APPENDIX K:

OSTROCODE PALEOECOLOGY OF RED MOUNTAIN SITE, MESA, ARIZONA

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Terra Nostra Earth Sciences Research

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Introduction

The Phoenix Basin is a prolific source of materials and data on Hohokam history. These people constructed a complex and extensive irrigation system before the arrival of Europeans along the Salt and Gila rivers (Haury 1976). To date, records of Hohokam irrigation in the area include all cultural periods (Pioneer, Colonial, Sedentary and Classic) (Doyel 1991; Haury 1976). Classic period canals are best documented (Adams et al. 2002). Red Mountain Freeway project sites, in Mesa, Arizona, contain artifacts that indicate occupation from the late Pioneer through the Colonial periods, although evidence of Classic period sherds is present (Yost et al. 2000).

Hohokam irrigation features along the Red Mountain Freeway corridor include main, distribution, and lateral canals, as well as a reservoir, documented for the first time to contain ostracodes. Canal ostracodes have proven to be a powerful tool to reconstruct environmental conditions at the time of canal operations (Palacios-Fest 1989, 1994, 1997a, 1997b; Palacios-Fest et al. 2001). Based on previous work on Hohokam canal ostracodes and the work of Adams et al. (2002) modern analog study, it is possible to recognize major aspect of evolution in irrigation technology, canal construction, and climatic effects.

Among the ostracode species present at the Red Mountain sites, some require a few weeks to complete their life cycles and adapt well to ephemeral conditions (e.g., Limnocythere staplini, Cypridopsis vidua; Anderson et al. 1998; Forester personal communication, 1989; Kesling 1951). In contrast, others need several months to mature and reflect permanent or long-term bodies of water (e.g., *Candona patzcuaro* [three months], *Darwinula stevensoni* and *Herpetocypris brevicaudata* [six months to a year]; Forester personal communication 1989; Cohen personal communication, 1989). Differences among such populations are used to distinguish periods of water discharge from desiccation, and examine human impact in the landscape.

The Red Mountain canals and reservoir provide a unique opportunity to document a period of intense soil salinization consistent with previous studies in the area (Palacios-Fest 1994, 1997a). The objectives of this study are to reconstruct the history of the hydrochemical nature of the canals, the salinity ranges, trends of salinization and dilution in response to human activity, and to propose a potential environmental cause to Hohokam decline in the area.

Area of Study

The Red Mountain Freeway right-of-way passes through Townships/Ranges 1N/5E (Sections 1–3) and 2N/5E (Sections 34 and 36) between State Route 87 and Gilbert Road (Yost et al. 2000:Figure 1). It impacts four sites with prehistoric water management features: AZ U:9:169(ASM), AZ U:9:200(ASM), AZ U:9:201(ASM), and AZ U:9:222(ASM). The sites are located on the Lehi Terrace, the lowest and youngest terrace of the Salt River. Yost et al. (2000) describes soil composition as clays and loams.

Located in the Lower Sonoran Desert, between 30 and 1,200 m above mean sea level (m amsl), the Phoenix Basin averages 600 m amsl. The Salt and Gila rivers drain the area. The maximum temperature may reach 46°C; rarely freezing temperatures are reached in winter (Yost et al. 2000). Annual precipitation is less than 13 cm. Summer monsoons (July-September) and winter rains (December-March) contribute precipitation (Sellers and Hill 1974). Modern hydrochemical analyses of the Salt and Gila rivers indicate a freshwater to slightly saline composition, dominated by Na^{+}, Mg^{2+}, and SO_4^{2-} (Hem 1985). The Salt River ranges from 800–1,200 mg l^{-1} of total dissolved solids (TDS) (Hem 1985 and the U.S. Department of Agriculture climatological data files, 1897–1905).

Materials and Methods

Eighty-six sediment samples were processed for ostracode analysis following routine procedures (Forester 1988) modified by Palacios-Fest (1994). Between 93 and 100 g of sediment were initially used to increase the chances for ostracode recovery. Sediment residuals were analyzed under a low-power microscope.

All 43 fossiliferous samples were examined to identify fossil contents and faunal assemblages. Total and relative abundances were recorded. In addition, standard taphonomic parameters were recorded for each sample to distinguish allochthony from autochthony of the ostracode population. Fragmentation and abrasion are used as indicators of transport. Encrustation is used as an indicator of authigenic mineralization. Coating is used as an indicator of stream action and authigenic mineralization. The redox index and color of the shell are used as indicators of burial conditions and preservation (Adams et al. 2002; Palacios-Fest et al. 2001). Disarticulation (carapace/valve (C/V)) and life cycle (adult/juvenile (A/J)) ratios were recorded as indicators of the synecology (ecology of the communities), as opposed to the autoecology (ecology of a single species) of the canals (Adams et al. 2002). However, autoecology was implemented to integrate the environmental framework. The specimens were placed in micropaleontological slides and saved in Terra Nostra Earth Sciences Research collection.

