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Organism interactions and their environmental significance, as exemplified by the Pliocene-Pleistocene fauna of the Kettleman Hills and Humboldt Basin, California

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ORGANISM INTERACTIONS AND THEIR ENVIRONMENTAL SIGNIFICANCE, AS EXEMPLIFIED BY THE PLIOCENE-PLEISTOCENE FAUNA OF THE KETTLEMAN HILLS AND HUMBOLDT BASIN, CALIFORNIA

A Dissertation

by

WILLIAM MAURICE HARRIS, JR.

Submitted to the Graduate College of
Texas A&M University
In partial fulfillment of the requirement for the degree of

DOCTOR OF PHILOSOPHY

August 1987

Major Subject: Geology

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ABSTRACT

Organism Interactions and Their Environmental Significance, as Exemplified by the Pliocene - Pleistocene Fauna of the Kettleman Hills and Humboldt Basin, California. (August 1987)

William Maurice Harris, Jr., B.S., Baylor University; M.S., Texas A & M University

Chair of Advisory Committee: Dr. Robert J. Stanton, Jr.

Evidence of organism interactions (predatory and non-predatory) in Recent samples from the Texas Gulf Coast and Pliocene - Pleistocene samples from the Humboldt Basin and Kettleman Hills of California were studied in order to determine their usefulness in interpreting the fossil record. The Recent samples were analyzed as potential fossil communities to determine the ecologic factors controlling the distribution of organism interactions. The Pliocene - Pleistocene samples of California were analyzed to determine latitudinal and temporal distribution of interaction types and interaction pairs.

Seven types of interactions were identified from the Recent and fossil material. They included gastropod predation, algal/fungal borings, clionid sponge borings, polychaete borings, encrusting bryozoans, attached bivalves, and encrusting barnacles.

The Texas Gulf Coast samples indicate that the distribution of interaction types was controlled by environmental stress at the sediment/water interface as it controls the availability of "host" shell materials (epifauna) and the viability of "guest" species. The intensity of interaction, with the exception of predation, was dependent on the presence of live epifauna and/or the presence of physical/biological processes which bring shell material to the surface and maintain it there.

The Humboldt Basin samples represented a depositional gradient from basin to shoreface. Predation by naticids occurred at all stratigraphic levels independent of water depth, with intensity increasing upwards as a function of available, preservable prey species. The other types of interactions did not appear until stable, shelfal conditions were established. The number of incidents of interaction increased upward in the section with an abrupt decline in the shoreface environments. The Kettleman Hills samples were from relatively stable environments. The interactions did not show changes through time, and host-guest preferences remained invariant. The Kettleman Hills data indicated that interaction relationships did not change within the time frame represented (approximately 4 million years) and that the changes seen in the Humboldt Basin were ecologically, not evolutionarily, produced.

Organism interactions provide useful tools for understanding shell accumulations and for making paleoecological interpretations. Detailed study of specific interaction pairs is needed to fully understand the importance of these pairs in the interpretation of the fossil record.

For the students...

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INTRODUCTION

Key to the concept of a modern marine community is that the members of that community interact with each other. In the processes of living, the organisms will compete for resources such as space, nutrients, and sunlight. In modern communities it is possible to observe organism interactions, detect the changes that a community undergoes as it matures, and note the roles which component species play within that community.

In the fossil record, however, it is possible to have an admixture of shells of organisms from several biological communities concentrated within a single stratum. Reconstruction of a single community out of the composite assemblage may be very difficult. Species may show conflicting environmental tolerances, share incompatible positions of dominance within the community, or appear to violate rules of competitive exclusion within the assemblage. Time resolution of geologic analyses is not precise enough to allow us to define a year's standing crop, detect seasonal variations within an environment, or separate out biological responses to short-term environmental variability. It may be possible, however, to recognize

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contemporary components of an assemblage by the interactions between individuals if the interaction between the two organisms resulted in modification of the shell or shells of the organisms involved.

Some organisms, in the process of living, modify the shells of the species with which they interact and in doing so leave a preservable record of that interaction. Some invertebrate species require a hard substrate for attachment or for protection and will utilize the shells of other organisms for that purpose. By cementing themselves to the shell or boring into the surface, they modify it. Each of these types of interactions has the same chance of being preserved as the shell itself. Predatory species that attempt to penetrate shells to get at the food inside leave a record of the attack that can be identified. In the process of breaking the shell, or boring into it, they leave characteristic traces of the interaction.

Objectives of the Study

The purpose of this study was to assess the preservation and usefulness of organism interactions in interpreting the fossil record. To accomplish this study, interactions were studied in Recent fauna from the central Texas Coast and in Pliocene - Pleistocene fauna of the Humboldt Basin and Kettleman Hills of California. These data were interpreted in terms of host - prey selectivity, evolution of interaction pairs, and paleoenvironment.

There were three major objectives of this research. The first objective was to compile evidence from the study areas (the Gulf Coast, Humboldt Basin, and Kettleman Hills) of the presence of organisms which had little potential for preservation as body fossils (ie. those with chemically unstable shells or no shells at all) but which are preservable if they interacted with other organisms and modified the shells of their hosts/prey in a characteristic manner. The organisms which modify the shells of host species are rarely included in faunal lists of fossil communities. A record of the types of interactions present at each of the study areas was compiled with attention being paid to the stratigraphic position and geographic distribution of each of the types of interaction pairs.

The second major objective was to evaluate the environmental distribution of the organism interaction pairs. The Gulf Coast of Texas provided a modern analogue to study the distribution of interactions within the shallow water depositional environments of the California locations. Analytic tools for interpretation of the fossil material were developed and tested against the known depositional environments of the Recent material. In the Humboldt Basin the differences in the depositional environments occurred both vertically within each of the sections which were studied and laterally between each of those sections. In the Kettleman Hills the lateral distribution of depositional environments was of primary interest although vertical differences through the sections were also observed.

The third objective was to look for possible evolution of interaction within the time interval represented by these strata. Because of the potential for change in interaction character of a host or guest species through time, the nature of these changes must be recognized. The changes in distribution of interactions within a stratigraphic section which are attributable to evolution within each type of interactions must not be confused with the changes in interaction pairs resulting from changes in depositional environment through that same time.

The Community in Paleontology

The determination of depositional environments using single genera and species is known as autecology (Dodd and Stanton, 1981). Most individual organisms do not live an isolated existence, but relate in one way or another to other individuals of the same species and of other species within the community. A community may be defined as an assemblage of co-occurring and interacting organisms that recurs in time and space and that is a recognizable unit with biotic controls (Schafer, 1972). The study of fossil communities is not without its problems. Some workers believe that because no two environments are identical, there can be no two communities that are the same (Raup and Stanley, 1978). While this premise may hold true between different microenvironments, large scale community structure can be recognized. Rollins and Donahue (1975) indicate that several types of fossil communities may be recognized using modern ecological stability-time concepts. The stability-time concept is based on the relationships between the environmental stability and diversity (Sanders, 1968). The paleocommunities defined by the methods previously listed do recur and occur within a defined time and space, and the assembages of fossils do represent the biotic control of the environment. The nature of the fossil record is such that these paleocommunities do not necessarily represent the group of interacting organisms.

Taphonomy plays an important role in what is perceived as the fossil community. Through taphonomic processes, most soft-bodied organisms are removed, and the preservation of hard-shelled species is biased by differences in shell mineralogy and shell structure

(Driscoll and Swanson, 1973). This bias may be compounded by time averaging. Time averaging occurs because of the nature of sediment accumulation. Sedimentation rates, which average approximately 3 cm/1000 years (Kukal, 1971; Olsen, 1978; Schindel, 1980), potentially could concentrate shell material of many generations within a single rock stratum if actual sedimentation rates approximate the average. Schindel states "sedimentation in nearly all depositional environments is either too slow or too intermittent to permit resolution of short-term continuous biological processes [such as interactions] in the fossil record." In that way, shells of individuals from many temporally distinct "communities" could be combined into an apparent single community. If the composite nature of the fossil assemblage is not recognized, it would be misinterpreted as the representation of a single community.

An alternate view of the nature of the fossil record is that very little of the living community has a potential for being preserved. Physical shell destruction and chemical dissolution in modern clastic environments rapidly remove most shells within a short time period. The fossil record, therefore, would represent either the very slow accumulation of shell material (having little relationship to the living community) or the incorporation of shells into shell layers through the big event (storms, hurricanes, etc.) (Cummins, et al., 1986a). Until we understand the nature of fossil accumulation, the relationship between the fossil community and the living community is left unresolved. For the interpretations of this study, time averaging is assumed.

Previous Studies in Organism Interactions

Direct evidence of organism interactions and community structure in the fossil record is best preserved in the relationships of encrusting and boring organisms to their host/prey. These hard-substrate organisms constitute "assemblages <u>in situ</u> with time averaging... reduced to a minimum due to the short life-span of the hosts and zero net sediment accumulation" (Bottjer, 1982). The literature on encrusting and boring (predatory and nonpredatory) organisms is extensive concerning both the activities of individual organisms (Boekschoten, 1970; Bromley and Surlyk, 1973; Kobluk and Risk, 1977; Brett, 1978; McNamara, 1978; Killingley and Lutcavage, 1983) and their paleoecological and paleoenvironmental reconstructions (Roughgarden, 1975; West, 1977; Bottjer, 1982; Karlson and Shenk, 1983; Akapan and Farrow, 1984). Organism interaction has been studied in terms of predation (Caullery, 1952; Carriker, 1951;

Bishop, 1975; Virnstein, 1977, 1979) and community structure (Boekschoten, 1970; Stanton and Dodd, 1976b; Scott, 1978; Levine, 1980; Stanton and Nelson, 1980; Stanton, et al., 1981; Kitchell, et al., 1981; Boggs, et al., 1984).

METHODS

Field Methods

Gulf Coast

Shallow marine benthic communities of the Texas Coast were studied at nine localities between Copano Bay and Laguna Madre at North Padre Island (fig. 1). These localities were selected to provide a range of water depth, salinity, substrate, wave energy, and turbidity. Beach environments were studied at: station 1, on the gulf side of Mustang Island near Park Road 4; station 2, along the Corpus Christi Ship Channel on the back side of North Mustang Island near the University of Texas Marine Food Research Lab; station 4, in Redfish Bay at Mustang Island State Park; and station 6, at Bird Beach Boat Basin in Padre Island State Park. Sandbar environments were studied off two of the beach localities: station 3, in Mustang Island State Park and station 5, at the Bird Beach Boat Basin. Oyster Bar environments were studied at station 7, off the south side of Steadman Island, and station 8, in Portland near Gunderson's Marine in Nueces Bay. The bay environment was studied at station 9, at the mouth of the Aransas River in Copano Bay.

Several parameters of the physical environment were determined at each station. Water samples were collected for later determination of salinities.

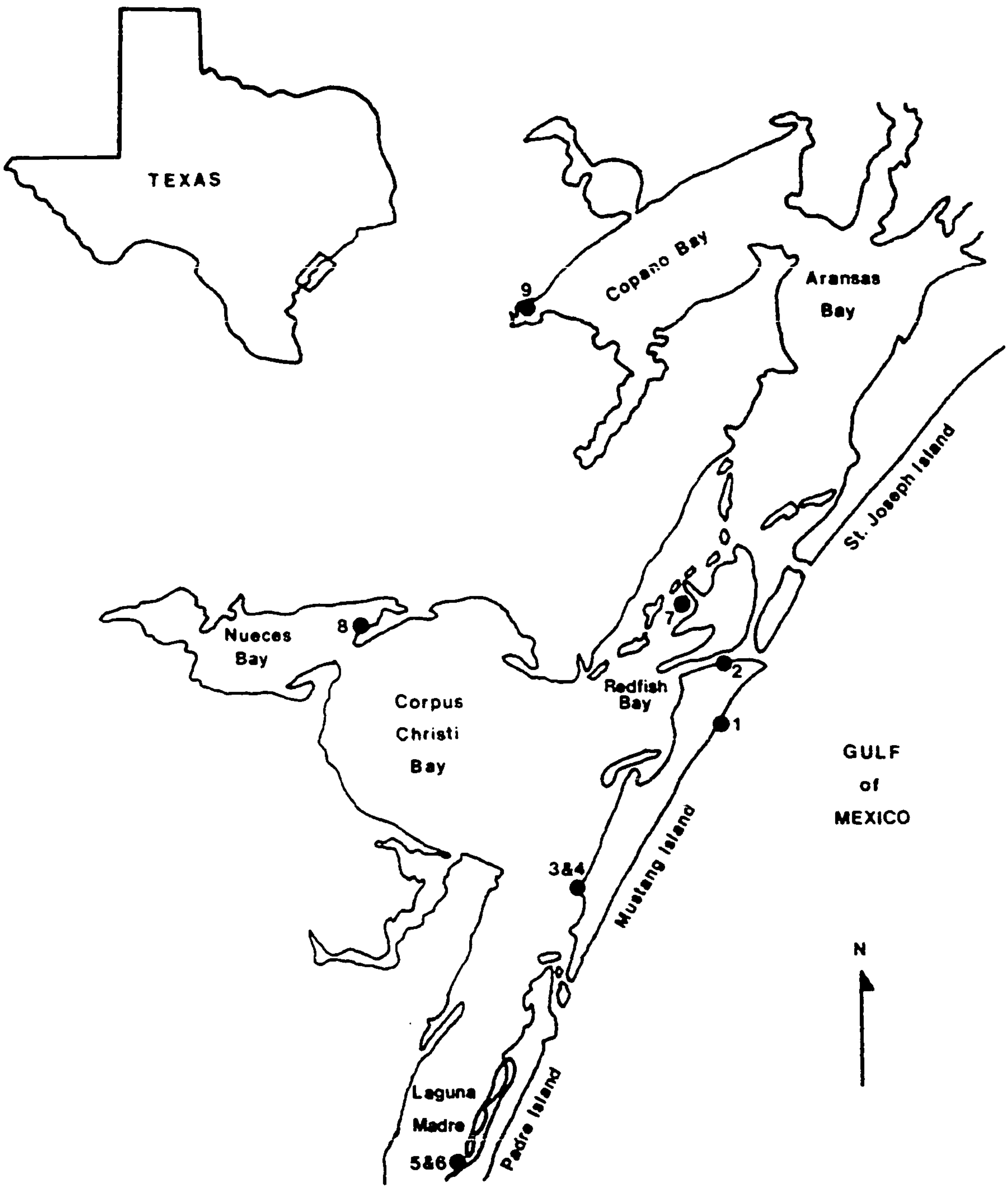


Figure 1. Map of Texas Coast showing the location of samples used in this study.

