Archaeological Investigations for the City of Mesa Sound Barrier on McKellips Road at the Mesa Terrace Mesa, Arizona

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POLLEN ANALYSIS

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This section presents the pollen analysis results from 11 sediment samples from two prehistoric canals identified by the MRSB project. Six samples from canal Feature 3 and five samples from canal Feature 5 represent profiles in trenches that cut obliquely across the canal alignments.

Two previous canal pollen investigations were completed southwest of the project area near the Hohokam sites of La Cuenca del Sedimento and Las Acequias. Fish (1987) analyzed 57 pollen samples from primarily mid-channel fill sediments and Gish (1989) analyzed 69 samples from canal bank and base sediments. These two studies and other canal pollen investigations (McLaughlin 1976; Nials and Fish 1988; Smith 1995) have shown that the abundance and composition of water-deposited pollen is influenced by the water capacity of canals and flow velocities. Pine pollen and the absolute abundance of pollen has been correlated with silt- to clay-sized sediments. Gish (1989) found small feeder canals were characterized by pollen from local plant communities, and larger main and distribution canals were characterized by more regional pollen derived from forests and riparian communities within the Salt River drainage basin. Analysts have also interpreted seasons of canal operation from pollen data, based on the representation of spring and summer flowering taxa (Fish 1987:166; Gish 1989:309; Nials and Fish 1988; Smith 1995). The pollen results from the McKellips Road canal samples are examined for similar trends.

Methods

Sample bag contents were thoroughly mixed and 20 cc subsamples extracted. A known concentration (25,084 grains) of tracer spores (*Lycopodium*) was added to each sample to estimate pollen concentration. Samples were treated with 10 percent hydrochloric acid (to remove carbonates), screened (.18 mm mesh), and treated for approximately 20 hours with hydrofluoric acid (to dissolve silicates). After the hydrofluoric step, samples were floated in zinc bromide (specific gravity 1.9), followed by acetolysis (to reduce organics).

Pollen assemblages were identified by counting slide transects at 400x magnification to a 200-grain pollen sum, if possible, then scanning the entire slide at 100x magnification to record additional taxa. Aggregates (clumps of the same taxon) were counted as one grain per occurrence, and the taxon and size recorded separately. The absolute abundance of pollen in each sample (pollen concentration) was estimated by relating the sample pollen count to the sample tracer count, calculated by the following formula:

$$PollenConcentration = \frac{\frac{PollenCounted}{TracersCounted} * TracerConcentration}{SampleVolume}$$

Pollen concentration is expressed as the number of pollen grains per cubic centimeter of sample sediment, abbreviated grains/cc. Concentrations in water-deposited sediments tend to reflect flow regimes. Turbulent high energy flows deposit sandy units, characterized by low pollen concentration values; low energy flows deposit silts and clay, which generally contain high concentrations of pollen. In this analysis, sample pollen concentrations are compared to the percent sand, silt, and clay analyzed from soil samples taken from the same stratum as the pollen samples. The pollen data are also evaluated using pollen percentages, which normalize sample counts to 100 ([taxon counted/pollen sum] *100), so that each taxon is expressed as a proportion of the sample pollen sum.

Pollen Results and Interpretations

Figure 15 shows the pollen percentage data from the two canal profiles graphically with samples ordered from the top of sections (zones 5 and 6) to the base (zone 1); Table 5 documents the data. The sediments from the two canals were different with Feature 3 characterized by more sand and Feature 5 by finer-grained silt to clay sediments. The sediment contrasts are reflected in the pollen results, especially the significantly greater pollen abundance (pollen concentration) in Feature 5 compared to Feature 3. Pollen concentrations in Feature 5 ranged from 4,400 to 66,500 grains/cc, and in Feature 3, concentrations were less than 5,600 grains/cc.

The pollen results from both canals include spring and summer flowering taxa, suggesting the canals flowed spring and summer. In Feature 3, the lowest zones 1, 2, and 3 are characterized by high Cheno-Am pollen, which may reflect a primarily local or canal bank vegetation source. A local pollen source in the lowest zones could result from low summer water levels. Cattail pollen in all zones in Feature 3 suggest slow water or pools during the summer. Zones 4, 5, and 6 in Feature 3 contained more regional pollen from taxa that pollinate during the spring (juniper and alder) and early summer (pine and oak), compared to the lower zones. The greater representation of regional pollen could indicate more water flowing during deposition of the upper zones. In the top zone 6, cattail pollen was high at 16 percent suggesting slow water during mid-summer.

The results from Feature 5 were characterized by higher pine percentages than Feature 3, which suggests more water flowing in Feature 5 during the early summer; however, higher pine in Feature 5 may also relate to the siltier sediments. The bottom zones in Feature 5 yielded high Cheno-Am percentages, which may represent local canal-side vegetation, and cattail pollen was represented in zones 1 through 4 suggesting low summer flows or pools. Zones 3 and 4 were distinct with local spring-flowering trees represented (mesquite, palo verde, ocotillo), and high pine pollen (2–3 percent).

Economic pollen types present in both canals were maize, cotton, cholla, and other cacti (includes saguaro). Both canals probably watered maize and cotton fields. Fish (1987) and Gish (1989) found maize pollen in all canal types (mains, distribution, laterals, feeders) in the system west of Las Acequias, and cholla was present in all types, but less frequently. Cotton pollen was rare, however, with only four occurrences of cotton pollen out of a total 126 samples analyzed (Fish 1987; Gish 1989). The two samples with cotton pollen from the 11 samples analyzed here suggest cotton fields along both canals. The cholla representation is high in both canals, and may reflect either thriving cholla communities along the slopes of the Mesa Terrace, or cholla cultivation along canal banks, as suggested by Gish (1989:331) and Smith (1995:116,117).

OSTRACODE ANALYSIS

Manuel R. Palacios-Fest

Canal ostracode analysis is increasingly proving to be a powerful tool for geoarchaeological studies. Ostracodes are microcrustaceans provided with a calcareous carapace, whose physical and chemical characteristics allow them to preserve well into the geologic record. Due to their diversity and abundance these organisms are good environmental indicators of prehistoric canals. To date, ostracodes have