Using faunal composition, a paleosalinity index was developed. The index weighs the relative salinity tolerances of the species present, ranging from high (positive values) to low (negative values) based on our current knowledge of their ecological requirements (Delorme 1989; Palacios-Fest 1994; Palacios-Fest et al. 2001). The equation used for the present study is:

SI = [3(percent *Limnocythere staplini*) + 2(percent *Cypridopsis vidua*) + percent *Candona patzcuaro*] - [percent *Physocypria pustulosa* + 2(percent *Herpetocypris brevicaudata*) + 3(percent *Ilyocypris bradyi*) + 4(percent *Darwinula stevensoni*)]

Results and Interpretations

Canals

Canal history is interpreted by examining three elements: lithostratigraphy, granulometry, and the fossil record. Ostracode criteria set by Delorme (1969, 1989), Forester (1983, 1986, 1988), Palacios-Fest (1994), and Adams et al. (2002) are combined with water chemistry data (Hem 1985) and previous canal reconstructions (Palacios-Fest 1994, 1997a, 1997b; Palacios-Fest et al. 2001) for the Phoenix area. Ostracode assemblages are used as a relative approach to determine the hydrogeochemical characteristics of the canals, based on the known ecological requirements of the species present.

Four granulometric fractions and grain-size frequencies were obtained during sample processing (Table K.1). Lithologically, the samples ranged from moderate yellowish brown (10 YR 5/4) to light brown (5 YR 5/6) gravelly silty sand to clay. The main mineralogical components were quartz, feldspars, biotite, muscovite schist, tufa, charcoal, and other rock fragments. Other minerals occurred less frequently.

Table K.1. Granulometry and Mineral Constituents of Canal Ostracode Samples, Red Mountain Freeway Project. (electronic table is on appended CD)

Paleontologically, the samples had low to moderately low numbers of ostracodes (1 to 176 specimens) and mollusk (1 to 22 specimens) abundances (Table K.2) Thirty-five samples out of 86 contained fossil ostracodes. Of these, 19 contained more than 10 specimens, capable of providing realistic environmental signals. Low to moderate abundance and low diversity characterized the assemblage. Total populations ranged from 1 to 176 specimens per sample, representing from 0.10 to 32.05 specimens per gram of sediment. Seven ostracode species were recovered: *Cypridopsis vidua*, *Ilyocypris bradyi*, *Limnocythere staplini*, *Candona patzcuaro*, *Herpetocypris brevicaudata*, *Physocypria pustulosa*, and *Darwinula stevensoni*. The latter three rarely occurred in the canals. However, complete carapaces of *D. stevensoni* dominated U:9:200, Feature 1, Sample 1815. *C. vidua*, *I. Bradyi*, and *C. patzcuaro* were the three more common species present in the canals. *L. staplini* occurred less frequently, but in U:9:200, Feature 1, Sample 1815, was abundant and mostly consisted of adult carapaces.

Table K.2. Taphonomy and Distribution of Ostracodes Recovered from Canal Samples, Red Mountain Freeway Project. (electronic table is on appended CD)

Based on the taphonomic features and total population, samples with less than ten specimens are here considered reworked. The interpretation of water chemistry is an approximation of the hydrochemical characteristics of input. Water chemistry ranged from type I (dilute) to type II (Ca-rich, dominated by Na^{+}, Mg^{2+}, Cl^{-} or Na^{+}, Mg^{2+}, SO_4^{2-}) (Eugster and Hardie 1978).

Considering faunal composition and associations, four distinct assemblages were recognized. Assemblage I was dominated by *Ilyocypris bradyi* (a streamflow indicator) and reflects dilute (type I) water chemistry. Assemblage II, dominated by *Cypridopsis vidua* (a slow flow indicator), reflects moderately saline (incipient type II) water chemistry. Assemblage III, dominated by *Limnocythere staplini* (a slow flow to still water indicator), reflects hypersaline (type II) water chemistry. Assemblage IV, dominated by *Candona patzcuaro* (a permanent, slow flow to still water indicator), reflects saline (type II) water chemistry. Frequently, *I. bradyi* is not the dominant species, even in Assemblage I, but its occurrence is related to episodes of water input, therefore its recognition as an assemblage. Also, the occurrence of *Candona patzcuaro* associated with either assemblage might indicate long-term standing water, especially if a stable adult/juvenile population is found.