Turbidity was measured by checking the visibility of a metal ruler as it was lowered into the water. The depth at which the end of the ruler disappeared was recorded. Sediment samples were collected, and grain size analyses and organic content were estimated qualitatively from the sediment sample. At stations where shells were sparse, an attempt was made to collect all of the shells within the area, being careful not to contaminate the sample with spoil materials. At stations with abundant shell material the samples were collected at random with care being taken not to bias the collection with shells having interactions.

The shells were treated in a salt water and sodium hypochlorite bath for one hour to kill the living organisms and facilitate the removal of the hermit crabs from the gastropod shells. Next the samples were washed with no less than six fresh water baths to remove all traces of the sodium hypochlorite. The materials were transported to Texas A & M University in plastic trash cans filled with enough water to completely cover the shells.

California

Pliocene - Pleistocene fossils were collected from the Humboldt Basin and Kettleman Hills of California (fig.2) to augment specimens collected and archived at

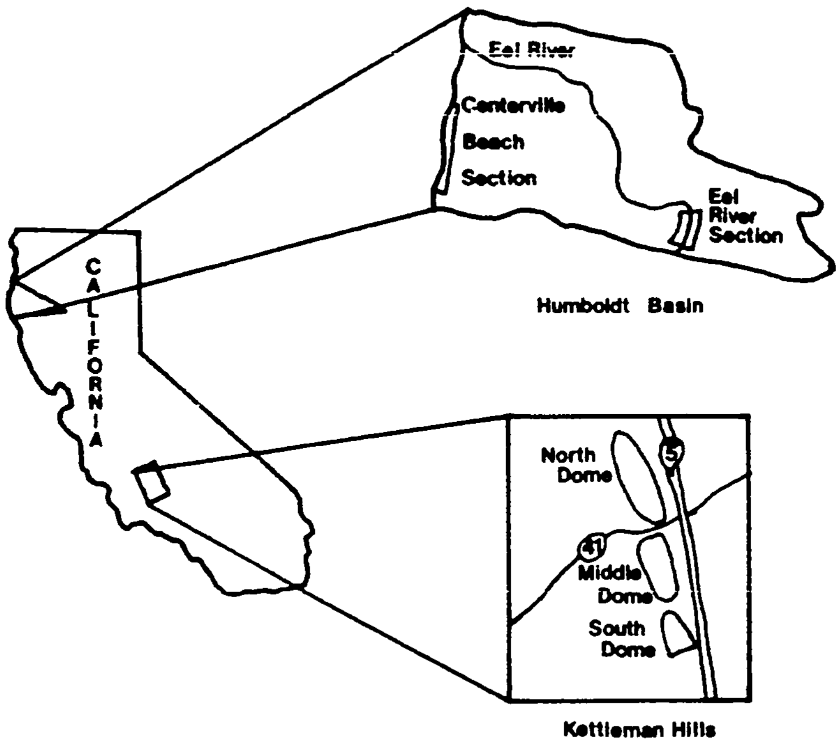


Figure 2. Map of California. Insets show the location of the two regions from which fossil material was collected for this study.

Texas A & M University by Drs. R. J. Stanton and J. R. Dodd. The samples from the Humboldt Basin were collected from the Centerville Beach and Eel River sections (Jennings, 1983). Stratigraphic samples of the macrofaunal shell material were collected from each of the sections. In the sparsely fossiliferous lower units, all of the in-place shells were collected. In richly fossiliferous units, a sample of thirty (or more) shells of each species was collected at random in order to not bias the sample towards shells with interactions. If interaction types were present but did not fall into the random sample, the sample size was increased in increments of twenty shells until representatives of all interaction types occurred within the sample.

Samples from the Kettleman Hills were collected from more than 170 stations in order to cover the complete range of stratigraphic horizons.

Laboratory Methods

The Gulf Coast material was rinsed four additional times upon arrival at Texas A & M University to completely remove all traces of salt water and sodium hypochlorite to prevent shell destruction. The attached, but not cemented, epifauna (such as the gastropod Crepidula) by this time had fallen from their host shells. The shells were vigorously brushed with a tooth brush to dislodge any loose epifauna which had not fallen off previously. The samples were treated so that the only interactions left on the shells were those which could potentially be preserved in the fossil record (i.e. cemented epifauna and endoliths). The samples were dried and identified to the lowest taxonomic level possible using Jean Andrews'(1971) Seashells of the Texas Coast.

The fossils from California were prepared carefully to avoid destroying evidence of interactions. Preservation of the fossils, particularly from lower stratigraphic units in the Humboldt Basin, was extremely poor. The condition of some of the fossils resulted in the loss of data in transportation to the lab. Fossils were identified by comparison with the collection of Drs. Stanton and Dodd, and species names were verified through the information included in Myra Keen and Herdis Bentson's (1944) Check List of California Tertiary Marine Mollusca and Barry Roth's (1979) Ph.D. dissertation from the University of California, Berkeley.

Each shell was studied at low magnification with a Zeiss binocular microscope and host and guest organisms, shell condition, articulation, and location of interaction on the host shell were recorded. Appendix I lists the organisms present at the Gulf

Coast localities. Appendix II lists the fossil fauna of the California localities. The life habit for each species is included in this appendix. Organisms were classified as being infaunal if they are either completely or are periodically covered by sediment. The epifaunal organisms were defined as those which lie on, attach to, or move about on the sediment surface. The degree to which infaunal shells are utilized is an important factor in the analyses of the processes which make these shells available for interaction. Appendix III lists the localities from the Kettleman Hills from which samples were used in this study. The data from the Humboldt Basin localities are summarized in Appendix IV.

Data Considerations

The data presented in this study are composed of individual specimens from localities of differing sample strategy within regions with different distributions of (depositional) environmental complexity. The pertinent ecologic data include: salinity, sediment type, water depth, ecologic stability, and faunal complexity. Each of these factors must be considered when comparing interaction information between samples and localities. Sample size and measurement of numerical significance presented a problem in the analyses. Individual samples varied between one to five hundred or more shells per locality, with most samples containing fewer than twenty specimens.

The Humboldt Basin sections present the best example of the problem of sample size. The problem was not the result of insufficient collection of samples but that the Pullen, Eel River, and lower Rio Dell were only sparsely fossiliferous. Even when every available shell was collected, the occurrence of one shell in a hundred to a thousand feet of section was not uncommon. Some of the strata in the upper portion of the Rio Dell Formation contained more shells than the entire lower section collectively. The problem was in comparing percentages of the interactions between the lower and upper sections. With the nature of the samples and all other problems mentioned above, it was decided to make qualitative observations from the quantitative data.

Each type of interaction is discussed in terms of the major objectives of this study. The interpretations presented within this section are based on the lithology, inferred depositional environment, faunal abundance and ratios, life habits, and the specific nature of the interaction types. The amount of data involved in the interpretation is too large to include a discussion of each individual sample from every location. Pertinent instances of individual interactions are included when discussion requires such. The data for the Texas Gulf Coast localities are provided in tables in that section. The data from which the conclusions are derived for the Humboldt Basin are presented in Appendix IV.

GULF COAST

The Gulf Coast of Texas (fig. 3) is used as the modern analogue for development of the methodology to be used on the Pliocene - Pleistocene localities in California. The area covered in this portion of the study lies between San Antonio Bay in the north and Baffin Bay in the south. The environments within the study area represent a wide range of clastic depositional settings. The variability in salinity, substrate character, turbidity, current influence, and water depth present in this area allows for the analysis of the factors which may affect the distribution of organism interactions.

The Gulf Coast of Texas has been extensively studied and characterized (for a comprehensive bibliography of studies on the Texas Gulf coast see Brown, et al., 1976). Parker (1959) studied the area around Rockport, Texas and Laguna Madre in order to determine the distribution of the macrofaunal assemblages of the bays and the lagoons of the south central Texas coast. He subdivided the environments of the Texas coast into eight types of environments (fig. 4); sampling for this study covers five of these. Copano Bay has been extensively studied by Calnan (1980), and the nature of shell accumulation has been studied in detail at sample location 9 (Cummins, et

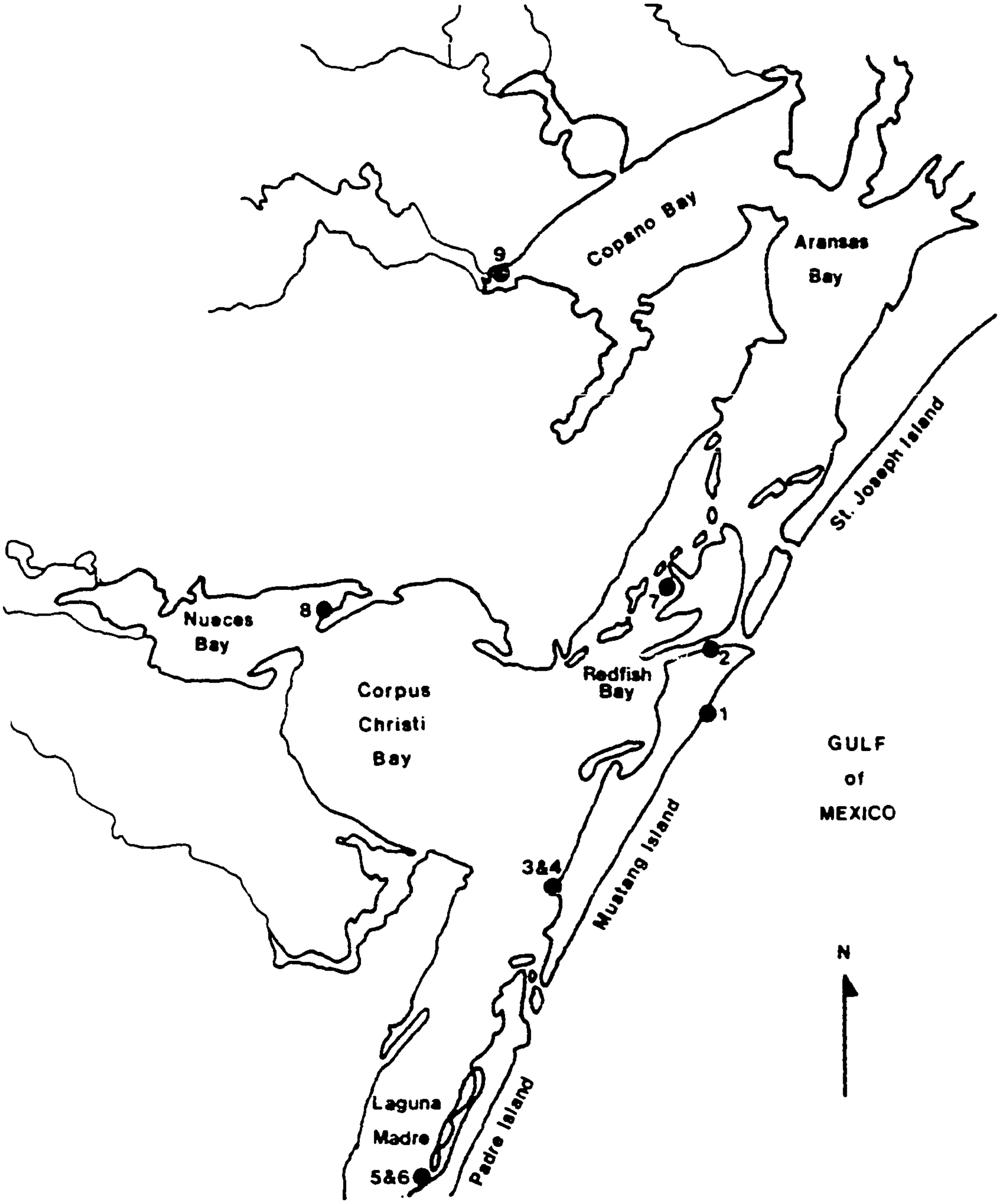


Figure 3. Detailed map of the Texas Coast showing sampling stations. 1. Gulf of Mexico Beach, 2. Corpus Christi Ship Channel, 3 & 4. Mustang Island State Park, 5 & 6. Bird Beach Boat Basin, 7. Steadman Island oyster bar, 8. Gunderson's Marine oyster bar, 9. Copano Bay.

