorted, gray (10YR6/1) silty clay loam. The unit is quite dry, soft, and friable, with no evidence of soil development. The unit appears to be quite young in age, probably no older late Holocene. Carbonate development is equivalent to Stage 1 (consisting of only an initial coating of carbonate on unconsolidated sediment), which supports the interpretation of a relatively young age. Unit A was present at SP1 and SP2, and is designated at each locality as A1. A similar deposit was found at SP 3, and is designated there as Unit A2.

Several shells of *Hydrobiidae* were found at the surface at SP1, but are absent below ~1 cm. This is likely due to aeolian deflation of the surface, which would serve to remove the fine-grained sediment, concentrating the heavier shells at the surface. Overall, the appearance and texture of this unit indicate it was formed in association with wetlands, and the former location of an active outwash channel is delineated by the presence of Hydrobiidae shells. Unit A did not contain material suitable for radiocarbon dating.

Unit B

Unit B is a grayish brown (10YR5/2), massive sandy clay. The unit is fairly hard, and is dry to slightly moist. Weak soil peds 1-3 cm in diameter were present. The peds are angular to subangular and prismatic. Unit B also contained 5-10% discontinuous subangular gravels, indicative of alluvial deposition. Carbonate development in this unit was also Stage 1.

The texture and physical characteristics indicate this unit was deposited in a fairly low-energy environment, although the presence of discontinuous gravel indicates that episodes of higher energy deposition occurred. The presence of this unit interbedded with wetland deposits could have resulted by either (1) episodic drying of the wetland and establishment of alluvial conditions, or (2) lateral migration of the outflow channel and associated wetlands in an area otherwise dominated by alluvial conditions. Based on the presence of continuous flow over the past century or more (including through several periods of drought conditions), and the position of the spring near the bedrock-alluvium contact, which would ensure fairly continual flow conditions, it is unlikely that the spring dried up for significant periods of time. Therefore lateral migration of the outflow channel and wetlands is the most likely scenario. Unit B did not contain shells or material suitable for ^{14}C dating.

Unit C

Unit C is a brown (7.5YR5/2), massive silty clay that is very hard. This unit contained strong peds 1-3 cm in diameter that were angular to subangular and prismatic. Secondary carbonate had filled microfractures of the silty clay, equivalent to late Stage 1 development. Clasts were not completely coated by carbonate, which is required for designation as Stage 2. This unit was deposited in a low-energy environment, which, unlike Unit B, was probably continually low energy based on the well sorted, fine grained sediment. Unit C did not contain shells or material suitable for dating.

CONCLUSIONS

In general, it appears the position of the ponds and active overflow channels generally mimic the location of wetlands in the recent past. The area west of Pond 3 contains the only unequivocal evidence of a former outflow channel associated with the spring at Agua Caliente Park. The former channel migrated between this area and an area south of the park boundary across Roger Road as evidenced by interbedded wetland and alluvial deposits. Although it is clear that these deposits are not the result of historical anthropogenic influence, we cannot be certain that the deposits were not at least influenced in some way by pre-historic inhabitants of the area. The wetland deposits appear to be no more than a few thousand years in age, which covers the same general period of time as nearby Hohokam settlements.

Based on the similar stratigraphy between Unit A at SP1 and SP2, it is likely that the area between Ponds 2 and 3 also contained wetlands. However, this area has been so extensively modified by historical actions that it is difficult to determine if this deposit was related to a natural meander of the outflow channel between the spring orifice and the area west of Pond 3, or a result of anthropogenic activity.

The remainder of the park surface is dominated by alluvial and, to a lesser extent, fluvial deposits. No other evidence of wetland deposits was found.

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