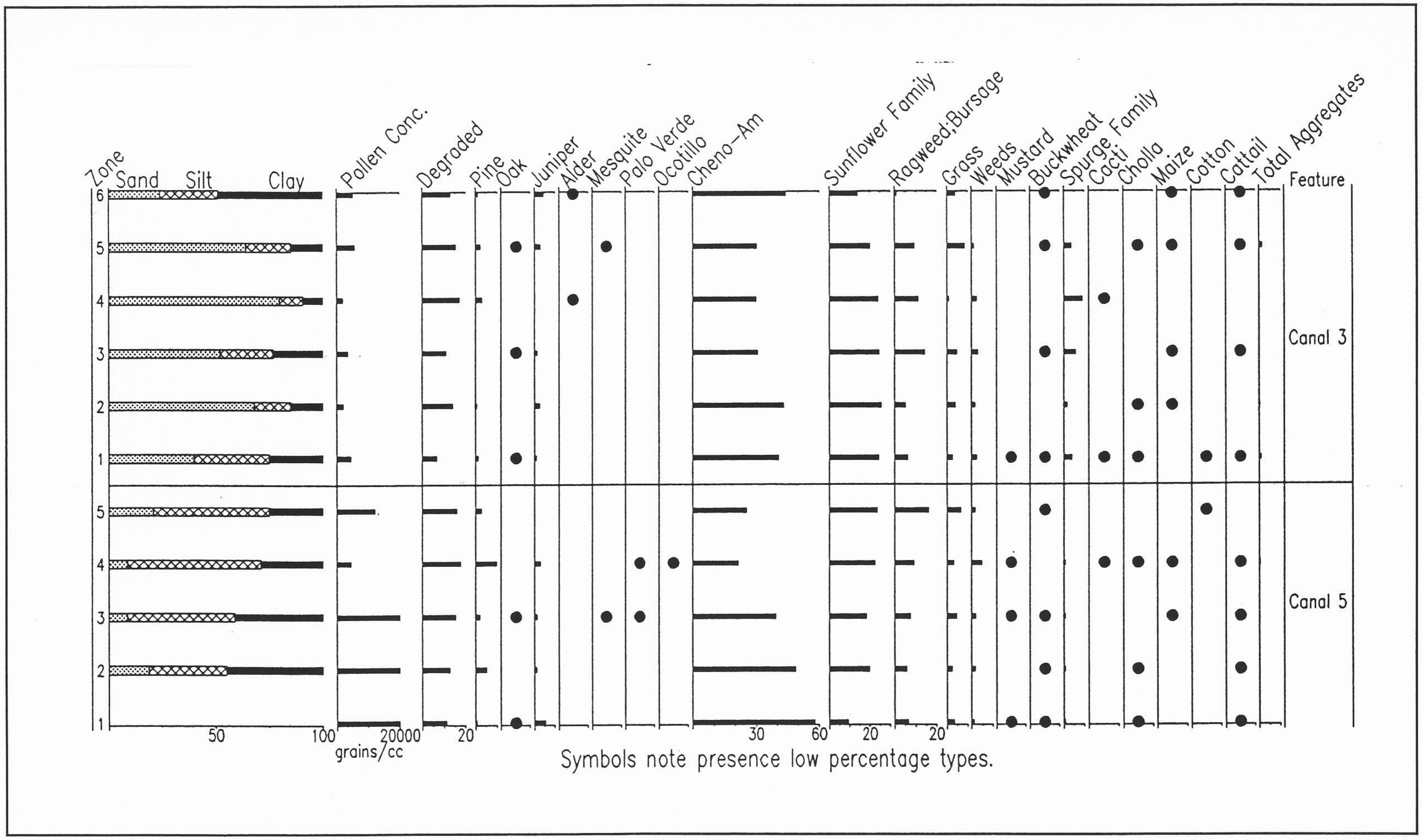

Figure 15. Canal sediment and pollen percentage data.

Table 5. Canal Samples Pollen Percentage Data. (Page 1 of 2)

Canal Feature:		3	3	3	3	3	3	5	5	5	5	5
Specimen No.		47	53	54	41	56	48	22	19	15	13	16
Zone		6	5	4	3	2	1	5	4	3	2	1
Sediment Type		Clay	Sandy Loam	Loamy Sand	Sandy Clay Loam	Sandy Loam	Loam	Silt Loam	Silty Clay Loam	Silty Clay	Clay	Loamy Clay
Sand/Silt/Clay %		24/27/49	64/21/15	80/11/9	52/25/23	68/17/15	40/35/25	21/54/22	9/62/29	9/50/41	19/36/45	
Tracers (initial conc. 25,084 grains; sample 20 cc)		56	48	87	76	117	66	22	70	8	4	4
Pollen Sum		230	216	134	212	201	232	213	243	247	212	204
Pollen Conc. gr/cc		5,151	5,644	1,932	3,499	2,155	4,409	12,143	4,354	38,723	66,473	63,964
Taxa Richness		11	16	10	13	12	18	12	19	19	14	14
Environment & Pollination Season	**Taxa**											
	Degraded	13.0	15.3	17.2	10.8	13.9	6.5	16.0	17.7	15.4	12.7	11.3
	Unknown	0.9	0.0	1.5	2.4	1.0	3.4	1.9	1.2	2.0	0.0	0.0
	Pine	0.9	1.9	3.0	0.0	0.0	1.3	2.8	8.2	2.0	2.8	0.0
Regional Summer	Pinyon Pine	0.0	0.5	0.0	0.0	0.5	0.0	0.0	1.6	0.0	2.4	0.5
	Oak	0.0	1.4	0.0	0.5	0.0	0.4	0.0	0.0	0.8	0.0	0.5
	Sagebrush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
	Juniper	4.3	2.8	0.0	1.4	2.5	0.9	0.0	2.9	1.2	0.9	5.4
Regional Spring	Mormon Tea	0.4	0.5	0.7	0.0	0.5	0.0	1.4	2.1	1.6	0.5	1.5
	Alder	0.4	0.0	X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mesquite	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Local Spring Trees	Paloverde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.4	0.0	0.0
	Ocotillo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	Tidestroemia	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
	Cheno-Am	43.9	30.1	29.9	30.7	42.8	40.5	25.4	21.4	39.3	48.6	57.8
	Sunflower Family	13.9	19.9	23.9	24.5	25.4	24.1	23.5	22.2	18.2	19.8	9.3
	Ragweed;Bursage	0.9	9.3	11.2	14.2	5.0	6.0	16.0	9.1	7.3	5.7	6.4
Local Shrubs, Herbs & Weeds Flowering Season Spring-Early Fall	Grass	3.9	8.3	0.7	4.7	4.0	2.6	6.6	3.3	4.5	2.4	3.4
	Spiderling	0.0	0.0	0.0	1.9	1.0	0.4	0.9	3.3	0.4	0.9	1.0
	Summer Poppy	0.0	0.0	0.0	0.0	0.0	0.9	0.0	X	0.4	0.0	0.0
	Globemallow	0.0	0.9	2.2	0.9	0.5	0.9	0.5	1.2	0.8	0.5	0.0
	Mustard	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.8	1.2	0.0	0.5
	Buckwheat	0.4	0.9	0.0	0.5	0.0	1.3	2.8	0.0	1.2	1.9	0.5

Table 5. Canal Samples Pollen Percentage Data. (Page 2 of 2)