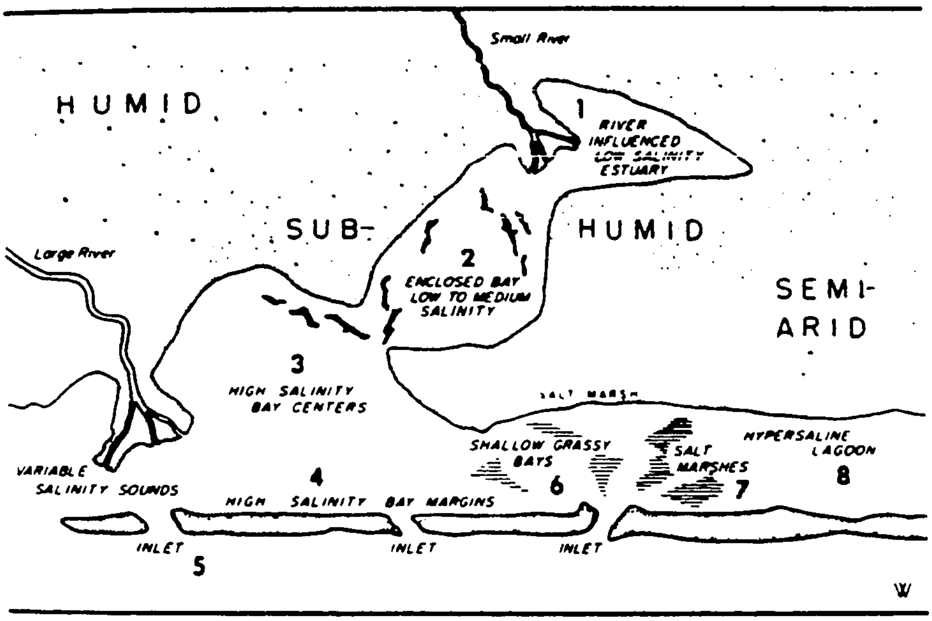


Figure 4. Classification of bay and lagoonal environments of the Texas Coast from Parker (1959).

al., 1986a; Cummins, et al., 1986b; Staff, et al., 1986).

The coastline of Texas has been actively building outward since the beginning of the Cenozoic era. The sediments of the Texas coastline were deposited in "fluvial-deltaic, barrier-strandplain-chenier ... bay-estuary-lagoon ... as well as eolian (wind) ... and well-developed marsh-swamp system(s)" (Brown, et al., 1976). As sea level fluctuated during the Pleistocene, the shoreline migrated across the coastal plain and shallow shelf areas. These movements of the shoreline are marked in relict shoreline deposits along the shores of the Laguna Madre and the bays. Approximately 3,000 to 2,500 years ago sea level stabilized at its present position, and the features of the today's coastline began to form. Small barrier islands (what are now St. Joseph, Mustang, and Padre Islands) began forming and grew by spit accretion and agglomeration. As the barrier islands formed, the waters of the bays became separated from the conditions of the open Gulf. The processes which have shaped the Texas coast to its present configuration continue to operate and modify the existing environments (Brown, et al. 1976).

The materials presented in this section are organized to provide the necessary information for the interpretation of organism interactions present at each of the locations. The physical and hydrological conditions at each of the localities are presented. A list of host organisms (and their distributions) is presented in Table 1. Characteristic interactions are discussed in the light of the conditions present at each locality. This is followed by an interpretation of the distribution of each type of interaction (predation, non-predatory shell borings, and encrustations).

Station Characteristics

Station 1, the only open gulf site, is on northern Mustang Island along a fifty foot section of beach immediately south of Beach Access Road 4. Shells were collected between the high tide mark and the first sandbar offshore (0 to 3 feet water depth). The salinity was 35 $^{o}/oo$ at the time of collection. The water was turbid, and visibility was limited to a depth of 1.5 feet. The area is subject to strong wave and current activities which suspend sediments to occlude visibility.

The substrate was composed of medium sand and shell material and was relatively low in organic content (dead oil present in the sample from offshore dumping makes observation of the natural organic content difficult). The sediment in the swash zone was firm but liquified easily with minor vibration. The

Table 1. Texas Coast faunal distribution. a. Gastropods.

Gastropod	Littorina (L.) irrorata	Vermicularia fargoi	Cerithium (T.) floridanum	Strombus alatus	Strombus ?	Crepidula (C.)	Crepidula (J.) plana	Crepidula	Polinices (N.) duplicatus	Thais (S.) h. floridana	Thais (S.) h. haysae	Murex (P.) pomum	Thais ?	Anachis a. semplicata	Cantharus (P.) cancellarius	Busycon contrarium	Busycon s. plagosus	Busycon ?	Oliva (I.) sayana	Terebra (S.) dislocata
North Mustang Island-Beach						X													X	
Corpus Christi Ship Channel		X	X	X	X	X			X	X	X	X	X		X	X	X			
Mustang Island State Park-Sandbar							X	X	X	X					X	X				
Mustang Island State Park-Beach	X					X	X	X	X	X		X			X	X		X		X
Bird Beach Boat Basin-Sandbar			X											X						
Bird Beach Boat Basin-Beach						X			X							X				
Steadman Island Oyster Bar			X				X	X		X				X	X	X				
Gunderson's Marine Oyster Bar								X	X											
Copano Bay																				

Table 1. Continued. b. Bivlaves.

	Bivalves	Family Arcidae	Barbatia	Anadara (C.) brasiliana	Anadara (L.) ovalis	Noetia (E.) ponderosa	Brachidontes (I.) exustus	Brachidontes (I.) recurvus	Atrina serrata	Aequipecten (P.) amplicostatus	Plicatula gibbosa	Anomia simplex	Family Ostreidae	Crassostrea virginica	Ostrea equestris	Diplonta semiaspera	Cardita (C.) floridana	Rangia cunesta	Donax v. texasina	Family Tellinidae	Tagelus (M.) plebeius
North Mustang Island-Beach									X			X	X				X		X		
Corpus Christi Ship Channel					X					X	X					X				X	
Mustang Island State Park-Sandbar										X											
Mustang Island State Park-Beach		X	X	X	X	X				X		X	X	X	X		X				X
Bird Beach Boat Basin-Sandbar										X										X	X
Bird Beach Boat Basin-Beach																					
Steadman Island Oyster Bar										X	X			X							
Gunderson's MarineOyster-Bar							X	X			X			X	X						
Copano Bay																		X			X

Table 1. Continued. C. Bivalves, arthropods, echinoderms, pices, polychaetes and inanimates.

	Dosina (D.) discus	Chione cancellata	Mercenaria campechiensis	Mercenaria c. texana	Corbula	Corbula ?	Periploma inequale	Arthropods	Balanid Barnacle	Crab claw	Arenaeus cribarius	Echinoderm	Mellita quinquesperforata	Pisces	Fish skull	Fish bone	Polychaete	Serpula sp.	Inanimate	Driftwood
North Mustang Island-Beach	X		X				X				X		X		X					X
Corpus Christi Ship Channel	X	X	X	X																
Mustang Island State Park-Sandbar	X		X			X														
Mustang Island State Park-Beach		X	X		X					X										
Bird Beach Boat Basin-Sandbar		X		X												X		X		
Bird Beach Boat Basin-Beach																				
Steadman Island Oyster Bar		X	X						X											
Gunderson's Marine Oyster-Bar																		X		
Copano Bay																				

currents constantly move the sediments and preclude the rooting of vegetation or establishment of sessile epifauna.

The shells of this station represent material *in situ* (collected live) and material carried northward and shoreward by wave induced and prevailing longshore currents.

The gulf beach station represents an ecologically complex area. Broad areas were alternately inundated with water and exposed to the air. High wave and current energies do not allow for a large epifaunal component. The only live epifauna observed were highly mobile and generally located near the first sandbar. The most conspicuous infaunal organism in the swash zone was the bivalve *Donax variabilis texasina* Reeve. *Donax* is brought to the surface by the surging water and crashing waves and quickly reburies itself before the next wave arrives. No other infaunal organisms were collected alive.

Station 2 is located along the shoreline of the Corpus Christi Ship Channel, one-quarter mile southwest of the University of Texas Marine Food Research Laboratory on north Mustang Island. This location is a "variable salinity sound environment" as defined by Parker (1959). Shells were collected along a sixty-five foot section of the beach, extending to one foot of water depth. Care was taken to ensure that no Pleistocene material, eroded out of the bank immediately north of the station, was collected. The older material was dredged out of the ship channel and is not characteristic of the present fauna of this environment. Inclusion of this older material in the analyses would have invalidated the usefulness of this station. The salinity was 33 $^{o}/oo$ at the time of collection, and the bottom was visible to depths below that which were sampled. Tidal currents moved shell material along the shore, and wave activity was almost non-existent.

The substrate was composed of fine sand and coarse silt-sized particles with locally abundant strands of shell material. The substrate was firm and relatively stable. Currents move the sediments along the beach to a lesser extent here than at the gulf beach station. There was no rooted vegetation, and the only plant material collected was derived from the nearby lagoon and floated in.

No live bivalves were collected. With the exception of Cantharus (P.) cancellarius, none of the gastropods were noted alive within the site. Numerous gastropod shells were collected with pagurid crustaceans (hermit crabs) in them. The majority of the shells collected at this site have been either biologically or mechanically transported to the location. Some of the shells represent the lagoonal environments to the southwest while most shells represent an inlet (or more normal saline) environment.

Station 3 is located in Redfish Bay on a sandbar off the beach in Mustang Island State Park, slightly north of the Fish Pass inlet. The site represents what Parker termed "inlet dominated." Samples were collected on a sandbar separated from the beach by a shallow (3 to 4 foot deep) channel filled with the seagrass _Thalassia testudinum_. Shells were taken from the south end of the sandbar in water depths of slightly less than one foot. The salinity at the time of collection was 32 $^{o}/oo$. Water visibility across the sandbar was unrestricted. The area is subjected to minor wave and current activity, and small current ripple marks were observed across the entire sandbar. Few shells were present on the surface of the sandbar.

The substrate was composed of fine sand-sized particles with very little clay and had a low organic content. Burrowing worms and sandtube worms were observed while the infauna was being collected. The sediment was firm and would not liquefy with agitation. The shallowness of water depth and the current activity act to exclude vegetation; no sessile epifauna were observed at this station. The shells of this station represent infaunal material and transported shells.

Station 4 is located in Redfish Bay on the beach across from station 3. Samples were collected from the shoreline and adjacent water to a depth of 6 inches. Salinity was 32 $^{o}/oo$, and the water was clear. Slow water currents move across the collecting area with minimal wave activity.

The beach has a fine sand, silt, and clay substrate with low shell abundance, and the sediment was organic rich. The surface was firm and was relatively stable being bound by algae and the sea grass Thalassia testudinum. Currents keep the shallow water nearshore areas from becoming anoxic and allow the lush growth of vegetation which would otherwise be impossible. The rooted vegetation provides protection. No shells were collected with live host organisms in them. Shell material was brought up to the beach from the channel/seagrass community by the hermit crabs, and most of the gastropod shells were found to be housing live hermit crabs.

The two Mustang Island State Park stations share similar water chemistry conditions but were physically different. The water from the Fish Pass inlet brings normal salinity organisms and shells to the back of the barrier island. These shells reach the beach but can not reach the sandbar across the shallow channel. The sediment of the sandbar is subject to intense heating during low tide in the summer. The water that flows across the sandbar is not significantly heated, but the sediment is.

Station 5 is located on a sandbar in Laguna Madre off of the beach at the Bird Beach Boat Basin in Padre Island National Park. This site represents Parker's "hypersaline lagoon." Samples were collected from a sandbar/spit formed on the north side of a storm washover channel. Shells were taken from a zone at the southernmost point of the sandbar. The water depth was a maximum of five inches. Salinity at the time of collection was 36 ^{o}/oo. The area is subjected to moderate wave and current activity.

The substrate was composed of medium sand-sized material and was low in organic content. The sediment was firm and slightly resistant to burrowing. The shallow water depth precludes the rooting of seagrasses, and the moderate currents remove most of the sessil epifauna. The shells of this station were primarily those of infaunal organisms. The gastropod shells were inhabited by hermit crabs.

Station 6 is located across from the sandbar at the Bird Beach Boat Basin. Shells were collected on the beach and adjacent shallow water areas. Salinity was 32 °/oo at the time of collection (it had rained within the past 24 hours), and the water was clear. Moderate currents flow across the beach from north to south, and wave activity was minimal.

The beach has a medium sand, silt, and clay substrate with low shell abundance. The surface was firm, relatively stable, and organic rich. There was rooted vegetation nearby, and the seagrasses help to baffle the wave energy before it reaches the beach. No live host were collected. Hermit crabs were found in the occupied gastropod shells, having removed these shells from the seagrass areas of the nearby channel.

The two Bird Beach Boat Basin stations were chemically and physically very similar. The currents from the northern end of Laguna Madre bring high salinity organisms and shells to this back barrier island station. These shells were transported to the sandbar/spit but did not reach the protected beach area across the shallow channel.

Station 7 is an oyster bank at the northern end of Redfish Bay on Steadman Island. Steadman Island is joined partially to Harbor Island (a predominantly man-made island) (Brown, et al, 1976). The closest Parker term for this location would be "shallow grassy bay." Samples were collected from an oyster bar (reef core) and surrounding areas. Water depth ranged from

2.5 to 3.5 feet. The salinity at the time of collection was 33 ^{o}/oo, and the bottom was visible throughout the total depth range. The area may be subjected to strong wave and current activity but is usually quiet.

The substrate was silty clay (around the reefs) and shell to shelly clay (in the reefs proper) and has a high organic content. The substrate was relatively soupy except where stabilized by the seagrass *Thalassia testudinum* or in the reef-proper.