Assemblage I marks water input and is commonly found in the lower strata of canals; however, its occurrence in higher strata is indicative of water pulses. Assemblage I inhabited U:9:169, Features 5 and 9, U:9:200, Features 13, 74, 91, and 121, U:9:201, Feature 7. Assemblage II represents episodes of slow flow stability; it was found in U:9:169, Features 5 and 9, and in U:9:200, Features 5, 13, and 91. Assemblage III indicates episodes of very slow to stagnant water conditions and high salinization; it was present in U:9:200, Features 1, 5, 13, 74, 91, and 121. Assemblage IV is similar to Assemblage III, but is almost monospecific or associated with *L. staplini*; it was found in U:9:169, Features 5 and 9, and U:9:200, Feature 1.

The hydrochemical evolution from Assemblage I to III or IV suggests increasing salinity from initial water input, then pulses of dilute water input and intervals of prolonged canal operation that allowed *C. patzcuaro* to settle. The faunal association is consistent with the water chemistry type I (dilute) and type II (Ca-rich, dominated by Na^{+}, Mg^{2+}, Cl^{-} or Na^{+}, Mg^{2+}, SO_4^{2-}) (Eugster and Hardie 1978). This association is similar to that found at Las Acequias (AZ U:9:44 (ASM)) and Pueblo Blanco (AZ U:9:128 (ASM)), reported previously (Palacios-Fest 1994, 1997a).

AZ U:9:169(ASM)

Feature 5

Feature 5 was a single large channel about 2 m wide and 1 m deep; sediments became finer upwards. No ostracodes were found in the lowest stratum. In the three strata analyzed above, abundances were low to moderately low (7–65 specimens) and assemblages were moderately diverse (3–5 species). *C. vidua*, *I. bradyi*, *L. staplini*, *C. patzcuaro*, and *H. brevicaudata* were found. *I. bradyi*. *L. staplini*, and *C. vidua* (Assemblage I) are dominant in Sample 1070, then *C. vidua* and *C. patzcuaro* (Assemblage II) dominate Sample 1071; finally, *C. patzcuaro* (Assemblage IV) dominates Sample 1072. The taphonomic parameters indicated moderately high fragmentation and abrasion that declined through time. Coating of some specimens (5 percent) was recorded Sample 1070. Authigenic mineralization or shell oxidation/reduction were not evident in the specimens. The A/J and C/V ratios showed that the faunal assemblage was self-perpetuated.

Thickness of the stratigraphic sequence suggested continuous water input. Decreasing grain-size suggested declining streamflow velocity. The faunal associations and taphonomic parameters showed that the canal initially had a population dominated by *I. bradyi* (Assemblage I), adapted to moderately saline water input. Despite the high relative abundance of *C. vidua* and *L. staplini* as it represents the initial water input, however, it is clear that water was not dilute. Based on the minimum salinity tolerance (mist) of *L. staplini* (500 mg l^{-1} of total dissolved solids, TDS) and the maximum salinity tolerance (mast) of *C. vidua* and *I. bradyi* (4000 mg l^{-1}), salinity of water input was somewhere in this range. A well-established suite of adults and juveniles of *I. bradyi* suggested the lower range.

Increasing salinity and decreasing streamflow were stressful for *I. Bradyi* and the species disappeared. Assemblage II replaced Assemblage I. The appearance of *C. patzcuaro* suggested prolonged, slow streamflow canal operation. The species maximum salinity tolerance (mast) of 5000 mg l^{-1} was probably not reached, as *C. vidua* dominated the environment, requiring lower salinity. As streamflow continued to decline and salinity increased near the end of canal operations, *C. patzcuaro* was the dominant species -Assemblage IV replaced Assemblage II. Regardless of the presence of *C. vidua* and *I. Bradyi*, water chemistry was probably hypersaline; *L, staplini* entered the canal. To date, no evidence of salinity greater than 4000 mg l^{-1} in Hohokam canals in the Phoenix basin has been recorded (Palacios-Fest 1994, 1997a, 1997b; Palacios-Fest et al. 2001). It is unlikely that water salinity exceeded this range at Feature 5. The paleosalinity index supports this interpretation.

Feature 9

Feature 9 was a single channel about 2.8 m wide and 1.1 m deep, with sediments coarsening upwards. Analyzed strata contained low to moderate sized populations (11–176 specimens) and had low diversity (3 species). Two species were dominant: *C. patzcuaro* (Assemblage IV) and *C. vidua* (Assemblage II). The former was most abundant (176 specimens) in Sample 1073 at the base of the feature; the latter was dominant in Sample 1074 above. The taphonomic features showed low fragmentation and abrasion (5–10 percent). Some stains in Sample 1074 reflected redox reactions. No coating or authigenic mineralization was evident. The A/J and C/V ratios indicated the faunal association established stability.