Canal Feature:		3	3	3	3	3	3	5	5	5	5	5
Specimen No.		47	53	54	41	56	48	22	19	15	13	16
Zone		6	5	4	3	2	1	5	4	3	2	1
Environment & Pollination Season	**Taxa**											
	Evening Primrose	0.0	0.0	0.0	0.0	0.0	X	1.4	0.0	0.0	0.0	0.0
	Spurge Family	0.0	3.7	9.0	5.7	1.5	3.9	0.0	0.4	0.4	0.5	0.5
	Cattail	16.1	2.3	0.0	0.5	0.0	1.3	0.0	0.4	2.0	0.5	1.5
	Cacti: includes Saguaro, Hedgehog et al.	0.0	0.0	0.7	0.0	0.0	0.9	0.0	0.8	0.0	0.0	0.0
Cacti & Cultigens	Cholla	0.0	X	0.0	0.0	0.5	0.4	0.0	0.4	0.0	X	X
	Maize	0.9	0.5	0.0	0.9	0.5	0.0	0.0	X	X	0.0	0.0
	Cotton	0.0	0.0	0.0	0.0	0.0	X	0.5	0.0	0.0	0.0	0.0
Exotic	Filaree;Crane's Bill	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total Aggregates	0.0	1.4	0.0	0.0	0.5	0.9	0.0	0.4	0.0	0.0	0.0
	Cheno-Am Aggregates	0	3(25)	0	0	0	2(6)	X(>100)	1(100)	0	0	0
	Maize Aggregates	0	0	0	0	1(3)	0	0	0	0	0	0
	Trilete Spores	0	3	0.1	2	1	0	6	147	1	0	0

received little attention as geoarchaeological tools (Forester 1987; Hodell et al. 1995; Palacios-Fest n.d., 1994, 1997). Occasionally, ostracodes have also been used to interpret modern urban drainages (Taylor 1991). Since 1989, Palacios-Fest (n.d., 1989, 1994, 1995, 1997) has focused on Hohokam irrigation canals to find evidence of canal hydraulics, seasonality, and operation based on ostracode faunal composition and geochemical signature.

Despite numerous efforts to elucidate Hohokam canal operations, many questions remain unanswered. For example, did the Hohokam have one or two agricultural cycles? If it were one cycle only, was it during the winter-spring or summer-fall season? If it were two cycles, were they year round or last only for a few months of each season? These conflicting questions reflect the need for further research in this field of micropaleontology to understand the role of ostracodes as paleoenvironmental indicators of human activity.

Ostracodes' Biology

Ostracodes are distinguished from other crustaceans not only in their microscopic size but more importantly in having a calcite carapace. The carapace may vary widely in shape (elongate, subrectangular, trapezoidal, subtriangular, and so forth). Their size is also variable (.5 mm to >2 cm), but adults usually range from .7 to 5 mm. Ostracode lifespans range from a few weeks (4–6; e.g., *Limnocythere staplini*) to over a year (e.g., *Darwinula stevensoni*). Their life-cycle entails eight to nine molting stages to become adults (Pokorný 1978). Among other characteristics, ostracode carapaces consist of two valves connected by a dorsal hinge (of great taxonomic significance), which the organisms operate by adductor muscles (Pokorný 1978). These muscles are attached to the valves approximately at the middle of the anterior half. The patterns left by the muscle scars are also of taxonomic significance.

Continental ostracodes are subject to frequent environmental changes, hence, the species may be adapted to eurytopic (broad environmental spectrum) or stenotopic (limited environmental spectrum) conditions (Delorme 1969). Wide tolerance to temperature (eurythermic) and/or salinity (euryhaline) allow some species to survive the extreme conditions often met by the prehistoric irrigation canals of the Southwest. In contrast, species restricted to a narrow range in temperature (stenothermic) and/or salinity (stenohaline) variations will survive better in stable environments (i.e., deep lakes, year-round operating canals). They may even live in undersaturated waters (like peats) but their valves will not preserve in the geologic record.

By using the information provided by ostracode paleontology and taphonomy it is possible to propose canal hydraulics and seasonality. Presence/absence patterns, species total and relative abundance, and potential assemblage associations allow an interpretation of environmental changes. Research on canal ostracodes offers a unique opportunity to explore the significance of these organisms to study human activity along riverain areas, where many civilizations have developed agricultural systems. The purpose of this study is to analyze and reconstruct the canal paleoecology based on ostracode assemblages from two prehistoric canals (Features 3 and 5) along McKellips Road.

Canal Stratigraphy

Table 6 summarizes the canal and sample identification by individual canal, stratigraphic position of samples within canals, and sediment type and color. Canal stratigraphy is the result of sediment load and flow regime. The sound barrier canal sediments consisted of gravelly sand to clay suggesting that controlled streamflows entered the canals. The depositional sequences recorded from the sound barrier

Table 6. Ostracode Sample Identification, with Characteristics.

NRI Sample	Feat.	Zone	Description	Lithology (%) Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Munsell Color	Texture
9-3-1	3	1	Gravelly silty clay	10	5	5	5	25	50	5YR5/6:5YR6/4	Friable
36-3-2	3	2	Silty clayey sand	0	5	10	45	15	25	10YR5/4:5YR3/4	Friable
6-3-3	3	3	Gravelly sandy clay	5	5	10	10	30	40	5YR5/6:5YR6/4	Friable
44-3-4	3	4	Gravelly sand	10	10	25	15	25	15	10YR5/4:5YR3/4	Friable
40-3-5	3	5	Gravelly clay	5	0	5	5	10	75	10YR5/4:5YR3/4	Compacted
38-3-6	3	6	Clay	0	0	0	5	10	85	10YR5/4:5YR3/4	Compacted
10-5-1	5	1	Gravelly silty clay	5	0	0	5	10	80	10YR5/4:5YR3/4	Friable
3-5-2	5	2	Sandy silty clay	0	0	5	10	10	75	5YR5/2:10YR5/4	Friable
7-5-3	5	3	Silty clay	0	0	0	5	10	85	5YR5/6:5YR4/4	Compacted
31-5-4	5	4	Clay	0	0	0	0	5	95	10YR5/4:5YR3/4	Compacted
32-5-5	5	5	Clay	0	0	0	0	5	95	5YR5/6:5YR4/4	Compacted

samples were mostly massive. Relatively finer sediments occur in these canals than those observed elsewhere (Palacios-Fest 1997).

Lithologically, Feature 3 consists of gravelly silty or sandy clays occasionally alternating with silty clayey sand or clay (Table 6). Six microstratigraphic units (earlier referred to a "zones") were recognized (Figure 9). Feature 5 consists of upward-grading sediments ranging from gravelly silty clay to clay (Table 6). Five microstratigraphic units were recognized (Figure 12).

Materials and Methods

Eleven sediment samples from Features 3 and 5 were analyzed for ostracode content (Table 6). Sampling intervals within canals were approximately 20 cm. Of these samples, seven contained ostracodes ranging from extremely rare (<5) to very abundant (between 500 and 1,000). The data were used to reconstruct individual canal history, to correlate equivalent strata between both features, and to define periodicity (seasonality) of canal operation during Hohokam occupation.