The shells of this station represent material *in situ* (collected live), material carried out from Steadman Island during storms, and material carried in by hermit crabs. The reefs off Steadman Island were located adjacent to a wind-tidal flat (Brown, et al, 1976). This area is protected by Harbor Island from the inlet influence of Aransas Pass and the open gulf. The construction of the causeway between Port Aransas and Aransas Pass isolates this station from environmental influences to the north (separating Redfish Bay from Aransas Bay). This station was the only one in which live naticids (*Polinices*) were observed preying on bivalve hosts. There were spoil piles throughout the area, and care was taken to avoid collecting reworked Pleistocene materials.

Station 8 is located west of Gunderson's Marine Boat Shop in Portland, within Nueces Bay. The oyster bar is separated from the shore by a dredged channel, approximately 6 to 7 feet deep. This location is that of a "bay margin" as defined by Parker. Shells were collected from the reef and the shallow water areas around it. Care was taken when sampling not to collect material dumped when the channel was dredged. Salinity was 28 $^{o}/oo$ at the time of collection, and high water turbidity restricted visibility to less than one foot. There were moderate currents passing over the sampling location, and wave activity is at times strong enough to break shells off of the buildup, as evidenced by the amount of rubble in the sediments around the reef proper.

The reef and surrounding area has a clayey shell to clayey medium sand substrate with locally high shell abundance. The surface was unstable except in reefal areas. There was rooted vegetation (*Diplanthera* [*Halodule*] *wrightii*), which acts to stabilize the substrate and provide protection in areas around the reef. Several organisms were collected live. Live host organisms include both gastropods and bivalves.

The reefs at this station are in a protected part of Nueces Bay at the north end of the Highway 181 bridge. Low salinity water from the Nueces River mixes with the more saline waters of Corpus Christi Bay. Damage done to the reefs by dredging has had detrimental effect on the biota. Relatively few live oysters were observed on the reef proper, and most of the reef served as refuge for the mobile epibionts of the area.

Station 9 is situated at Black Point at the southern end of Copano Bay and is located at the point where the Aransas River and Chiltipin Creek empty into the bay. This site represents Parker's "river influenced low salinity estuary." Shells were taken from a zone within approximately 200 feet of the bridge. Water depths ranged between one to 2.5 feet. The salinity at the time of collection was 5 $^{o}/oo$, and the water was turbid. The water's turbidity at this location is the result of sediment being brought into Copano Bay by the Aransas River. The area was occasionally subjected to strong current activity.

The substrate was composed of medium sand, silt, and clay and has a relatively high organic content. The sediment was soupy except for patches which have been stabilized by the bivalve _Rangia_ _cuneata_ Gray. The margins of the area were sparsely vegetated with seagrass.

The shells of _Rangia_ at this station were removed from within the sediment. The live organisms were largely infaunal, and the shells of the dead organisms were lying at the sediment surface.

Interactions by Station

Each station is characterized by different and distinctive interactions. Table 2 shows the number of shells present at each of the localities. The degree of utilization of host shells and the relative percentages of the different types of non-predatory interactions are also indicated. These percentages are the result of the combined influence of water chemistry, substrate availabililty, currents, nutrients, and the compatibility of the organisms. In cases where the hosts were alive when the interaction takes place, the combined requirements of both organisms are important. The distribution of predation, especially of the gastropods, is controlled by the availability of suitable prey. Epibiontic and endolithic organisms utilize the shells of live and dead hosts. The physical character of the shell becomes more important than the ecology of the host organism when these guests use the shells after the death of the host.

The interactions from the beach of the Gulf of Mexico are presented in Table 3. Most of the shells from the beach were not involved in interactions. The shells which show the most intensive interaction, the

Table 2. Texas Coast shells with indication of utilization and interaction

Station	Total Shells	% None	% Epibionts	% Endoliths
Gulf of Mexico Beach	231	74.02	5.19	20.77
Corpus Christi Ship Channel	141	20.56	46.80	32.62
Mustang Island State Park, Sandbar	105	58.09	19.04	22.85
Mustang Island State Park, Beach	249	56.22	18.47	25.30
Bird Beach Boat Basin, Sandbar	51	80.39	15.68	3.92
Bird Beach Boat Basin, Beach	41	46.34	29.26	24.39
Steadman Island Oyster Bar	131	24.42	45.80	29.77
Gunderson's Marine Oyster Bar	87	28.73	52.87	18.39
Copano Bay	70	71.42	25.71	2.85

Total Shells = 1106

Table 3. Fauna and interactions from the North Mustang Island, Gulf of Mexico beach location.

	Host	Driftwood	Gastropod-general	Crepidula sp.	Oliva (I.) sayana	Bivalve-general	Atrina serrata	Ostreidae	Anomia-simplex	Cardita (C.) floridana	Donax variabilis texasina	Chione cancellata	Dosina (D.) discus	Mercenaria campechiensis	Periploma inequale	Crab claw	Arenaeus cribarius	Mellita quinquesperforata	Fish skull
None		2	6		1	21		5	1		16	1	3	2	2	2	1	105	1
Cliona						2		16											
Cheilostome bryozoan					1		3	3		1									
Natacid boring											6		1						
Oyster			1				1	4				1		1					
Polydora-small (.1-.5mm)		3		1	2			13		1									
Polydora-medium (.5-1mm)		2			2			9		1									
Polydora-large (1+mm)		1			1			1											
Sepulid worms							2	2											
Crab breakage					3														
Barnacle							4							1					

Ostreidae with greater that 72% of the shells showing some type of interaction, are not typical of the beach and were shells that have been brought in by currents and wave action. The most active guest organisms were the polydoran worms and the encrusting bryozoans. The gastropod Oliva (I.) sayana showed a tendency to be bored by the all sizes of the worm Polydora commensalis. The shells of Oliva did not possess hermit crabs when collected and were found in the deepest water of the collecting zone.

The interactions from the beach of the Corpus Christi ship channel at the Marine Food Research Lab are presented in Table 4. Most of the shells from the beach were involved in extensive interactions. Aequipecten (P.) amplicostatus, Plicatula gibbosa, and Mercenaria campechiensis contained the highest numbers of interactions of the bivalves found. Aequipecten and Plicatula were dominated by the activities of epibiontic organisms while Mercenaria was dominated by the borings of Polydora; the difference can be related to life habit of the host organism, Mercenaria being infaunal. Strombus(?) and Thais (Stramonita) haemastoma floridana were involved in the most interactions involving the gastropods. Thais was the most selected host species of this location. Guests of Thais include equal numbers of epibiontic and

Table 4. Fauna and interactions from the Corpus Christi Ship Channel location, North Mustang Island. a. Gastropod-general to *Chione cancellata*.

Host	Gastropod-general	Vermicularia fargoi	Cerithium (T.) floridanum	Crepidula (C.) sp.	Polinices (N.) duplicatus	Strombus?	Strombus alatus	Thais ?	Thais (S.) haemistoma floridana	Murex (P.) pomum	Busycon contrarium	Busycon spiratum plagosus	Bivalve-general	Anadara (L.) ovalis	Aequipecten (P.) amplicostatus	Plicatula gibbosa	Cardita (C.) floridana	Diplodonta (P.) semiaspera	Chione cancellata
None		1	1	1	4				1					1	1		3	1	10
Cliona						1										1			1
Cheilostome bryozoan					2	1	1	1	16	1	2		1	1	1	1			2
Naticid boring													1		1		1		11
Oysters					2	1	1		17	1	2		1		1	2			1
Barnacle					1	1		1	14	1	2	1		1	4	1			2
Polydora-small (.1-.5mm)	1				1	1			16	1	1		2	1	1				6
Polydora-medium (.5-1mm)					1	2		1	17	1			1		2				5
Polydora-large (1+mm)								1	3										3
Serpulid worm					2	1	1		15		2		1		2	1			1
Sand Tube worm					1								1						

Table 4. Continued. b. Dosina (D.) discus to Crassostrea virginica.

	Host	Dosina (D.) discus	Mercenaria campechiensis	Mercenaria c. texana	Tellinidae	Ostrea equestris	Crassostrea virginica
None		4	1	1	1	1	
Cliona			5			11	
Cheilostome bryozoans			3				
Naticid boring		1			1		4
Oysters			2			2	5
Barnacle			3			4	6
Polydora-small (.1-.5mm)			6			7	15
Polydora-medium (.5-1mm)			6	1		6	7
Polydora-large (1+mm)			2			2	4
Serpulid worm			3			2	4
Sand Tube worm							

endolithic guests. The most active guest organisms at this station were the cheilostome bryozoans, oyster spats, barnacles, all sizes of *Polydora*, and the serpulid worms.

The interactions from the sandbar at Mustang Island State Park are presented in Table 5. Most of the shells from the sandbar were not involved in any interactions. The bivalve *Aequipecten* (*P.*) *amplicostatus* was the most utilized bivalve host with only epibiontic interactions. *Polinices* (*Neverita*) *duplicatus* and *Busycon contrarium* were the most active of the gastropod hosts. *Polinices* shows a tendency towards *Polydora* borings over other interactions. *Busycon* had a more even mix of interactions with endolithic and epibiontic organisms. The most numerous interactions were with the barnacles, small polydorans, and crabs. Slightly less than three- quarters of the barnacles were found on gastropod shells with almost half of those on the shells of *Busycon*. The occurrences of the small polydorans and the signs of crab predation were concentrated on the shells of *Polinices*.

The interactions from the beach at Mustang Island State Park are presented in Table 6. Less than half of the shells from the beach were involved in interactions. *Chione cancellata* was the most selected

Table 5. Fauna and interactions from the Mustang Island State Park, snadbar location.

Host	Crepidula (Crepidula?)	C. (Janacus)plana	Polinices (N.) duplicatus	Thais (S.) haemastoma floridana	Cantharus (P.) cancellarius	Busycon contrarium	Aequipecten (P.) amplicostatus	Dosina (D.) discus	Mercenaria campechiensis	Corbula ?
None	9	23	18		1	1	2	4	2	1
Cliona		1	1			5				
Cheilostome bryozoans		1	3	1		5				
Muricid boring			1							
Naticid boring			!							
Oysters						4				
Barnacles			4	1	1	8	1	2	1	
Polydora-small (.1-.5mm)			14	3	2	6				
Polydora-medium (.5-1mm)			1	1	1	7				
Polydora-large (1+mm)			1	2		5				
Tube worm		1	1	1	1	6	1			
Crepidula (Janacus)plana							3			
Crepidula sp.			1			4				
Crab breakage			6	1	1					

Table 6. Fauna and interactions from the Mustang Island State Park, beach location. a. Littorina (L.) irrorata to Crassostrea virginica.

Host	Littorina (L.) irrorata	Crepidula sp.	Crepidula (C.) sp.	Crepidula (J.) plana	Polinices (N.) duplicatus	Terebra (S.) dislocata	Thais (S.) haemastoma floridana	Murex (P.) pomum	Cantharus (P.) cancellarius	Busycon ?	Busycon contrarium	Bivalve-general	Arcidae	Anadara (C.) brasiliana	Anadara (L.) ovalis	Barbatia	Noetia (E.) ponderosa	Ostreidae	Ostrea equestris	Crassostrea virginica
None	2	2	14	17	12	2	1				1	4				1				
Cliona			1		1		2	1			9		1				1	1	2	1
Cheilostome bryozoan							5	2	1		11			1						
Naticid boring					1				1						1					
Oysters				1			4				12						1	1	2	1
Barnacle					4		3	2			17			1			1		3	
Polydora-small (.1-.5mm)					5		6	1	2	1	16	2	1	1	1		2		2	1
Polydora-medium (.5-1mm)					3	1	5	1	2	1	17	2		1			1		3	1
Polydora-large (1+mm)					1		3												1	
Serpulid worm			5	1	1		6				19								1	1
Astrangia astraeiformis																				
Crepidula					1			1			3									

Table 6. Continued. b. <u>Aequipecten</u> (<u>P</u>.) <u>amplicostatus</u> to Crab claw.

Host	Aequipecten (P.) amplicostatus	Anomia simplex	Cardita (C.) floridana	Tagelus (M.) plebeius	Chione cancellata	Mercenaria campechiensis	Corbula	Crab claw
None	3	8	1	2	66			1
Cliona					9	1	1	
Cheilostome bryozoan					2			
Naticid boring					3			
Oysters	1				3			
Barnacle	1				7	1		
Polydora-small (.1-.5mm)	1				25	1	1	
Polydora-medium (.5-1mm)					12			
Polydora-large (1+mm)					1			
Serpulid worm								
Astrangia astraeiformis					2			
Crepidula								

bivalve host organism at this site. Slightly less than half of the *Chione* were involved in interactions, most of them involved with polydoran guests. The gastropods *Polinices* (*N.*) *duplicatus*, *Thais* (*S.*) *haemastoma floridana*, and *Busycon contrarium* were the dominant gastropod hosts. *Polinices* shows a similar relationship with endolithic polydorans on the beach as they have on the adjacent sandbar. *Busycon* interactions were almost evenly weighted between endolithic (oyster spats and barnacles being the dominant epibionts) and epibiontic organisms. *Thais* occurred almost exclusively as a host organism with few unutilized shells. The most active guest organisms were the oyster spats, barnacles, and smaller polydorans.

The interactions present on the sandbar at the Bird Beach Boat Basin station on northern Padre Island are presented in Table 7. Shells without interactions predominate in this environment where most of the hosts were infaunal, and the shells of the dead organisms were partially or wholly buried. The most active host was *Tagelus* (*M.*) *plebeius* with slightly less than a third of the shells showing an interaction. The most prevalent guest was the sandtube worm with all of its activity on *Tagelus*.

Table 7. Fauna and interactions from the Bird Beach Boat Basin, sandbar location.