The thickness of canal fill suggested continuous, slow streamflow. A slight increase in grain size implied a subtle increase in water velocity. The faunal association and taphonomic parameters showed that the canal was initially dominated by *C. patzcuaro* (Assemblage IV). The sudden appearance of a large ostracode population suggested that Sample 1073 did not represent initial water input; instead, the canal must have reached stability before hosting this almost monospecific assemblage. Water salinity was high (close to 4000 mg l^{-1}), allowing *C. vidua* and *I. bradyi*.

As streamflow velocity increased, salinity declined, favoring *C. vidua* (Assemblage II). However, the presence of *L. staplini* indicated salinity remained relatively high. The paleosalinity index shows a subtle increase in salinity through time, contrary to the signal from changing assemblages. The reason for the difference is uncertain.

AZ U:9:200 (ASM)

Feature 1

Feature 1 was a medium-sized main canal. It was reengineered multiple times, stretching more than 7.2 m; the final channel was 2.6 m wide and 0.60 m deep. Thickness of canal strata suggested episodes of prolonged canal operation. Grain-size fluctuations indicated the canal was subject to frequent water discharge. Sediments fluctuated from gravelly sand to clay and showed several episodes of water input. A control sample from outside the feature, three early channel strata, and six strata from the final channel were analyzed. Control Sample 1802 was a silty clay loam and contained no ostracodes. Channel 1, Sample 1815, contained four ostracode species: *I. bradyi*, *L. staplini*, *C. patzcuaro*, and *D. stevensoni*; moderately low abundance (90 specimens) and low diversity characterized the sample. *L. staplini* (Assemblage III) dominates the faunal association. The taphonomic parameters show no to low fragmentation and abrasion (0 to 10 percent) but significant authigenic mineralization and coating (20 to 30 percent) and oxidizing stains. The A/J and C/V ratios suggested the faunal was well established. Channel 2 samples contained no ostracodes. Channel 3 was almost entirely unfossiliferous, except for the top stratum analyzed (Sample 1799). Two species, represented by very low abundance (1 and 2 specimens) were introduced at the end of the record: *C. patzcuaro* and *L. staplini*. Assemblage IV entered the canal. The taphonomic features showed no effects. The A/J and C/V ratios showed the faunal assemblage was reworked. Apparently, water moved so rapidly through this location of Feature 1 that ostracode populations could not become established.

Channel 1 was fed by saline water or it represented the terminal stage of canal operation, just before a new channel was excavated. Faunal Assemblage III and taphonomic features suggested that a *L. staplini*-dominated population was stable; therefore, the sample likely represented the final stage of streamflow. Water was moderately saline, as indicated by the co-occurrence of *L. staplini* (minimum salinity tolerance (mist) 500 mg l^{-1}) and *D. stevensoni* (mist 2000 mg l^{-1}).

Channel 2 experienced a fast flow discharge and a sudden and drastic decrease in streamflow velocity as shown both by the lithostratigraphic and granulometric diagrams. No ostracodes were recovered from this channel, confirming short canal operations. Streamflow was probably too fast to allow ostracodes to become established or to be preserved in the sediments.

Channel 3, the final channel, was also almost devoid of ostracodes. Grain-size and lithostratigraphic sequences suggested the canal was subject to punctuated, fast streamflow. The faunal assemblage dominated by *C. patzcuaro* (Assemblage IV) at the end of the record most likely reflects the terminal stage of canal operations. Water salinity might have exceeded 4,000 mg l^{-1}, as two high salinity tolerant species were the only types found in the upper most stratum analyzed, *C. patzcuaro* (200–5,000 mg l^{-1}) and *L. staplini* (500–75,000 mg l^{-1}). The paleosalinity index may not be a useful an indicator—only one sample contained ostracodes; however it showed highly saline conditions near the end of the record.

Feature 5

Feature 5 was a main canal about 3.50 m wide and 1.75 m deep. Earlier channels are not well defined due to excavation of final channel (Yost et al. 2000). Canal fill was massive and sediments coarsened upwards. Eight samples from arbitrary intervals were analyzed. Low abundance (2–15 specimens) and diversity (2–4 species) characterized the sequence. Six species were found in the canal: *C. vidua*, *L. staplini*, *C. patzcuaro, H. brevicaudata*, *P. pustulosa*, and *D. stevensoni,* but not more than four co-existed in any given. The taphonomic parameters showed no to low fragmentation and abrasion (0–5 percent). No other effects were evident. The A/J and C/V ratios indicated ostracodes established a community soon in the record. Assemblage III (Sample 1794) entered the canal and evolved into Assemblage II (Sample 1812) and Assemblage IV (Samples 1801,1797, and 1800).

The final channel was characterized by a thick stratigraphic sequence suggesting, low channel discharge that gradually increased in velocity. The faunal association and taphonomic features showed that water discharge introduced an Assemblage III population that evolved to an Assemblage II and then to Assemblage IV. Introduction of *L. staplini* together with *C. vidua* suggests moderately saline water input. Also, the presence of this assemblage reflected slow streamflow, consistent with the granulometric data.