Samples were prepared using Palacios-Fest 's version of the protocol described by Forester (1991). Sediment residuals were analyzed using a low power stereoscopic microscope. Routine micropaleontological study of all seven fossiliferous samples was conducted to determine fossil content and faunal assemblages. Total and relative abundance were recorded. Due to the small sample size characteristic of these flowing systems, taphonomic features were used to establish origin of specimens (Delorme 1989; Forester 1988). The degree of fragmentation, encrustation, coating, abrasion, and a relative reduction/oxidation (Red-Ox) index, as well as the adult:juveniles and the carapaces:valves ratios were used to define sample reliability. Based upon species abundance, a paleosalinity index was used to establish the canal operation history (Palacios-Fest 1994, 1997). The paleosalinity index (SI) was derived from the equation:

SI = (3(% *L. staplini* + % *C. beaconensis*) + 2(% *C. patzcuaro*) + (% *C. vidua*)) - ((% *I. bradyi*) + 2(% *C. ophthalmica*) + 3(% *D. stevensoni*))

Table 7. Generalized Environmental Conditions Controlling Ostracodes Present at the Sound Barrier.

Species	Habitat	Permanence	Temperature (°C)	Total Dissolved Solids (TDS)	Chemistry (Eugster and Hardie 1978)
Limnocythere staplini	Lake, pond, gentle stream	Ephemeral (~1.5 months) or permanent	Eurythermic (8-30°C)	500-75,000 ppm	Ca^{2+}-rich / HCO_3^--poor
Cyprideis beaconensis	Lake, pond, stream	Permanent or ephemeral (+3 months)	Eurythermic (13-28°C)	1000-40,000 ppm	Ca^{2+}-rich / HCO_3^--poor
Candona patzcuaro	Lake, spring, pond, stream	Permanent or ephemeral (+3 months)	Eurythermic (8-30°C)	200-5000 ppm	Ca^{2+}, (Mg^{2+}), HCO_3^--rich to Ca^{2+}-rich / HCO_3^--poor
Cypridopsis vidua	Spring, pond, lake, stream	Permanent or ephemeral (+3 months)	Eurythermic (8-30°C)	100-4000 ppm	Ca^{2+}, (Mg^{2+}), HCO_3^--rich to Ca^{2+}-rich / HCO_3^--poor
Ilyocypris bradyi	Stream, spring	Permanent, maybe ephemeral	Eurythermic (8-25°C)	100-4000 ppm	Ca^{2+}, (Mg^{2+}), HCO_3^--rich to Ca^{2+}-rich / HCO_3^--poor
Cypria ophthalmica	Lake, pond, gentle stream	Permanent, maybe ephemeral	Stenothermic (15-25°C)	50-5000 ppm	Ca^{2+}, (Mg^{2+}), HCO_3^--rich to Ca^{2+}-rich / HCO_3^--poor
Darwinula stevensoni	Lake, pond, stream	Permanent or ephemeral (+6 months)	Stenothermic (15-25°C)	50-2000 ppm	Ca^{2+}, (Mg^{2+}), HCO_3^--rich to Ca^{2+}-rich / HCO_3^--poor

The index weights species with incrementally higher salinity tolerances positively and weights species with incrementally lower salinity tolerances negatively. *L. staplini* and *C. beaconensis* are assigned the same index weight since both represent very similar conditions, except for lifespan. The latter requires longer time to mature than the former one.

Ostracode Results

Micropaleontology

Tables 7 and 8 summarize the species recorded in the MRSB canals and the environmental conditions controlling their occurrence. Low diversity and generally low abundance was recorded in these canals. Of the seven species present, *Candona patzcuaro* was the commonest, all other species — *Limnocythere staplini, Cyprideis beaconensis, Cypridopsis vidua, Ilyocypris bradyi, Cypria ophthalmica* and *Darwinula stevensoni* — occurred occasionally throughout the record. Table 7 shows that most of these species tolerate a wide range of environmental variation in water pathways from type I (dilute) to type II (Ca-enriched with high concentrations of Na^+, Mg^{2+} and SO_4^{2-}) of Eugster and Hardie (1978). Based upon Palacios-Fest (n.d.) previously established Assemblages I (*L. staplini*-dominated), II (*L. staplini/C. patzcuaro*-co-dominated) and III (*C. patzcuaro*-dominated) were recognized from these canals. Other species were also significant to establish the paleoenvironmental trend observed in each canal.

Feature 3, consisting mostly of gravelly fine sediments (from sand to clay), contained four species: *L. staplini, C. patzcuaro, C. vidua* and *I. bradyi*. Poor diversity and abundance characterize this canal. Abundance ranged from very rare (5–10 specimens) to abundant (100–500). *L. staplini* and *C. patzcuaro* dominated this canal. Zone 1 and 4 held no fossils. Zone 2 and 3 had very rare ostracodes (*C.*

Table 8. Ostracode Species Total and Relative Abundance and Salinity Index.

Sample:	NRI-9-3-1	NRI-36-3-2	NRI-6-3-3	NRI-44-3-4	NRI-40-3-5	NRI-38-3-6
Feature	3	3	3	3	3	3
Zone	1	2	3	4	5	6
Bulk Wt (g)	42.1	52.33	42.65	46.82	53.38	62.75
Residual Wt (g)	3.25	24.81	8.8	28.89	2.17	1.46
Ostracodes/g	0	0.2	0.14	0	3	0.3
Population	0	10	6	0	148	19
# *L. staplini*	0	0	0	0	63	1
% *L. staplini*	0	0	0	0	43	5
# *Cy. beaconensis*	0	0	0	0	0	0
% *Cy. beaconensis*	0	0	0	0	0	0
# *C. patzcuaro*	0	10	6	0	67	13
% *C. patzcuaro*	0	100	100	0	45	68
# *C. vidua*	0	0	0	0	12	3
% *C. vidua*	0	0	0	0	8	16
# *I. bradyi*	0	0	0	0	6	2
% *I. bradyi*	0	0	0	0	4	11
# *C. ophthalmica*	0	0	0	0	0	0
% *C. ophthalmica*	0	0	0	0	0	0
# *D. stevensoni*	0	0	0	0	0	0
% *D. stevensoni*	0	0	0	0	0	0
Salinity Index	0	100	100	0	157	47
Sample:	NRI-10-5-1	NRI-3-5-2	NRI-7-5-3	NRI-31-5-4	NRI-32-5-5	
Feature	5	5	5	5	5	
Zone	1	2	3	4	5	
Bulk Wt (g)	50.48	44.21	43.51	55.63	46.64	
Residual Wt (g)	3.81	0.72	0.96	0.12	0.16	
Ostracodes/g	0.1	5	21	0	0	
Population	4	210	930	0	0	
# *L. staplini*	0	138	241	0	0	
% *L. staplini*	0	66	26	0	0	
# *Cy. beaconensis*	0	5	0	0	0	
% *Cy. beaconensis*	0	2	0	0	0	
# *C. patzcuaro*	4	63	530	0	0	
% *C. patzcuaro*	100	30	57	0	0	
# *C. vidua*	0	3	55	0	0	
% *C. vidua*	0	1	6	0	0	
# *I. bradyi*	0	1	71	0	0	
% *I. bradyi*	0	0	8	0	0	
# *C. ophthalmica*	0	0	18	0	0	
% *C. ophthalmica*	0	0	2	0	0	
# *D. stevensoni*	0	0	15	0	0	
% *D. stevensoni*	0	0	2	0	0	
Salinity Index	100	230	101	0	0	

patzcuaro). Zone 5 contained the highest fossil content recorded in this canal (148 specimens), including all four species. Zone 6 fossil composition declined to rare (10–20 specimens) ostracodes (Table 8).