Host	Cerithium (T.) floridanum	Anachia avara semplicata	Aequipecten (P.) amplicostatus	Tagelus (M.) plebeius	Chione cancellata	Tellinidae	Mercenaria campechiensis texana	Serpula sp.	Fish bone
None	6	1		19	1	10	1	1	1
Cheilostome bryozoan			1						
Naticid boring						1			
Polydora-v. small (<.1mm)				1					
Polydora-small (.1-.5mm)				1					
Sand Tube worm				6					

The interactions present at the beach at the Bird Beach Boat Basin station on northern Padre Island are presented in Table 8. With the exception of *Crepidula* (epibionts themselves), the only host shells present were those of dead gastropods, and they were utilized by hermit crabs. Over sixty percent of the shells present had some type of interaction with serpulid worms and *Crepidula* being the most active guests.

The interactions present on the reef near the Steadman Island station in northern Redfish Bay are presented in Table 9. Most of the shells were involved in interactions. The bivalve *Crassostrea virginica* was the most interactive host. *Crassostrea*, making up the reef structure, was affected by all of the present guest organisms. *Thais* (*S*.) *haemastoma floridana* and *Busycon contrarium* were the most interactive gastropod hosts. *Thais* was affected by an equal number of epibiontic and endolithic organisms; there were no unaffected shells present in the sample. The guest organisms on *Busycon* were predominantly epibiontic with cheilostome bryozoans and balanid barnacles present. The most active guest organisms were *Cliona* and oysters. Live *Cliona* were collected in *Crassostrea* shells only at this site. This station was the only one in which a live gastropod was found boring into the shell of a bivalve (a *Mercenaria* fragment).

Table 8. Fauna and interactions from the Bird Beach Boat Basin, beach location.

Host	Crepidula (C.) sp.	Polinices (N.) duplicatus	Busycon contrarium
None	9	3	
Oysters	2		1
Chama		2	
Barnacle	1	1	1
Polydora-small (.1-.5mm)		4	
Polydora-medium (.5-1mm)		1	1
Serpulid worm		8	1
Crepidula sp.		7	

Table 9. Fauna and interactions from the Steadman Island oyster bar location.

Host	Cerithium (T.) floridanum	Crepidula sp.	Crepidula (J.) plana	Thais (S.) h. floridana	Cantharus (P.) cancellarius	Anachis avara semplicata	Busycon contrarium	Arcidae	Aequipecten (P.) amplicostatus	Chione cancellata	Mercenaria campechiensis	Crassostrea virginica	Plicatula gibbosa	Barnacle
None	22	1	2		1	1		2	2	1				1
Cliona	1	1					1			2		54	1	1
Cheilostome bryozoan				1			5					30	3	
Oyster				2			3			1		81	6	
Barnacle				5			6			1	3	15	2	
Polydora-small (.1-.5mm)	1	1		6			4					36	6	
Polydora-medium (.5-1mm)		1		1			3			1		18	1	
Serpulid worm	1	1		4			6			1	3	30	7	1
Crepidula sp.				1			1							
Naticid boring												2		

The interactions present on the reef near Gunderson's Marine station in northern Nueces Bay are presented in Table 10. Most of the shells at this station were also involved in interactions. The oysters, Crassostrea virginica, Ostrea equestris, and Plicatulata gibbosa were the most interactive hosts. The epibionts on the oyster shells were the cheilostome bryozoans, oysters (adult and spat), and barnacles. This was not unexpected because the oysters make up the frame of the reef and were present for attachment by other organisms.

Few interactions were present at the mouth of the Aransas River station in southern Copano Bay (Table 11). Rangia cuneata dominated this environment and its interactions. Cheilostome bryozoans and barnacles were the dominant guests found on Rangia. These guest organisms were primarily concentrated on the anterior tip of the infaunal shell where the siphons are extruded. Guest organisms on other portions of the Rangia shell were found on the shells of dead Rangia lying on the sediment surface.

Specific Interactions

Throughout the stations sampled in this study, with the exception of the Copano Bay location, the guest organisms on bivalve hosts show no preference for attachment location which can be attributed to the life

Table 10. Fauna and interactions from the Gunderson's Marine (Portland, Texas) oyster bar location.

Host	Brachidontes (B.) exustus	Busycon contrarium	Crepidula (J.) plana	Polinices (N.) duplicatus	Serpula sp.	Ostrea equestria	Crassostrea virginica	Plicatula gibbosa
None	2	1				7	2	8
Cheilostome bryozoan	1			1		20	8	2
Oyster			1			30	7	15
Barnacle	1		2			3	9	
Polydora-small (.1-.5mm)			1			21	7	13
Serpulid worm			2		1	15	1	

Table 11. Fauna and interactions from the Copano Bay location.

	Host	
	Tagelus (.M) plebeius	Rangia cuneata
None		50
Cheilostome bryozoan	1	14
Oyster		8
Barnacle	1	17
Polydora-medium (.5-1mm)		2
Crepidula sp.		1
Brachidontes (I.) recurvus		4
Sand Tube worm		1

habit of the live host. The orientation of the epibiontic guest organisms was a function of the attitude of the shell on the substrate. The infaunal Rangia cuneata at Copano Bay had epifuanal guests located on the exposed portion of their shells. These surfaces provide some of the only substrate in this environment and were utilized by all available guest organisms.

In interactions between live gastropods and epibiontic guest organisms, no preference for attachment location was noted. Some of the gastropod shells were covered from the apex to the bottom of the body whorl by cheilostome bryozoans and/or were bored completely by the sponge Cliona. The distribution of the bryozoans on the conch and presence of the bryozoans and clionid borings inside of the body whorl indicate that the guest organisms interacted with the shell after the gastropod host had died.

The only clear evidence for crab predation was present at the beach station on the Gulf of Mexico side of Mustang Island. The shell material of the body whorl of the gastropod Oliva (I.) sayana has been peeled off in a pattern characteristic of crab predation (Schafer, 1980). Potential crab predation evidence exists in the shells of the gastropod Polinices (N.) duplicatus from the sandbar at the

Mustang Island State Park station. The body whorls of the *Polinices* were almost entirely removed. The poor condition of these shells and the degree of encrustation preclude labeling this as crab predation.

Some gastropod shells, especially those of *Polinices* (*N.*) *duplicatus* and *Busycon contrarium*, possess a unique distribution of epibiontic and endolithic organisms. The distribution of the guest organisms was not controlled by a live gastropod host but by the activities of the pagurid crustaceans (hermit crabs) which use their shells as homes. Gastropods hold their shells with the aperture downward or only slightly elevated to the front. The pagurids orient the aperture much higher (fig. 5a), relative to the substrate, and the way that they move the shell concentrates the guest organisms onto an area on the body whorl, one-quarter to one-half revolution behind the aperture (fig. 5b). The shell surface in contact with the sediment is uniformly clear of epibionts and endolithic organisms and shows signs of abrasion. This distribution of organisms was noted by Walker (1986) in samples from the modern shells of Bodega Bay, California and fossil shells from the California Pleistocene. She termed this activity 'pagurization'.

A single pagurid will use a wide range of shell sizes as it grows. Pagurids were observed in shells of

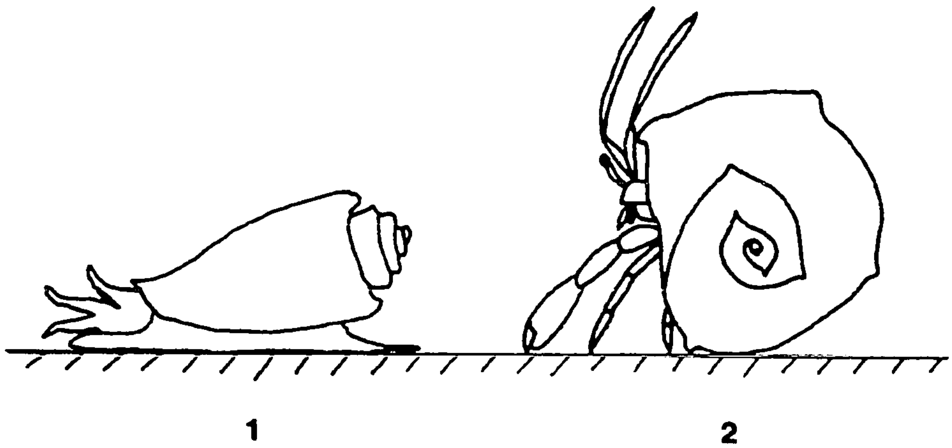


Figure 5a. Relationship of gastropod shell orientation to inhabitant: 1. gastropod, 2. hermit crab.

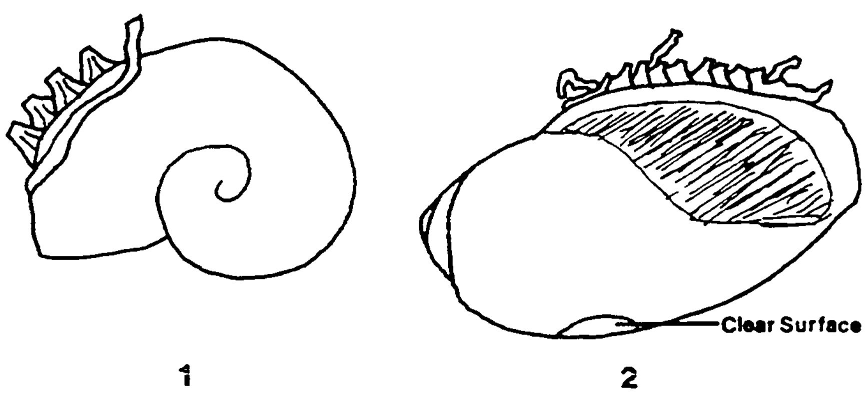


Figure 5b. Distribution of epibiontic guest organisms on pagurized shells. 1. Apical view, 2. Apertural view.

Cantharus (*Pollia*) *cancellarius* at station 6. These shells were less than 1 cm in length. Pagurids were observed in all of the sizes of the shells of *Polinices* (*N.*) *duplicatus* at the same station; some of these shells reached a length in excess of 20 cm. Utilization of all shell sizes, as observed in this study, would lead to the conclusion that the pagurids do not affect the shell size distribution of the gastropods as previously proposed (Walker, 1986).

The pagurids removed shells of gastropods from the seagrass and oyster reef environments, where live gastropods are found, and moved them into the shallow beach environments. To attempt to reconstruct the ecological structure of the beach community using the ecology of the live gastropod species, and not the pagurids ecology, would lead to erroneous conclusions. In the act of moving the shells, the pagurids were homogenizing the faunal component of laterally distinct environments. This biotransportation of shell material does not yield distinctive shell deposits. Unlike shells which have been transported by currents, the shells transported by the pagurids do not show any signs of being concentrated, oriented in the sediment, or size selected by the activities of the pagurids. Without the distribution of the epibiontic and endolithic organisms, the detection and proper utilization of pagurized shells' ecological information are extremely difficult.

Shells of the live gastropods and unoccupied shells of the dead gastropods did not display any preferred orientation of guest organisms. Most live gastropods had shells which were clear of endoliths, and a large number of these shells had no epizoans. The shells of the infaunal gastropods show an epizoan encrustation characteristic of epifauna if they are "pagurized." In the fossil record the presence of epibiontic guest organisms could indicate incorrect life habit information for the host species.

Station Relationships

A method for visually displaying the interaction character of the localities was developed for use in this study (fig. 6). The diagram uses the percentages of shells with epibiontic guests, endolithic guests, and the percentage of shells which were free of guests as apices. In this way, the diagram describes both the abundance of utilized shells and the types of organisms that use them. With this diagram, the general character of each locality is readily comparable to that at other locations. By presenting the data in this manner, it is possible to distinguish between stations with similar host fauna from different environments, if the environmental factors affect the

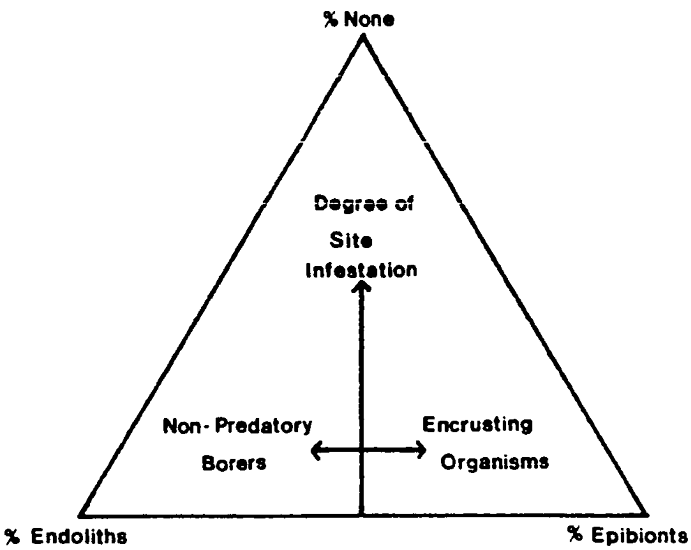


Figure 6. Ternary diagram used for the display and comparison of interactions found at the Texas Coast location. Points located at apices represent 100% of the sample.

availability of guest organisms, and between widely different environments, regardless of host distributions.