Initial salinity was probably close to 4,000 mg l^{-1} (*C. vidua*'s mast). As canal operation proceeded, Assemblage II replaced Assemblage III. Water was more dilute, allowing settlement of species like *H. brevicaudata* (200–3,000 mg l^{-1}), and *P. pustulosa*, unable to tolerate salinity greater than 600 mg l^{-1}. Furthermore, these species prefer faster streamflow than *L. staplini*, consistent with increasing grain-size high in the canal. Streamflow continued to fill the canal, probably at greater velocities, but still slow enough to allow *C. patzcuaro* and *L. staplini* to settle—Assemblage IV was established. Towards the end of the record these were the only two species present, suggesting salinity rose beyond *C. vidua*'s maximum tolerance, but remained below *C. patzcuaro*'s mast (5,000 mg l^{-1}). The paleosalinity index is consistent with episodes of salinization and dilution.

Feature 13

Feature 13 was a main canal about 3.8 m wide and 1.1 m deep, consisting of two channels. The older channel was almost destroyed by the younger cut. The final channel had massive fill similar to Feature 5. Canal sediments were mostly silt; granulometric data indicated alternating episodes of increasing and decreasing streamflow. One sample from the first channel and six from the second channel were analyzed. Channel 1 was unfossiliferous. Channel 2 hosted a low abundance (1–6 specimens) and low diversity (3 species) of ostracodes. Five species were found in this canal: *C. vidua*, *I. bradyi*, *L. staplini*, *C. patzcuaro*, and *P. pustulosa*. Taphonomic parameters show lowed fragmentation and abrasion (5–10 percent) in the upper most stratum analyzed (Sample 1813); no other effects were recorded. The A/J and C/V ratios suggested the faunal population was well established in the latter part of the record. Assemblage III (Sample 1806) entered the canal and evolved into Assemblage II (Samples 1803 and 1813).

The faunal association and taphonomic parameters indicated the canal was subjected to at least two episodes of water input. The earlier discharge lasted for a short period and delivered no ostracodes to the system. Flow was suspended and then resumed. The latter cycle introduced an adult population of *L. staplini*, *C. patzcuaro*, and *P. pustulosa*—Assemblage III entered the canal, despite the occurrence of *P. pustulosa*. The paleosalinity index suggests saline conditions. Ostracodes probably did not settle in this canal until the final episodes of use, when a suite of adults and juveniles formed the population. Assemblage II replaced Assemblage III. Ostracodes are not abundant at any time and it is possible that the entire population was introduced, reflecting the water chemistry of the source, rather than evolution in the canal.

Feature 74

Feature 74 was a large, complex water control feature within Feature 1, a main canal. Sixteen natural stratigraphic levels when excavated from Feature 74; seven levels were analyzed for ostracodes. The sediments, fining upwards, ranged from silty sand to clay. Ostracodes were absent at the lower four strata. In strata where they were found, abundances (13–59 specimens) and diversity (four species) were moderately low. *I. bradyi*, *L. staplini*, *C. patzcuaro*, and *H. brevicaudata* were recovered. The taphonomic parameters showed low to high fragmentation and abrasion (5–50 percent); no other effects were evident. The A/J and C/V ratios showed that ostracodes had established a stable Assemblage IV population.

Continuous water input characterized the Feature 74. Two episodes of high water discharge are evident from the granulometric data. Coarse sand suggests fast flow and prevented ostracodes from settling. Ostracodes appear as flow decreased substantially, but are not abundant (13–59). *I. bradyi* and *H. brevicaudata* were introduced but did not establish a community. Faunal association and taphonomic parameters showed that *L. staplini* and *C. patzcuaro* were introduced and a stable population developed late in the features history. Assemblage IV suggested slow moving to stagnant water. Introduction of the two low salinity tolerant species (*I. bradyi* and *H. brevicaudata*) indicated salinity was lower than 3,000 mg l^{-1} (*H. brevicaudata*'s mast). The paleosalinity index is consistent with a moderate salinity environment.

Feature 92

Feature 92, a medium sized main canal, was reengineered multiple times; the final two channels were clear. Sediments alternated from gravelly loam to clay. No ostracodes were recovered from the eight samples analyzed. Apparently, frequent, strong pulses of water made the canal an unsuitable environment.

Feature 121

Feature 121 was a main canal leading to Feature 91, a reservoir. Two channels were evident, fine sediments characterize the fill. Fossils were found in both channels. The first channel held a sparse ostracode population (21 specimens) distributed among five species: *C. vidua*, *I. bradyi*, *L. staplini*, *C. patzcuaro*, and *P. pustulosa*. Taphonomic features showed low fragmentation and abrasion (5–10 percent), no other effects. The A/J and C/V ratios suggested the faunal association was stable. Assemblage III entered the canal.