Feature 5, consisting mostly of clay, contained the highest diversity and abundance recorded from the study area. All seven species were recovered from this feature and their abundance ranged from extremely rare (<5) to very abundant (500–1,000 specimens). *L. staplini* and *C. patzcuaro* dominated at different times this canal. Other species occurred sporadically throughout the record. Zone 1 held extremely rare ostracodes (*C. patzcuaro*), but zone 2 had abundant specimens (210), *L. staplini* dominated the interval accompanied by *C. patzcuaro, C. beaconensis*, and to a lesser extent *C. vidua* and *I. bradyi*. Zone 3 was the richest (930) and most diverse; it contained six species. *C. patzcuaro* was the dominant species associated with *L. staplini, I. bradyi, C. vidua, C. ophthalmica* and *D. stevensoni*. Zones 4 and 5 had no fossils (Table 8).

Paleoecology

Figures 16 and 17 present the ostracode paleontologic and paleoecologic records for Features 3 and 5, respectively. Diagrams are arranged from datum line to canal base, but for interpretation of canal history, they will be described from bottom to top. Ostracode abundance diagrams show total population and species relative abundance through canal history. These diagrams are arranged according to decreasing tolerance to total dissolved solids (TDS), with the highest TDS tolerant species to the left and the more freshwater species to the right. Pie diagrams facilitate recognition of species relative proportions within sample. In addition, the taphonomic characteristics by interval shown in Table 9, allowed recognition of the fauna's origin and associated subfossils.

Ostracode relative abundance diagrams enabled recognition of three assemblages previously described by Palacios-Fest (n.d.). Assemblage I is dominated by *L. staplini*, it suggests saline to hypersaline conditions. Assemblage II is co-dominated by *L. staplini* and *C. patzcuaro*, this a transitional assemblage between I and III. Assemblage III is characterized by *C. patzcuaro*, an indicator of low to moderate salinity.

Feature 3 consisted of six strata (Figure 16). Zone 1 did not contain ostracodes and as Table 9 shows the fragmentation rate was extremely high suggesting that all organisms recovered from this interval were transported to the canal postmortem. Zone 2 held very rare specimens of *C. patzcuaro*. Lack of carapaces, low adult/juvenile ratios, and little fragmentation but some abrasion imply that the canal was subject to a continuous medium energy flow. Zone 3 had very rare valves of *C. patzcuaro*, lack of carapaces, and adult valves with strong evidence of fragmentation and abrasion indicating a high energy flow. Zones 2 and 3 held an allochthonous Assemblage III. Zone 4 was deprived of organisms, only mollusk shell fragments were recovered; high energy flow characterized this interval. Zone 5 contained the most diverse and abundant ostracode fauna with all four species present. Absence of carapaces and moderate fragmentation suggest medium energy, but the adult/juvenile ratios and low abrasion imply that this interval was subject to medium to low energy discharge. Autochthonous Assemblage II characterized this episode. Zone 6 included all four species, but valves were from very rare to rare showing evidence of low fragmentation and abrasion. Lack of carapaces and high adult/juvenile ratios indicate an allochthonous fauna transported by medium energy input.

Feature 5 consisted of five intervals (Figure 17). Zone 1 contained extremely rare juveniles of *C. patzcuaro*. High fragmentation and abrasion rates, as well as lack of carapaces and adults, imply the allochthonous origin of this "Assemblage III." Zone 2 had abundant ostracodes including five species: *L. staplini, C. beaconensis, C. patzcuaro, C. vidua* and *I. bradyi*. The occurrence of carapaces and moderate adult/juvenile ratios associated with moderate fragmentation and abrasion in fine sediments

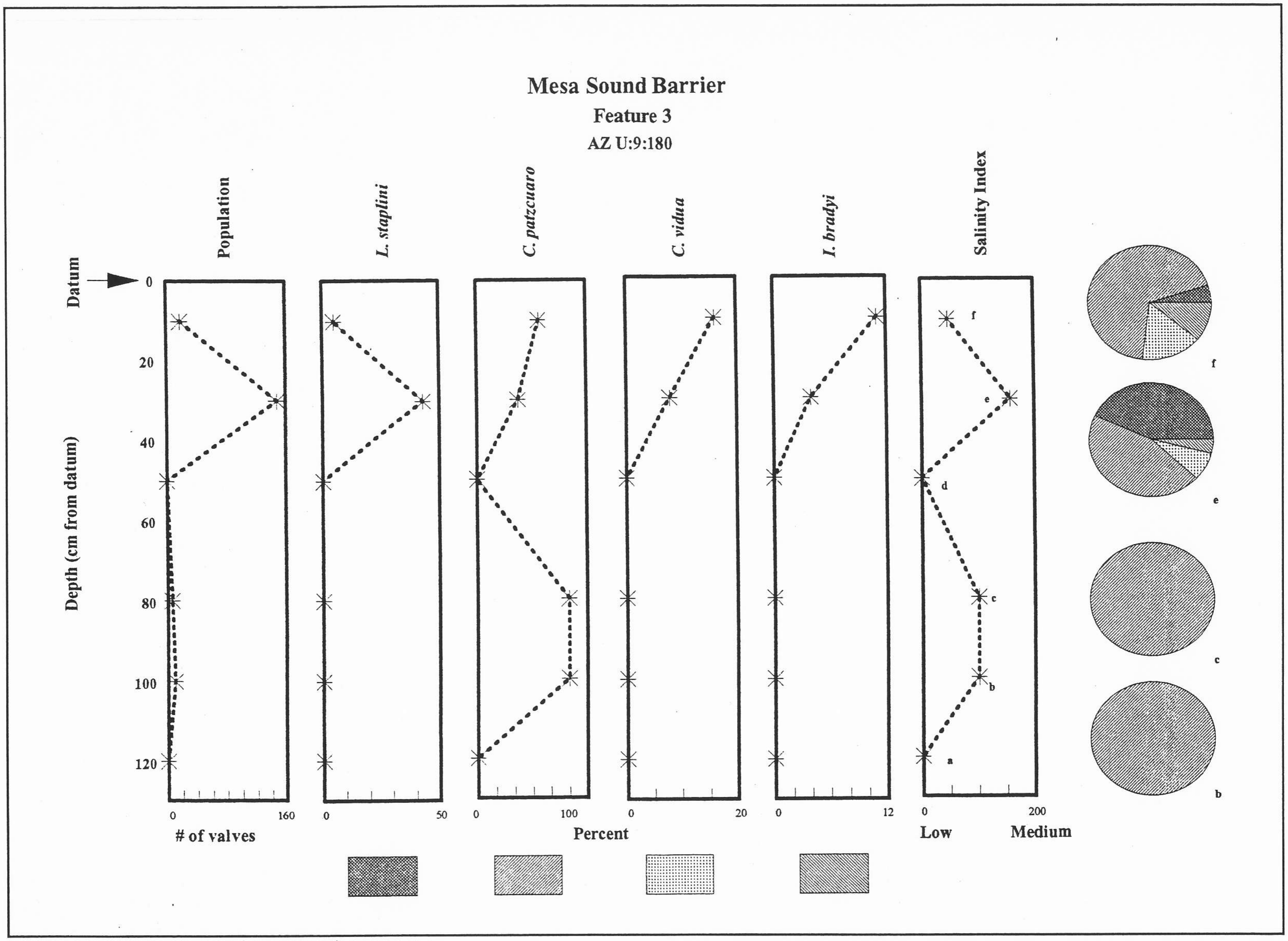

Figure 16. Ostracode abundance charts for Feature 3.