Figure 7 displays the positions of the interaction composition at each of the stations. The Gulf of Mexico beach, Bird Beach Boat Basin sandbar, and Copano Bay stations have the fewest shells involved in interactions. Each of these stations was populated by infaunal (or shallowly infaunal) organisms as the result of adverse conditions present at the sediment/water interface. The high-energy environment of the shoreface at the gulf beach location precludes inhabitance by most epifaunal molluscan species. The epifaunal gastropod shells found here were empty at the time of collection. The presence of large numbers of the sand dollar Melita quinquesperforata contributed to the low overall interaction intensity at the station. Live Melita were found on the second sandbar offshore (where the waves begin to break). When they die, their shells are brought to the shore by wave generated currents, and most are rapidly disarticulated by the crashing waves. This activity happens rapidly after death, and there is not enough time to develop interactions before these shells are destroyed. The presence of warm, stagnant, shallow water over the Bird Beach Boat Basin sandbar location precludes the

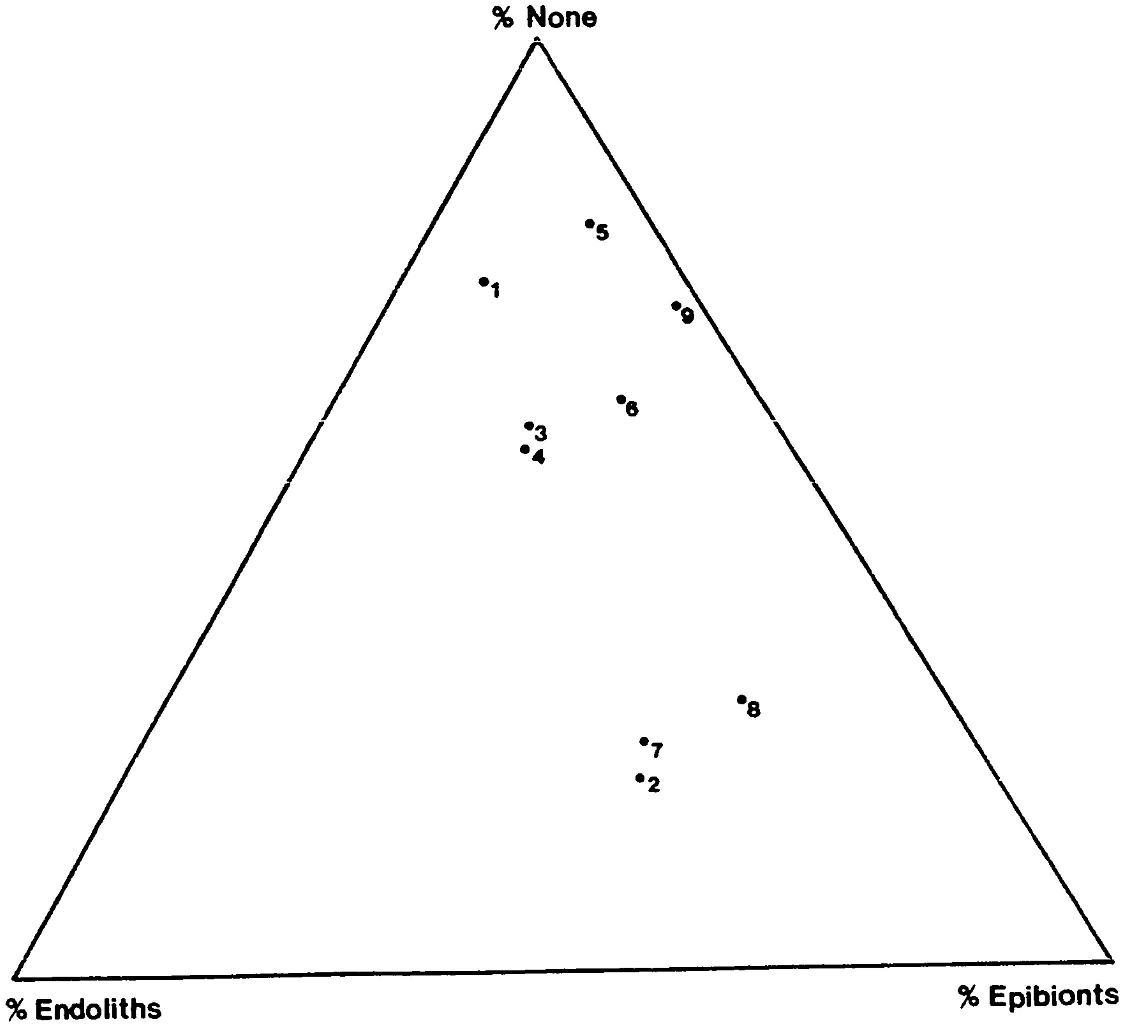


Figure 7. Percentage interactions present in the samples from the Texas Coast stations. 1. Gulf of Mexico beach, 2. Corpus Christi Ship Channel, 3. Mustang Island State Park sandbar, 4. Mustang Island State Park beach, 5. Bird Beach Boat Basin sandbar, 6. Bird Beach Boat Basin beach, 7. Steadman Island oyster bar, 8. Gunderson's Marine oyster bar, 9. Copano Bay.

formation of large epifaunal host populations, and all live host organisms collected there were infaunal. The shells that were exposed on the surface were those of thin-shelled bivalves (Tagelus and some tellinids) and some small gastropods. The shells are too thin to be bored by polydorans, and clionids are fragmented rapidly after exposure. The Copano Bay station has an exclusively infaunal host species component, and, although what was brought to the surface was utilized, this percentage was low relative to the standing host crop at any one time because of shell destruction (Cummins, et al., 1986a). As indicated by these three stations, the presence of a high percentage of unutilized shells in a fossil community may represent stressed environments. In the fossil record, rapid burial also may lead to underutilization of shells by interactants. The type of environmental pressures which result in low utilization can be varied, and the causes are not readily evident from the position of the station on the diagram.

Both of the Mustang Island State Park stations group close together. The similarity of the two stations is related to the overriding control of the waters of Fish Pass. Water depths were greater at this sandbar than at Bird Beach. The Mustang Island State Park sandbar station also differs in that it is continuously bathed by waters flowing in through Fish Pass. The water conditions allowed for a greater epifaunal host component on the sandbar. The water conditions on the sandbar did not differ from those of the shoreline, and, therefore, both stations from this location possess close interaction relationships.

The Bird Beach Boat Basin locations, sandbar and beach, were dissimilar. The sandbar at Bird Beach is a relatively stagnant water environment with no epifauna. Pagurid crabs, found in the channel separating the sandbar from the beach, take the gastropod shells out of the seagrass beds into the less harsh beach environment and not onto the sandbar. The only shells collected from the beach were pagurized gastropod shells. Lack of an infaunal component at the beach gives it a lower percentage of unutilized shells.

Both of the oyster bank stations, Steadman Island and Gunderson's Marine show extensive utilization of shell material by both epizoic and endolithic organisms. The substrate conditions relegate most epifaunal organisms to attachment on the reef mass. These stations have the largest percentage of host organisms present as epibiontic guest organisms. The degree of interaction at these locations shows a high degree of interdependence. Reduced salinity at the Gunderson's Marine station appears to adversely affect endolithic organisms (Cliona was not present here). More work needs to be done to establish the use of relative endolith/epizoan percentages to distinguish between inner bay and lagoonal oyster reefs.

The Marine Science Food Research Lab beach location has the highest percentage of utilized shells of the localities in the study. Most shells were utilized by more than one type of guest organism with both epizoans and endoliths present. The large number of interactions is explained in the nature of the shell accumulation at this beach. Shell material is moved along the beach by currents in the Corpus Christi ship channel. Shells are moved up into shallow water and are continuously maintained at the sediment surface by the same currents. Hermit crabs also carry the shells into this area of beach from the channel and were noted moving against the currents at ebb tide. Shell accumulation at this station is the result of physical and biological transportation. The high degree of shell utilization is a function of the amount of time that these shells are maintained on the surface.

Summary

The physical environment (substrate, salinity, water depth, turbidity, and wave activity) is the primary control of the distribution of the hosts and guests. The relationship between the types of interacting organisms and the environments that characteristic interaction pairs are found in is a complex one. The physiological requirements of both the host organism and the guest organism must have been relatively similar, if interaction occurred when both were alive. If the shell has been colonized after death of the host, only the requirements of the guest will lead to the correct interpretation of the depositional environment. The identification of transported shells in a fossil assemblage is important when using interaction pairs to determine paleoenvironment. Differences in the mechanisms of mechanical and biological transportation can yield differences in the amount and types of interactions.

The differences in the intensities of interactions between epifaunal and infaunal host species from the Gulf Coast stations are displayed in Table 12. With the exception of the Copano Bay locality, 18% or more of the shells of infaunal organisms were involved in interactions at each of the stations. The degree of shell utilization within the Texas coast areas studied is a function of the residence time of the shell on the sediment surface. Epifauna are subject to the activities of epibionts and endoliths throughout their lives. If the shell is maintained on the surface after death, by physical or biological means, a diverse set

Table 12. Intensity of interactions found within the epifaunal and infaunal organisms (as defined in the introduction) from the localities on the Texas Coast.

	Interaction Intensity	
	Epifauna	Infauna
Gulf of Mexico Beach	90.7	48.8
Corpus Christi Ship Channel	88.2	61.9
Mustang Island State Park:		
Sandbar	26.1	53.7
Beach	38.3	46.1
Padre Island State Park:		
Sandbar	11.1	18.4
Beach	25.0	78.6
Steadman Island Oyster Bar	68.9	92.3
Gunderson's Marine Oyster Bar	75.6	0.0
Copano Bay	0.0	26.4

of interactions can develop on the shell. Infaunal organisms that are brought to the surface have only the time until reburial to be involved in interactions. Depending on the time of their exposure, diverse and intricate interactions can develop on the shells.

It is possible that the mechanisms that maintain shells on the surface, and are engaged in interactions, keep the shells from being incorporated into the sediment and preserved. The data from the Humboldt Basin and the Kettleman Hills indicate that preservation of intensely utilized shells is the exception and not the rule in fossil accumulations.

HUMBOLDT BASIN

The Gulf Coast data has shown that there are diverse ecological elements that control the distribution and degree of organism interactions. Each of the stations represents the variations within an overall depositional setting. Differences from station to station were the result of faunal variations brought on by environmental differences. In time, these environments will migrate as the Texas coast builds outward, and the potential fossil record would include a mixture of shells from several adjacent environments.

In order to study interactions across a large environmental gradient, an area with directed changes in the depositional settings was chosen. The Neogene Wildcat Group of the Humboldt Basin, northern California (fig. 8) contains a continuous section of basinal to littoral sediments. The Humboldt Basin formed rapidly during Late Miocene. Through the Pliocene and into the Pleistocene, the basin was filled with sediments and became progressively shallower (Jennings, 1983). The changes in environments in the shoaling basin provide the setting for this portion of the study. Two sections in the onshore portion of the Humboldt Basin were sampled for macrofauna, one at Centerville Beach and the other along the Eel River by Scotia (fig. 9). The geology of the area and the

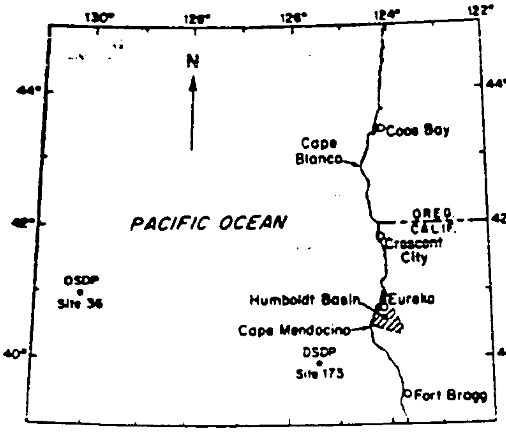


Figure 8. Index map showing geographic location of the Humboldt Basin (from Burckle, et al., 1980).

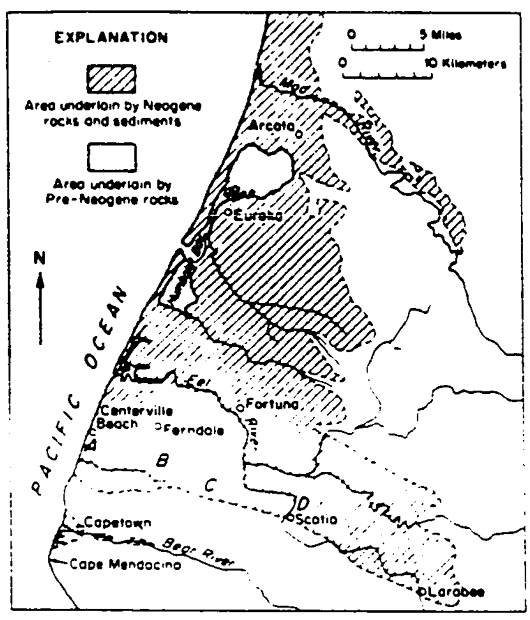


Figure 9. Generalized geologic map of Neogene strata of the Humboldt Basin showing the location of the text sections. A. Centerville Beach, B. Eel River (from Burkle, et al., 1980).

stratigraphy was first described in detail by Ogle (1953).

The Eel River section is located along the banks of the Eel River by the towns of Rio Dell and Scotia (fig. 10). The lower portion of the Wildcat Group (Pullen, Eel River, and lower portion of the Rio Dell Formations) is exposed on the west bank of the river, upstream from the town of Rio Dell. The upper portion of the Wildcat Group (the middle and upper portions of the Rio Dell, Scotia Bluffs, and Carlotta Formations) is exposed along the railroad tracks on the east bank of the river, downstream from the town of Scotia. The Centerville Beach section is located north of False Cape and Cape Mendocino (fig. 11). The rocks of the Wildcat Group are exposed in the seacliffs at this section. The northward dip of the beds provides easy access to the complete section along the coastline.