Within the second channel, two strata held sparse ostracode populations (1–14 specimens) and had low diversity (1–3 species): *C. vidua*, *I. bradyi*, *L. staplini*, and *D. stevensoni*. Taphonomic parameters indicated low to moderately high fragmentation and abrasion (5–30 percent), no other effects were evident. The A/J and C/V ratios showed that when the second stratum was deposited, a stable ostracode population existed. A single valve near the top of the canal was likely reworked. Assemblage 1 dominated the second channel.

The lithostratigraphic and granulometric data suggested relatively fast flow, but the faunal association and taphonomic parameters did not support this evidence. Assemblage III dominated the early channel, suggesting a slow, saline flow. *L. staplini* established a community; other species were introduced or they represent incipient settling of a population. Despite the discrepancies, salinity was lower than 2,000 mg l^{-1} (*D. stevensoni*'s mast).

Channel 2 strata suggested at least two episodes of water input. Both were moderately fast, preventing ostracodes from settling. The first episode was short and allowed ostracodes to colonize the canal, as streamflow ceased or decreased substantially. *I. bradyi*, *C. vidua* and *L. staplini* were the only species present. Moderately saline water entered the canal, allowing Assemblage I (*I. bradyi*-dominated) to form a stable community. Salinity was probably greater than 2000 mg l^{-1} (*D. stevensoni*'s mast), but lower than 4,000 mg l^{-1} (*I. Bradyi*'s mast), as *D. stevensoni* is absent. Towards the end of the record, salinity decreased below *D. stevensoni*'s mast. The paleosalinity index also shows a dilute water trend.

AZ U:9:201 (ASM)

Feature 3

Feature 3 was a main canal about 2.75 m wide and 0.90 m deep (Yost et al. 2000). The lithostratigraphic and granulometric data suggested relatively fast flow, with an interval of no flow, probably desiccation. No ostracodes were recovered. Absence of ostracodes might have resulted from winter canal operations. Winter is a difficult time for juveniles to survive, however, adults may tolerate low temperatures and be transported into the site. No interpretation is warranted.

Feature 7

Feature 7 was a main canal formed by three channels, the older was not well defined. The last two were clear parabolas. Channel 1 was partially destroyed by Channel 2 and it is about 2.10 m wide and 0.65 m deep (Yost et al. 2000). Sediments in both channels were mostly fine (sandy silt to silty clay), except Sample 1104 of Channel 1, where silty sand dominates. Channel 1 was unfossiliferous. Channel 2 hosted a low to moderately high population (12–151 specimens) with low diversity (3 species); *C. vidua*, *I. bradyi*, and *C. patzcuaro* were present. Taphonomic features indicated low fragmentation and abrasion (5–15 percent), and low authigenic mineralization and coating (5–10 percent). The redox index showed strong oxidizing stains. The A/J and C/V ratios suggested the faunal association established an Assemblage IV community.

Channel 1 lithostratigraphic and granulometric data indicated continuous, moderately fast flow at. No ostracodes were recovered. No further interpretation is warranted. Channel 2 was dug into Channel 1; it was about 1.35 m wide and 60 cm deep. The faunal association and taphonomic features agreed with the lithostratigraphy and granulometry of the unit. Fine sediments indicated slow flow for a prolonged time, allowing *C. patzcuaro* to settle as an almost monospecific population. Salinity was moderately low, less than 4,000 mg l^{-1} (*I. Bradyi*'s mast). The paleosalinity index showed a similar trend

AZ U:9:222 (ASM)

Feature 3

Feature 3 is a main canal about 2.2 m wide and 0.9 m deep. The sediments, fining upwards, consist of silty sand to silty clay. Sample 1051 contained a few valves (nine specimens) of two species: *C. vidua* and *C. patzcuaro*. Taphonomic parameters showed low effects (fragmentation, abrasion, authigenic mineralization and coating) and a slight shell oxidation. The A/J and C/V ratios showed an entirely Assemblage IV juvenile population that did not reach maturity.

The gradual change from sandy silt to silty clay suggested moderately slow flow. The occurrence of a few ostracodes near the top of the feature indicated a community of *C. patzcuaro* was forming. Salinity was lower than 4,000 mg l^{-1}, given the abundance of juveniles and the occurrence of *C. vidua*. Since the sequence is not complete, it is not possible to advance any further interpretation.

Feature 6

Feature 6 at T-1 of U:9:222 (ASM) consisted of a single channel with two strata (Figure 151, center). Fine sediments (silty clay) characterized the sequence (Figure 151, right-center). The canal is unfossiliferous.

Feature 6 is a possible distribution canal, about 1.6 m wide and 0.5 m deep. The lithostratigraphic and granulometric data indicated a slow flow to still water environment. Lack of ostracodes cannot be explained, since this is an ideal environment for these organisms. No further interpretation is warranted.