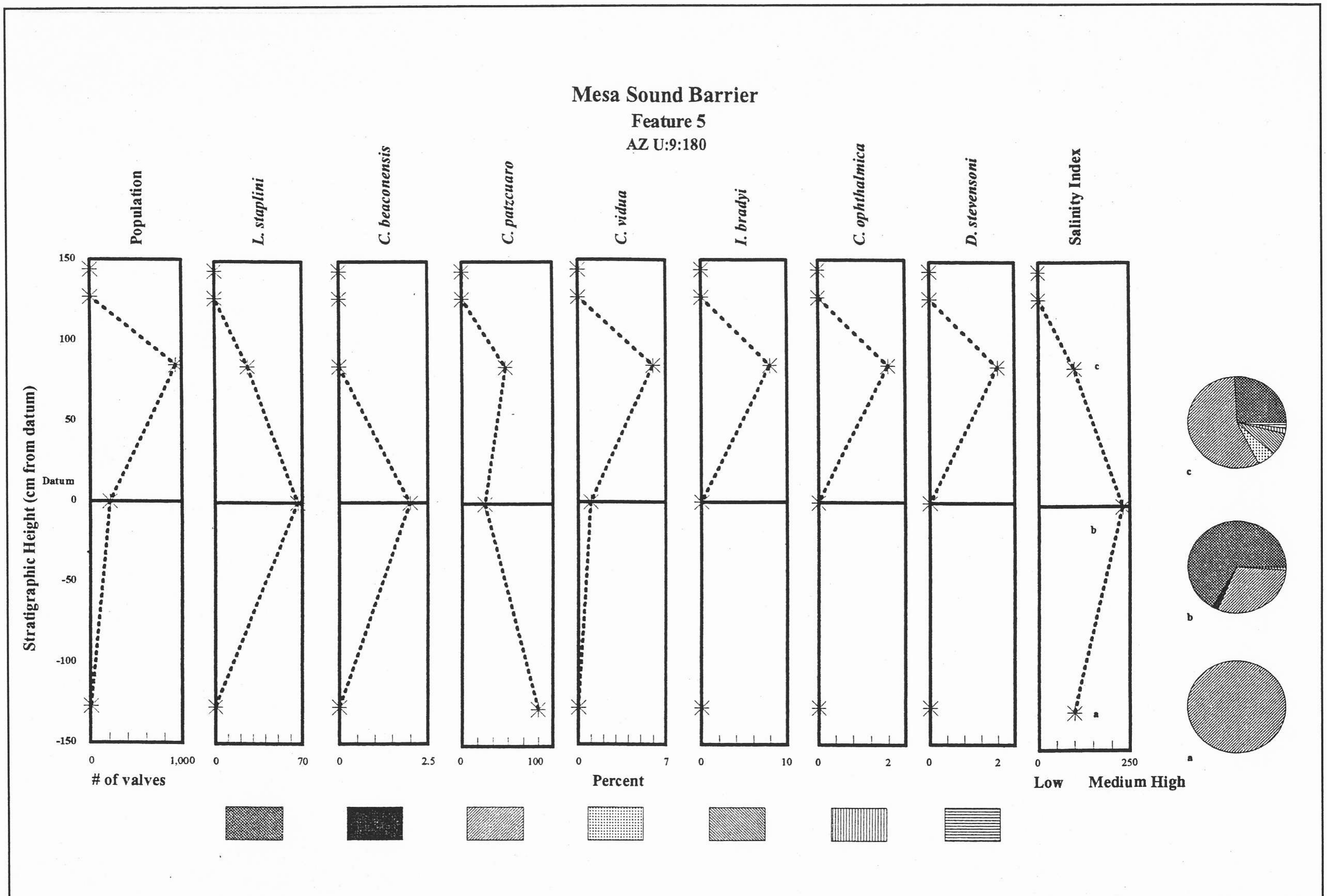

Figure 17. Ostracode abundance charts for Feature 5.

Table 9. Ostracode Taphonomic Characteristics.

Sample:	NRI-9-3-1	NRI-36-3-2	NRI-6-3-3	NRI-44-3-4	NRI-40-3-5	NRI-38-3-6
Feature	3	3	3	3	3	3
Zone	1	2	3	4	5	6
% Fragmentation	100	5	70	100	45	20
% Encrustation	0	0	0	0	5	0
% Coating	0	0	0	0	5	0
% Abrasion	30	25	225	10	15	10
Red-Ox	1	0	1	1	1	1
Other Subfossils:						
Calcareous	Tubes	X	-	-	X	X
Charcoal	-	-	-	-	-	-
Mollusks	X	X	X	X	X	X
Ooginia	-	-	-	-	-	-
Sample:	NRI-10-5-1	NRI-3-5-2	NRI-7-5-3	NRI-31-5-4	NRI-32-5-5	
Feature	5	5	5	5	5	
Zone	1	2	3	4	5	
% Fragmentation	50	30	20	100	5	
% Encrustation	0	10	5	0	0	
% Coating	0	10	5	0	0	
% Abrasion	30	15	5	30	0	
Red-Ox	0	-1	1	0	0	
Other Subfossils:						
Calcareous	-	X	-	X	X	
Charcoal	-	X	X	X	-	
Mollusks	X	X	X	X	X	
Ooginia	-	X	-	-	-	

suggests an autochthonous fauna subject to medium energy discharge. Assemblage I characterized this interval. Zone 3 held very abundant ostracodes: *L. staplini, C. patzcuaro, C. vidua, I. bradyi, C. ophthalmica* and *D. stevensoni*. Moderately abundant carapaces, relatively high adult/juvenile ratios (~0.35), and low fragmentation and abrasion indicate the in situ development of Assemblage III or maybe II, due to the high relative abundance of *L. staplini*. Zones 4 and 5 had no fossils.