These sections have been sampled by other workers, and studies have been published on the diatom biostratigraphy (Burkle, et al., 1980), foraminiferal biostratigraphy (Haller, 1967), megafaunal biostratigraphy (Ogle, 1953, and Faustman, 1964), sedimentology (Piper, et al., 1976), carbon and oxygen isotopes (Kammer, 1979; and Dodd, et al., 1984), trace fossils (Jennings, 1983) and magnetostratigraphy (Dodd, et al., 1977). Many of the conclusions in this study

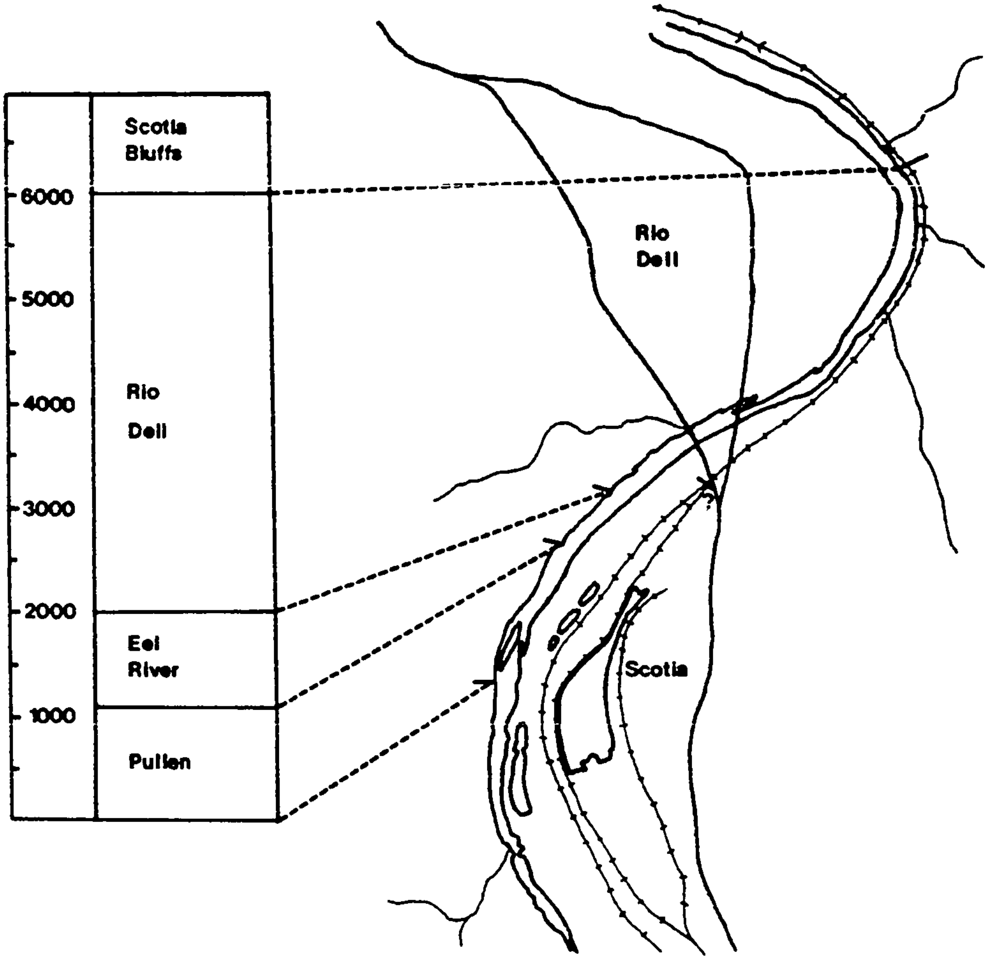


Figure 10. Stratigraphic section of the Wildcat Group at the Eel River section with map showing the collection zones by formational units.

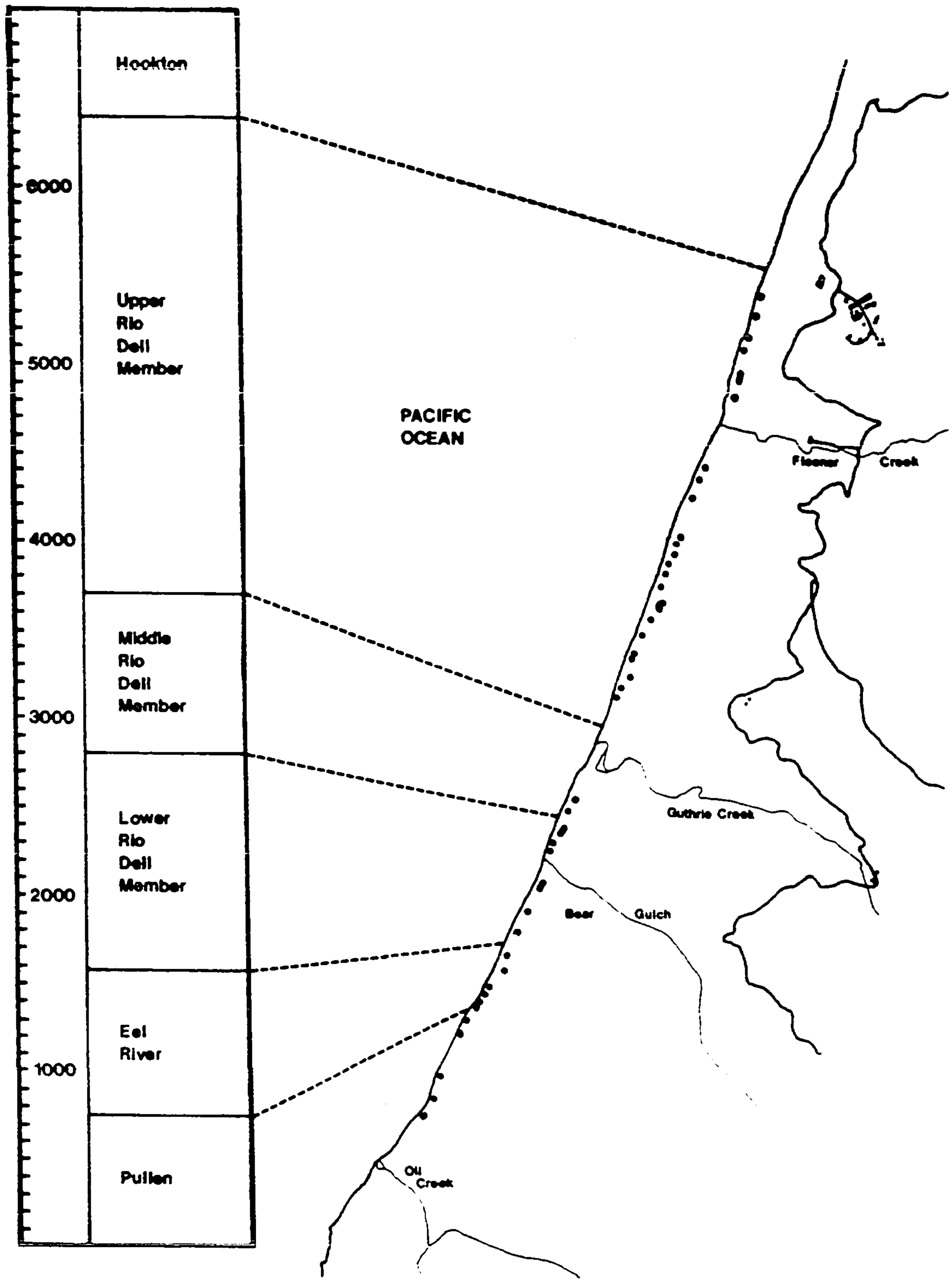


Figure 11. Stratigraphic section of the Wildcat Group at Centerville Beach section with map showing the collection zones by formational units. Black dots represent sample sites.

are based on the strong biostratigraphic and paleoecologic framework prepared by these previous studies.

The sediments of the Centerville Beach section represent the open marine, deep-water portion of the onshore Humboldt Basin whereas those of the Eel River section represent more basin-margin conditions. The samples used in this study were collected in situ. Precautions were taken to avoid the collection of "float" material. These precautions were taken to avoid mixing samples of stratigraphically distinct faunas.

Stratigraphy and Sedimentology

The Humboldt Basin formed at the site of convergence between the margin of the American plate and the margin of the Gorda plate (Dodd, et al., 1984). The initial transgressive phase of basin formation is represented by the Late Miocene to Early Pliocene shallow water deposits of the lower Pullen Formation (fig. 12). The upper Pullen, Eel River, and lower Rio Dell Formations represent deep water basinal sedimentation. As subsidence slowed and the basin filled, sedimentation graded upward into slope (middle Rio Dell Formation), shelf (upper Rio Dell Formation and Scotia Bluffs Sandstone), and continental deposits (Carlotta Formation) (Jennings, 1983). The Rio Dell

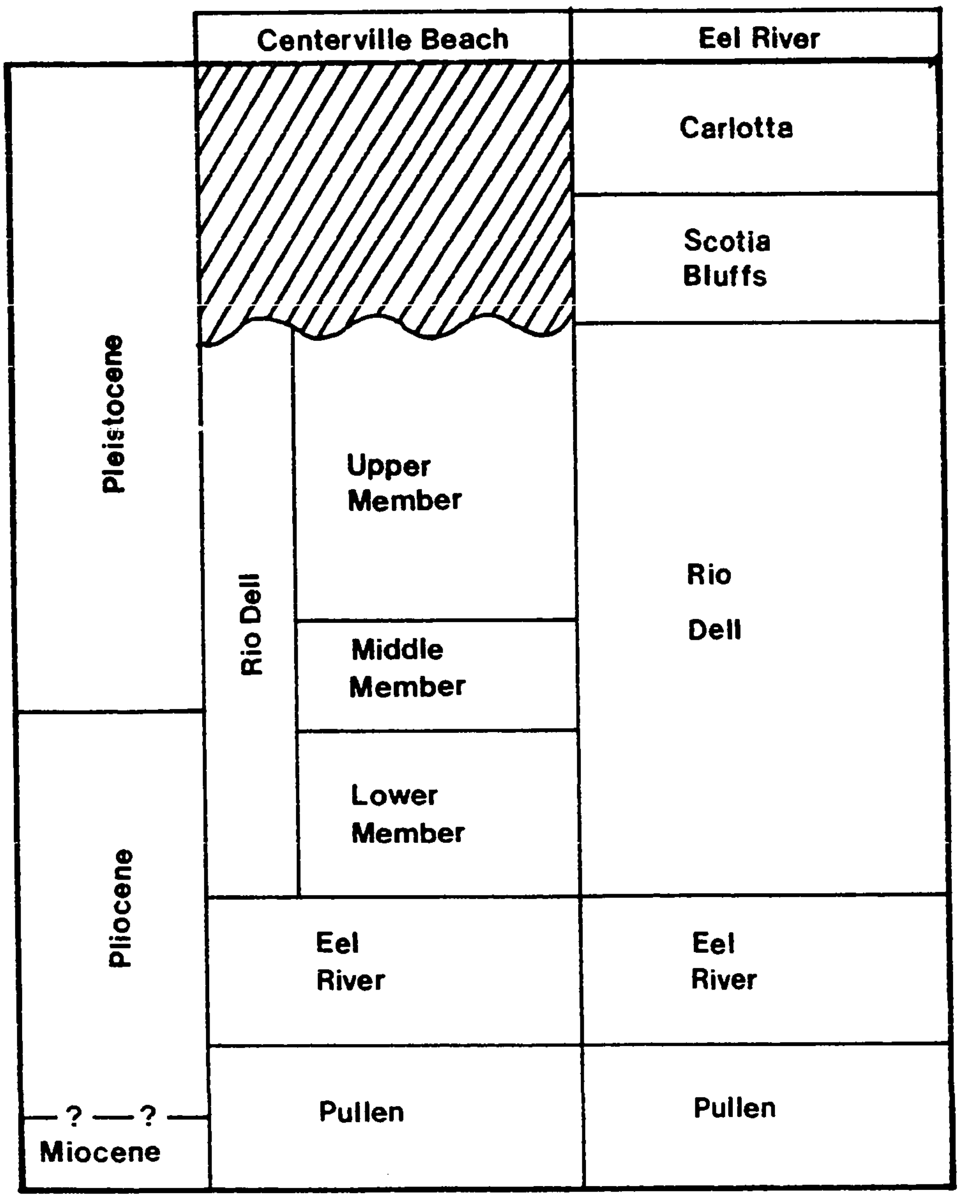


Figure 12. Comparison of the stratigraphic sections at the Centerville Beach and Eel River localities (after Burkle, et al., 1980).

Formation, undifferentiated at the Eel River section, can be subdivided at the Centerville Beach section based on lithology.

Eel River Section

With a total stratigraphic thickness in excess of 6000 feet, the Eel River section is one of the thickest continuous exposures of the Wildcat Group in the Humboldt Basin (fig. 13). The dominant lithology of the Eel River section is massive clayey siltstone. The distinction between the Pullen, Eel River, and Rio Dell Formations is based on the presence or absence of the mineral glauconite.

The basal portion of the Pullen Formation contains conglomeratic lenses of matrix-supported pebble and clay clasts. These lenses are developed on an unconformity surface between the Pullen Formation and the underlying Yager Formation. The lithology of the lower Pullen is indicative of deposition by debris flows. The Pullen Formation, about 400 feet above the base, grades into a fine-grained, conchoidally weathered, extensively fractured clay siltstone. The stratigraphic thicknesses of the Pullen at the Eel River and Centerville Beach sections are nearly equal.