Feature 10

Feature 10 is a lateral canal about 1.5 m wide and 0.3 m deep. Like Feature 6, this canal was characterized by slow flow to still water conditions. Again, ostracodes were missing. No further interpretation is warranted.

AZ U:9:200(ASM)

Feature 91, Reservoir

Feature 91, a reservoir, was at least 17 m wide and 3 m deep and had more than 20 sedimentary episodes. Seventeen samples from three locations were analyzed, representing eight reservoir strata and a control sample (Tables K.3 and K.4). Samples were collected in three locations: the northern edge (seven samples), the center (six samples), and the southern edge (three samples). The sediments alternated from gravelly loam to silty clay. Lithostratigraphic and granulometric data indicated the reservoir was repeatedly filled. The faunal association and taphonomic parameters indicate the reservoir held water for prolonged periods All samples, except the control, contained ostracodes.

Table K.3. Granulometry and Mineral Constituents of Reservoir Ostracode Samples, Red Mountain Freeway Project. (electronic table is on appended CD)

Table K.4. Taphonomy and Distribution of Ostracodes Recovered from Reservoir Samples, Grouped According to Stratum, Feature 91, U:9:200, Red Mountain Freeway Project. (electronic table is on appended CD)

The northern samples had low (17–35 specimens) abundance, but high diversity (seven species). Species included: *C. vidua*, *I. bradyi*, *L. staplini*, *C. patzcuaro*, *H. brevicaudata*, *P. pustulosa*, and *D. stevensoni*. Taphonomic features showed low fragmentation and abrasion (5–10 percent) and no other effects. Initially, Assemblage II entered the reservoir, evolved into

Assemblage III and returned to Assemblage II. The A/J and C/V ratios indicated that through most of the record, the faunal population was stable.

The northern set of samples included deposits that reflected the early history of the inlet entering the reservoir (Strata 4p, 4q, 4r, and 4s). Dilute water introduced *D. stevensoni* to the reservoir; Assemblage I was established. The reservoir remained active for a prolonged period, as *D. stevensoni* flourished and *H. brevicaudata* entered the reservoir. The former requires six months to complete its life cycle (Palacios-Fest 1994); the latter requires at least three months, since it prefers permanent water bodies (Forester 1991). When Strata 4p and 4r were deposited, the reservoir was still or slow flowing. Salinity declined below 2,000 mg l^{-1}. The paleosalinity index showed a similar trend of dilute input. Coarse-grained sediments (Strata 4q and 4s) represented pulses of water input and contained no ostracodes. Stratum 4s represented a large input event; when water discharge stopped; a pond-like environment formed. Afterward, conditions were more saline and *D. stevensoni* disappeared. *L. staplini*, *C. patzcuaro*, and *C. vidua*, became established; the community resembled Assemblage III. Salinity probably rose over 2000 mg l^{-1} (*D. stevensoni*'s mast), but did not exceed 4,000 mg l^{-1} (*C. vidua*'s mast). *C. patzcuaro* did not complete its life cycle; no adults were recovered, indicating short-term water pulse into the reservoir. Finally, granulometric data showed a new pulse of water input (Strata 4c and 4d); no ostracodes were recovered.

Samples from the center of the reservoir represent the second manifestation of the reservoir. Overall, samples had low to moderately low (2–58 specimens) abundances and diversity was high (six species). Species included *C. vidua*, *I. bradyi*, *L. staplini*, *C. patzcuaro*, *P. pustulosa*, and *D. stevensoni*. Taphonomic parameters showed low to high fragmentation and abrasion (5–30 percent), low authigenic mineralization (5–10 percent), and no coating and some oxidizing stains were recorded by the redox index. The A/J and C/V ratios indicated the faunal association was introduced and established a community. Assemblage III entered and, with some fluctuations, dominated the reservoir's central history.

Fine sediments at the base (Stratum 4b) suggested slow flow to still water conditions. Faunal association and taphonomic features indicated that hypersaline waters filled the reservoir. A monospecific Assemblage III (*L. staplini*-dominated) implied salinity exceeded that of other salinity tolerant species like, *C. patzcuaro* (5000 mg l^{-1} mast). Gradual water input (shown by faunal diversity, taphonomy, and granulometric data) allowed other species to settle. Assemblage II briefly replaced Assemblage III, but then returned to saline conditions and Assemblage III dominated the rest of the central reservoirs history. While Stratum 4c1 was being deposited, salinity ranged from 600 mg l^{-1} (*P. pustulosa*'s mast) to 2,000 mg l^{-1} (*D. stevensoni*'s mast), despite *L. staplini* (Assemblage III) dominating the environment. Fast flow entered the reservoir (Stratum 4c2), no ostracodes settled. The occurrence of highly fragmented and abraded specimens Stratum 4d implied that streamflow was strong just before the unit accumulated. As flow velocity slowed, ostracodes colonized and Assemblage III dominated the reservoir, suggesting the water pulse was brief and the pond returned to slow flow to still conditions. Salinity was close to 4000 mg l^{-1} (I. *Brady*'s mast). Hypersaline conditions (>5,000 mg l^{-1}) closed this episode, as shown by the monospecific Assemblage III in Stratum 4e.