Interpretation

The paleoecologic sequence described for Feature 3 suggests that this canal was initially flooded by a high energy streamflow. Occurrence of *C. patzcuaro* (only) implies that dilute water entered the canal. Coarse sediments from zones 1 to 4 is consistent with taphonomic features observed in Table 9, suggesting that it was a main or large distribution canal and that the site was close to the headgate. Following zone 4, canal operation stabilized at a low and constant streamflow allowing colonization by *I. bradyi* and *C. vidua*, discharge indicators. During zone 5, progressive stability favored *C. patzcuaro* and *L. staplini*. The latter requires low energy flow to survive, thus its occurrence appears to indicate near to stagnant waters. A good ontogenetic record for *C. patzcuaro* and *L. staplini* (~35 percent adults) confirms that these organisms were autochthonous to Feature 3. Since *C. patzcuaro* needs more than three months to complete its life cycle, it is likely that zone 5 represents a moderately long-term episode. In addition, occurrence of *L. staplini* reflects increasing salinity of canal waters. At the end of the record, zone 6, Feature 3 was once again subject to dilute water discharge, strong enough to sweep away microcrustaceans.

Feature 5 was initially flooded by high energy, low to moderately saline waters. Abundant and diverse ostracode fauna during zone 2 indicate that this canal water input stabilized for a moderately long term (longer than two months but shorter than six months), as indicated by the occurrence of several mid-term species but absence of *D. stevensoni*, a long-term species. Zone 3 suggests continuing stability of canal water input allowing the full development of an autochthonous fauna; however, at this time fresher water entered the system as indicated by the appearance of *D. stevensoni* and *C. ophthalmica*. In addition, the occurrence of *D. stevensoni* adult and juvenile valves demonstrate long-term canal operation. High diversity and assemblage composition are consistent with slow moving, dilute water input. Sometime between zones 3 and 4 Feature 5 was abandoned. Ostracode assemblages, taphonomy, and lithology suggest that Feature 5 was a distribution canal, subject to long-term operations until it was abandoned.

Discussion

Feature 3 appears to be a main or large distribution canal because of its coarse sediments and poor ostracode content. Ostracode fauna is allochthonous throughout most of the record and did not establish until zone 5. In addition, when ostracodes are present they mostly reflect low to moderately saline water. Based upon these observations Feature 3 was probably continuously fed by the Salt River throughout the early months of the year when dilute waters drain downstream from snowmelt. Feature 3 remained active for the rest of the winter and spring until increasing salinization of canal waters made its operation impractical. Similar strategies are currently observed at the Magdalena farmlands in Sonora, Mexico, where, usually, little irrigation water is used during the period between late June and September (Palacios-Fest, unpublished data). The ostracode record is consistent with Hackbarth's field observations with respect to energy discharge, and probably the abundant fauna at zone 5 is the result of a stabilized abandoned canal. In contrast with Hackbarth's observations suggesting canal abandonment sometime after zone 4, the ostracode fauna indicates that a dilute streamflow entered the canal at zone 6. *Ilyocypris bradyi, C. vidua* and *C. patzcuaro* adult:juvenile ratios, especially the latter, support this hypothesis (Figure 16). Although its origin is uncertain, zone 6 probably resulted from natural flooding of the abandoned canal (Figure 9).

Feature 5 appears to be a distribution canal initially flooded by a rapid discharge, but equally rapidly stabilized, supporting a rich ostracode fauna at zones 2 and 3. In contrast to Feature 3, ostracode fauna here is mostly autochthonous as demonstrated by the co-occurrence of adults and juveniles and frequent complete carapaces (conditions that require low water flow velocity). In addition, the salinity increase shown between zones 1 and 2 supports the hypothesis of canal stabilization, resulting in increasing canal water evaporation. Based on ostracode assemblage characteristics it is reasonable to expect higher evaporation rates in canals with low water flow velocities than those with fast water flow velocities. Subsequent water dilution interpreted from zone 3 suggests human control of water input. This interpretation is consistent with Hackbarth's recognition of large contiguous cobbles in and near the bottom of the canal (zone 1) suggesting that water flow in the canal may have been hampered by the rocks. Low energy water flow is suggested by sediment mottling all across the canal.

PROJECT COMPARISONS

Hypothetical gradients between canals of AZ U:9:180(ASM) and the Price Road site of La Cuenca del Sedimento (Locus 1 and 2 = AZ U:9:68(ASM); Locus 3 = AZ U:9:69(ASM)) (Ackerly and Henderson 1989) were generated to ascertain whether connections between the prehistoric features from the two project areas could be ruled as implausible. Classic period Hohokam canals of the Scottsdale canal system (Huckleberry 1995) were used to suggest what possible gradients might be expected. The

Scottsdale system is an appropriate analog for AZ U:9:180(ASM) and La Cuenca del Sedimento features because canals from both sites were on, or below, the Mesa Terrace escarpment. Presumably, similar engineering problems would have confronted the builders of the two systems. In addition, the gradients of historic canals near the project area were summarized for comparison.

Three estimates were used for the canal system comparisons. Huckleberry (1995:51) calculated a "liberal estimate" of a gradient of .002 for the prehistoric Scottsdale canal system by using the modern slope as a proxy measurement. In the same way, the historic Hayden and Peterson canals were used to estimate a minimum gradient that might be expected between the Price Road and McKellips Road project areas. Both historic canals pass within 1 mile of the La Cuenca del Sedimento project area; their gradients were calculated from the 1952 USGS Tempe quadrangle map that shows their routes. The Hayden Canal (at the north end of La Cuenca del Sedimento) had a gradient of .0013 as it traversed the Lehi Terrace east-to-west. The Peterson Canal was in Locus 3 of La Cuenca del Sedimento and visible on the map west of Loci 3 and 4 where it had a gradient of .0014 as it traveled toward the southwest. The final canal gradient estimate is a minimum canal gradient based on Katzer (1989:234). He states that the Hohokam avoided building canals with low gradients and suggests that .09 is the minimum slope used at La Cuenca del Sedimento (Katzer 1989:229).

The purpose of this comparison is to determine whether water would flow in a system, given the known canal elevations at the two sites. Basal elevations of the AZ U:9:180(ASM) canals were determined relative to points used for the McKellips Road construction effort. At the four La Cuenca del Sedimento loci, the canal elevations were calculated from the average ground surface in the locus, minus the canal depths (as determined from profiles shown in Ackerly and Henderson 1989). Table 10 summarizes the possible gradients using straight line distances between the two project areas. Notice that the straight line distance correlates with hypothetically shallower canal gradients because the four loci at La Cuenca del Sedimento were arranged in ascending elevations away from the river (i.e., the higher elevation of Locus 4 translates into shallower gradients in Locus 4 compared to Loci 3, 2, and 1; likewise, Locus 3 relative to 2 and 1, etc.).

Significantly, all of the hypothetical canal gradients fall between the maximum prehistoric estimate (.002) and the historic canal gradients (.0013). This consistency of gradients implies that both McKellips Road Features 3 and 5 could have extended at least as far as La Cuenca del Sedimento. This comparability was expected for Feature 5 since it was constructed along the Mesa Terrace (at a higher elevation than needed to irrigate the Lehi Terrace that was at the base of the terrace) and obviously designed to transport water farther to the southwest. On the other hand, it was unexpected that Feature 3 could deliver water as far away as La Cuenca del Sedimento since this canal was on the Lehi Terrace and was expected to have irrigated land near the McKellips Road project area. The implication of the hypothetical gradients in Table 10 is that either canal could have supplied water to all four of the La Cuenca del Sedimento loci.

At least four canals at La Cuenca del Sedimento could not be associated with Feature 5 of AZ U:9:180(ASM) since they postdate the McKellips Road features (Table 10). The age of Feature 5 (A.D. 600–950) implies that the canal system could have been in operation relatively late in the Preclassic, but four of the La Cuenca del Sedimento canals were dated to the Classic period (Locus 2, Canal 2; Locus 3, Canal 1; Locus 4, Canals 2 and 3). Likewise, one of the canals (Locus 2, Canal 61) was in operation at La Cuenca del Sedimento too early to have been associated with McKellips Road Feature 5.

Table 10. La Cuenca del Sedimento Canal Data.

Locus	Canal	Elevation Below MRSB Feature 3	Elevation Below MRSB Feature 5	Distance Between Project Areas	Hypothetical Gradient to MRSB Feature 3	Hypothetical Gradient to MRSB Feature 5
1	46	14.2	15.1	8,368 m	.0017	.0018
1	102	16.0	16.9	8,368 m	.0019	.0020
2	1	15.8	16.7	8,609 m	.0018	.0019
2	2	15.3	16.2	8,609 m	.0018	.0019
2	3	16.4	17.3	8,609 m	.0019	.0020
2	4	15.6	16.5	8,609 m	.0018	.0019
2	5	15.9	16.8	8,609 m	.0018	.0020
2	10	15.4	16.3	8,609 m	.0018	.0019
2	11	15.4	16.3	8,609 m	.0018	.0019
2	16	15.8	16.7	8,609 m	.0018	.0019
2	17	15.7	16.6	8,609 m	.0018	.0019
2	19	15.2	16.1	8,609 m	.0018	.0019
2	61	15.4	16.7	8,609 m	.0018	.0019
2	89	15.3	16.2	8,609 m	.0018	.0019
3	1	14.1	15.0	8,851 m	.0016	.0017
3	3	14.2	15.1	8,851 m	.0016	.0017
3	4	14.0	14.9	8,851 m	.0016	.0017
3	5	13.9	14.8	8,851 m	.0016	.0017
3	6	13.7	14.6	8,851 m	.0015	.0016
3	7/8	13.3	14.2	8,851 m	.0015	.0016
4	3	12.3	13.2	9,575 m	.0013	.0014
4	5	11.9	12.8	9,575 m	.0012	.0013
4	19	12.3	13.2	9,575 m	.0013	.0014

A selected sample of some of the sedimentological samples collected from La Cuenca del Sedimento canals were compared to the McKellips Road features; this comparison does *not* imply a possible connection between any of the canals. Instead, since the distance from headgates has a profound impact on the types of sediments that are deposited in canals, the comparison informs more about what section of the canal was sampled and the similarity of water flow regimes among canals. Notice the dissimilar sediments in Features 3 and 5 of the McKellips Road site which corresponds to different headgate elevations (i.e., headgates of the two canals had unequal distances to the river).

The McKellips Road Feature 5 strata showed increasing amounts of silt higher in the profile (Figure 14). A similar situation is noted for three of the Preclassic La Cuenca del Sedimento features (Locus 2, Canals 2 and 10; Locus 3, Canal 3). The minor constituent role of sand in the profiles is also noteworthy. In the case of La Cuenca del Sedimento canals compared to McKellips Road canals, the similar sediment texture suggests a similar distance from headgates or a similar water flow regime. This comparison indicates that these canals could not have had headgates in the same vicinity, since the McKellips Road project area is over 5 miles east of the La Cuenca del Sedimento canals.

The McKellips Road Feature 3 strata were heavily weighted to sand, with only minor elements of silt and clay. Only the historic McKellips Road canal (Feature 4) and Locus 2, Canal 16a of La Cuenca del Sedimento had similar ratios of sediment. Feature 3 is also one of the few canals that lacked consistency between its adjoining strata. This disjointed appearance is similar to Feature 22 of AZ U:9:99(ASM). Hackbarth (1995) attributed such unconformities to rejuvenation of canals caused by new headgates, realignment, or cleaning of the canals above where the samples were collected.

Feature sediment ratios were also contrasted from the Scottsdale canal system (Huckleberry 1995). The canal samples from the Scottsdale system were collected from relatively close to the heads of the canals, which accounts for their coarse-grained materials. Notice in particular the relatively substantial amount of sand from Features 22 and 24, AZ U:9:99(ASM); these features were on the Lehi Terrace and would have been relatively close to their headgates.

Pollen samples from the canals were examined in light of the observations made by Fish (1987) and Gish (1989) at the La Cuenca del Sedimento canals. The results of the Price Road work indicated that pollen is distributed in canals by a number of factors: water transportation which contributes to a wide spectrum of pollen types, aspects of seasonality are evident in canal sediments, and water flow regimens affect pollen frequencies in canals.

Agricultural products are evident in the pollen samples from the McKellips Road canals. Maize was the most common domesticate item, although other economically important plants were also well represented. The occurrence of cotton in the McKellips Road canals was at a higher incidence rate (2 of 11 samples) than what was observed at the Price Road features (4 out of 126). This difference may be related to what section of the canals were sampled or the different ages of the canals. In either case, the presence of these plants confirms their use upstream from the McKellips Road project area.

Ostracode samples from the canals inform about the temperature and salinity of water flows in the features. Feature 3 of the McKellips Road project was characterized by a low diversity and low abundance of species; in contrast, Feature 5 had an abundant assemblage. The ostracode evidence indicated that the earliest water flow regime in Feature 3 was too rapid to allow colonies to become established. Instead, the water flow was fast and continuous, which supports the observation of lateral migration of the channel. Apparently, Feature 3 served as a main or large distribution canal whose headgate was relatively close to the McKellips Road project area. Lower speed water flows were present in the upper strata of the feature. Feature 5's ostracode assemblage was markedly different from Feature 3. An inference about the distance to a headgate was not possible for Feature 5, but its topographical situation demonstrates a greater distance to its headgate than for Feature 3. The lower three strata of Feature 5 had ostracode evidence that implied its use as a main or distribution canal for a long period of time. Abandonment of the canal resulted in few ostracodes and no estimates of the water flow regime.

When compared to canals from the north side of the Salt River, the two McKellips Road canals' ostracode data appears to have little in common. Only one McDowell-to-Shea project feature dates to the same time period (Feature 22 of AZ U:9:99) and it exhibits a number of cleanings during its use (A.D. 700–890/990). This scenario is very different from the McKellips Road project, where Feature 3 has few ostracodes and Feature 5 has a more stable environment for ostracode development. The ostracode colony data for Feature 22 at AZ U:9:99 are indicative of short duration of water flows in the late spring or early summer, followed by more stable water entry into the canal (Miksicek 1995:128; Palacios-Fest 1995:100).

the area may be able to inform about three topics: confirm the route of Feature 7 and its connection to the South Canal, provide perpendicular cross sectional profiles of the features, or discover additional archaeological resources. In particular, elevations above 376 m AMSL were not visible during this investigation and canals that follow the Mesa Terrace at this elevation, or higher, could be located by future work.