Samples from the southern edge had low abundances (5–8 specimens) and was not diverse (three species). Ostracode species included *C. vidua*, *I. bradyi*, and *L. staplini*. Taphonomic features showed low fragmentation and abrasion (5–10 percent), and occasional low authigenic mineralization (5 percent) and oxidizing stains. The A/J and C/V ratios suggested the faunal association was introduced, but did not fully develop. Assemblage III entered the southern edge of the reservoir and was then replaced by Assemblage II. Dilute water allowed *I. bradyi* and *C.*

vidua to enter and become established in the reservoir. Salinity dropped below 4,000 mg l^{-1} towards the end of the record. It is possible that the final stage of desiccation was destroyed by modern activity in the area.

When ostracode summary data are grouped according to strata (Table K.5), differences between sample locations become apparent, as does the reservoirs history. As stated, the inlet was examined only in the northern part of the reservoir. The earliest strata (4p and 4r) reflected the most dilute (freshest) water in the record, dominated by Assemblage I. Relatively high valve concentrations in Stratum 4p reflected a stable community. After the reservoir was "remodeled", water levels were probably low, creating saline conditions and inhibiting ostracode growth, as Stratum 4b was deposited. The northern edge of the feature might have been deeper, allowing a larger population. Stratum 4c was problematic: the sample from the center of the reservoir had the greatest abundance of ostracodes, while the samples from the edges had none. Perhaps water levels were low, but persistently maintained with input, allowing a stable population in the center of the feature, but keeping the shores uninhabitable. If so, this situation was maintained through the remainder of the reservoir's history, with occasional periods of freshening.

Table K.5. Selected Ostracode Indices, Grouped According to Stratum, Feature 91 (a Reservoir), U:9:200, Red Mountain Freeway Project. (electronic table is on appended CD)

Discussion and Conclusions

The Red Mountain Freeway canals provide important ecological information to understanding Hohokam activity in the Phoenix Basin. In this sense, these canals were similar to the Pueblo Blanco canals of the Scottsdale Canal System (Palacios-Fest 1997a). They differ in that the Red Mountain data indicated prolonged episodes of salinization whereas Pueblo Blanco canals suggested more frequent intervals of salinization and dilution of canal waters. The estimated salinity ranges documented in this study were consistent with the first hydrogeochemical reports from Hohokam canals (Palacios-Fest 1994, 1997b). Indeed, the estimated values suggested salinity was usually greater than 2000 mg l^{-1} (*D. stevensoni*'s mast). More frequently, salinity ranged between 2,000 and 4,000 mg l^{-1} (*C. vidua* and *I. Bradyi*'s mast), and occasionally exceeded 5000 mg l^{-1} (*C. patzcuaro*'s mast), allowing the high salinity tolerant *L. staplini* to establish a monospecific Assemblage III. Rarely were waters very dilute (below 600 mg l^{-1}; *P. pustulosa*'s mast). Ostracode paleoecology and estimated salinity ranges are consistent with Hem's (1985) water chemistry analysis of the Salt River in the Phoenix basin.

Variations in ostracode assemblages were not as dramatic as those of Pueblo Blanco (Palacios-Fest 1997a). Assemblages III and IV were the most frequent and constant clusters. In several cases, Assemblage III entered the canals, suggesting canal operations occurred in late spring-early summer. As for Pueblo Blanco, canal operation may have occurred from late winter to early summer, before monsoon season. This pattern may explain episodes of dilute water discharge late in the Pueblo Blanco canal history.

Results of this study were similar to those from the URS Fire Station Project at the Sky Harbor International Airport (Palacios-Fest et al. 2001). The two studies suggest a period of increasing salinization of soils. Are the sites contemporaneous? Radiocarbon dates from the two locations may elucidate this question.

Shell chemistry analysis of the Mg/Ca and Sr/Ca ratios will be critical to establishing water temperature and salinity. The former is relevant to determining the time of year the canals were in use and will provide a comparison to the first estimates made from Hohokam canals (Palacios-

Fest 1997b). The latter is necessary to quantify salinity estimates. To date, Palacios-Fest (1997b) salinity estimates are the only source of information regarding water salinity from Hohokam canals in the Phoenix basin. Confirmation or rejection of these results are important for future research.

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