The contact between the Eel River and Pullen Formations at the Eel River section is placed at the occurrence of a thin, pebbly interval and accompany-

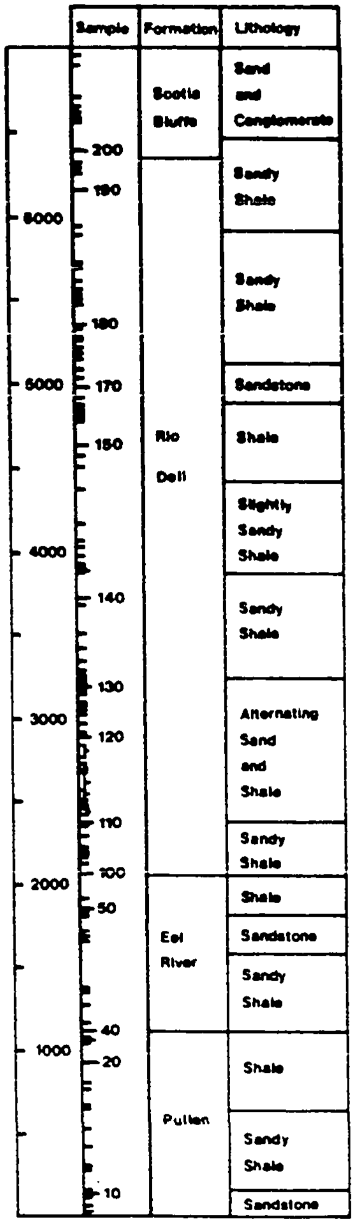


Figure 13. Stratigraphic section at the Eel River locality indicating lithologies and sample horizons. Sample numbers refer to the listing in Appendix IV.

ing glauconitic bed about 1200 feet into the section (Ogle, 1953). The lower portion of the Eel River Formation is composed of several glauconitic beds and coarse- grained, channelized glauconitic sandstones. The dominant lithology in the middle of the Eel River Formation changes from the glauconitic sand back to a darker, massive, weathered clay siltstone. The upper part of the Eel River Formation is composed of massive clayey siltstones with pebble clasts and wood fragments common.

The Rio Dell Formation is not subdivided into the Lower, Middle, and Upper Members at the Eel River locality because the changes in lithology are indistinct. The lower portion of the Rio Dell consists of fine-to-medium grained, poorly sorted sandstones which are interbedded with conchoidally weathered, fractured, clayey siltstones. Five hundred feet into the Rio Dell, the dominant lithology changes to massive clayey siltstones. The boundary between the lower and middle portions of the Rio Dell Formation at this section is gradational and is placed where the clayey siltstones give way to concretionary lenses and sandstone beds.

Most of the middle portion of the Rio Dell Formation is composed of massive clayey siltstones with exposures generally being covered by vegetation. The clayey siltstones grade into alternating beds of thick (10 to 20 feet), massive, fine-grained sandstones and massive, conchoidally fractured, weathered clay siltstones which grade back into clayey siltstones.

The "phantom-banded' sequence of the Rio Dell Formation appears at the boundary between the middle and upper portions of the Rio Dell. Texturally, the "phantom-banded" sequence is a cleaner, fine-grained sandstone. The typical sequence within the bands is that of a scoured basal contact with a basal shell lag, changing to a laminated sandstone, and finally to a homogenized (bioturbated) zone. The upper portion of the Rio Dell contains three "phantom-banded" sequences. Clayey siltstones, characteristic of the entire upper portion of the section, exist between these sequences. Six hundred feet below the top of the Rio Dell, the bands become less distinct, and the unit becomes finer grained.

The contact between the Scotia Bluffs and the Rio Dell Formations is gradational and is characterized by a change in lithology to massive, tan, medium-grained sandstones. The sandstones of the Scotia Bluffs are fine-grained at the base and grade into medium-grained sandstones and conglomerates near the top. Bi-directional crossbedding and bar-shaped sand and conglomerate deposits of the Scotia Bluffs Formation reflect the influence of wave and tidally dominated processes. Macrofaunal remains are found in the lower portion of this formation in the conglomeratic channel deposits (Jennings, 1983).

Centerville Beach Section

At the Centerville Beach section approximately 5600 feet of Wildcat Group sediments are exposed. The Centerville Beach section (fig. 14) begins at the base of the lower Pullen north of False Cape and is underlain by the mudstones and siltstones of the Upper Jurassic/ Lower Cretaceous Yager Formation. The contact between the Upper Rio Dell and the overlying Hookton Formation is unconformable. The dominant lithology at this section is a very fine-grained, massive, clayey siltstone with occasional fine-scale planar laminations.

The lower Pullen Formation at this section is a blocky, fractured siltstone and is characterized by the occurrence of glauconitic, sandy and conglomeratic lenses. The fauna found within this portion of the Pullen indicate shallow-water deposition. The middle Pullen is composed of mudstones with cream-colored concretions. These concretions have been interpreted as mudballs which may represent debris transported downslope into the basin along with some glauconitic material (Jennings, 1983). The upper portion of the

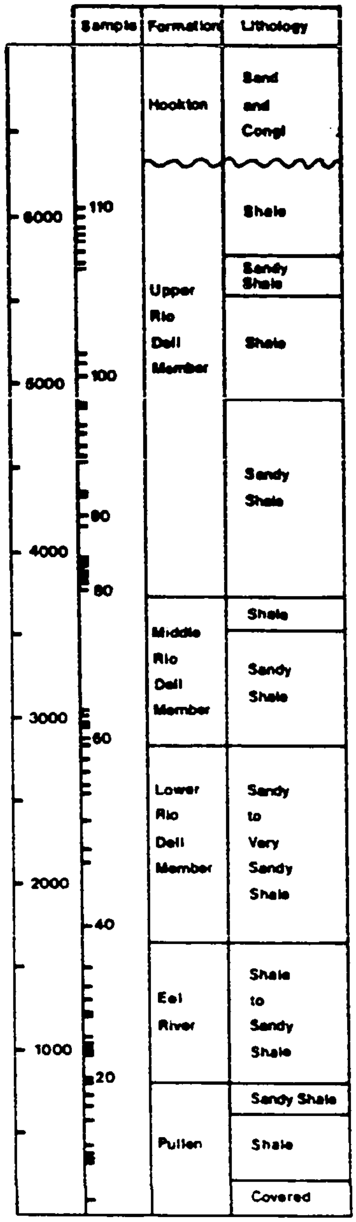


Figure 14. Stratigraphic section at the Centerville Beach locality indicating lithologies and sample horizons. Sample numbers refer to the listing in Appendix IV.

Pullen Formation consists of massive, conchoidally weathered clay siltstone and mudstone. Wood fragments, whale bone fragments, and concretionary lenses are common in this unit. Macrofauna are virtually absent in the Pullen Formation with the exception of some shells in the lower, shallow-water portion.

The presence of several glauconitic units marks the contact between the Pullen and Eel River Formations. The Eel River Formation is characterized by glauconitic units, massive clay siltstones, and bedded sandstone units. The base of the Eel River Formation is marked by several sandstone units with well-preserved A,B,C Bouma sequences. These thin-bedded turbidite units are overlain by thicker layers of massive, fine- to medium-grained sandstones. Individual channel lenses possess scoured, irregular basal contacts and are overlain by thin, ripple-dominated sandstones and glauconite beds. The sand lenses are surrounded by conchoidally weathered clay siltstone. Above the turbidite units, rhythmically interbedded layers of thin ripple-dominated sandstones and siltstones become dominant. The rhythmically bedded units are evidence of slower flow regimes characteristic of distal turbidite deposition and the presence of reworking currents. This sequence (the ripple-dominated sandstones) continues throughout the upper portion of the Eel River Formation and extends into the Lower and Middle Rio Dell Formation. The contact between the Eel River and the Rio Dell Formations is gradational and is marked by a reduction in glauconite content.

The Centerville Beach section of the Rio Dell Formation can be subdivided into the Lower, Middle, and Upper Members based on lithologic differences. The Lower Rio Dell Member consists of 1000 feet of thin-bedded, interbedded ripple-dominated sandstones and siltstones which are overlain by clay siltstone and claystone seams. The base of the Middle Rio Dell Member is marked by a change to rhythmically bedded, ripple-dominated sandstones. This sequence of ripple-dominated sandstones continues throughout the Middle Rio Dell.

The presence of several glauconitic lenses marks the transition between the Middle and Upper Rio Dell Members. Interbedded with these glauconitic lenses are lenses of thin sandstone, seams of thinly-laminated claystones, massive clay siltstone, and thin ash beds. Tan sandy concretions are also found at this level. Higher up in the section, clay siltstone with abundant bivalve and gastropod fragments, iron-stained concretions, and wood chip layers becomes the predominant lithology. Four hundred feet into the

Upper Rio Dell Member, the clay siltstone grades into layers of alternating sandstones and siltstones that are analagous to the "phantom-banded" sequences of the Eel River section. The banding is not as developed at this section. The Upper Rio Dell Member is characterized by the occurrence of alternating sequences of clay siltstones, claystone seams, and "phantom-banded" sediments. Some of the "phantom-banded" sandstones are characterized by the presence of basal shell lags overlying massive sandstones and planar laminated siltstones. These sequences are suggestive of either turbidite or storm generated deposition. Some of the exposures of the Upper Rio Dell Member are obscured by creek drainage, faulting, and landslides. The Upper Rio Dell is overlain unconformably by the Hookton Formation. The uppermost Rio Dell, Scotia Bluffs, and Carlotta Formations are missing in this section. The Hookton Formation is composed of medium-to-coarse- grained cross-bedded sandstones and conglomerates suggestive of continental deposition.

Depositional Setting

The depositional setting of the Humboldt Basin provides the framework for this paleontologic analysis. Ingle (1976), in his study of diatoms and foraminifera in the Humboldt Basin, proposed water depths and basin settings for the Centerville Beach section (fig. 15). Ingle places the Pullen Formation below water depths of 1900 meters on the basin plain. The Eel River Formation, Lower Rio Dell Member, and the lower half of the Middle Rio Dell Member were grouped into a deep sea fan classification with water depths starting at 1750+ meters and shallowing to 1200 meters. The upper portion of the Middle Rio Dell Member and the lower third of the Upper Rio Dell Member are basin slope deposits. The water depths rapidly decrease from 1200 meters to 200 meters. Ingle proposed that the upper two-thirds of the Upper Rio Dell Member were representative of outer shelf and shelf edge depostion. with water depths no shallower than 100 meters at the upper boundary unconformity. Jay Philips (oral comm.) believes that the water depths of Ingle's studies did not take into account the possibility of upwelling currents and that deeper water fauna could have lived at shallower depths. This would mean that Ingle's figures could be taken as lower limits to water depths.

Stanton (oral comm.) also feels that the depositional classifications of Ingle were too extreme and proposes that the Pullen and Eel River Formations at the Centerville Beach section represent basinal conditions (fig. 16). He feels that the Lower, Middle, and lower third of the Upper Rio Dell Members were

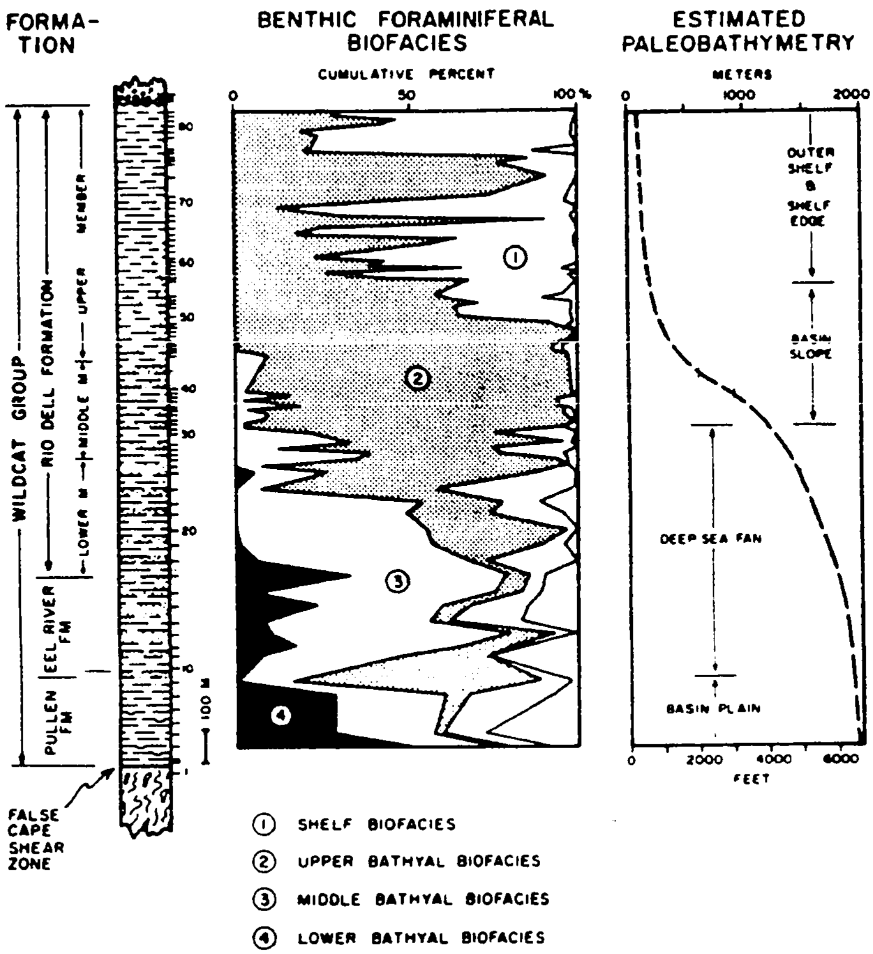


Figure 15. Benthic foraminiferal biofacies and estimated paleobathymetry for the Centerville Beach location (from Ingle, 1980).

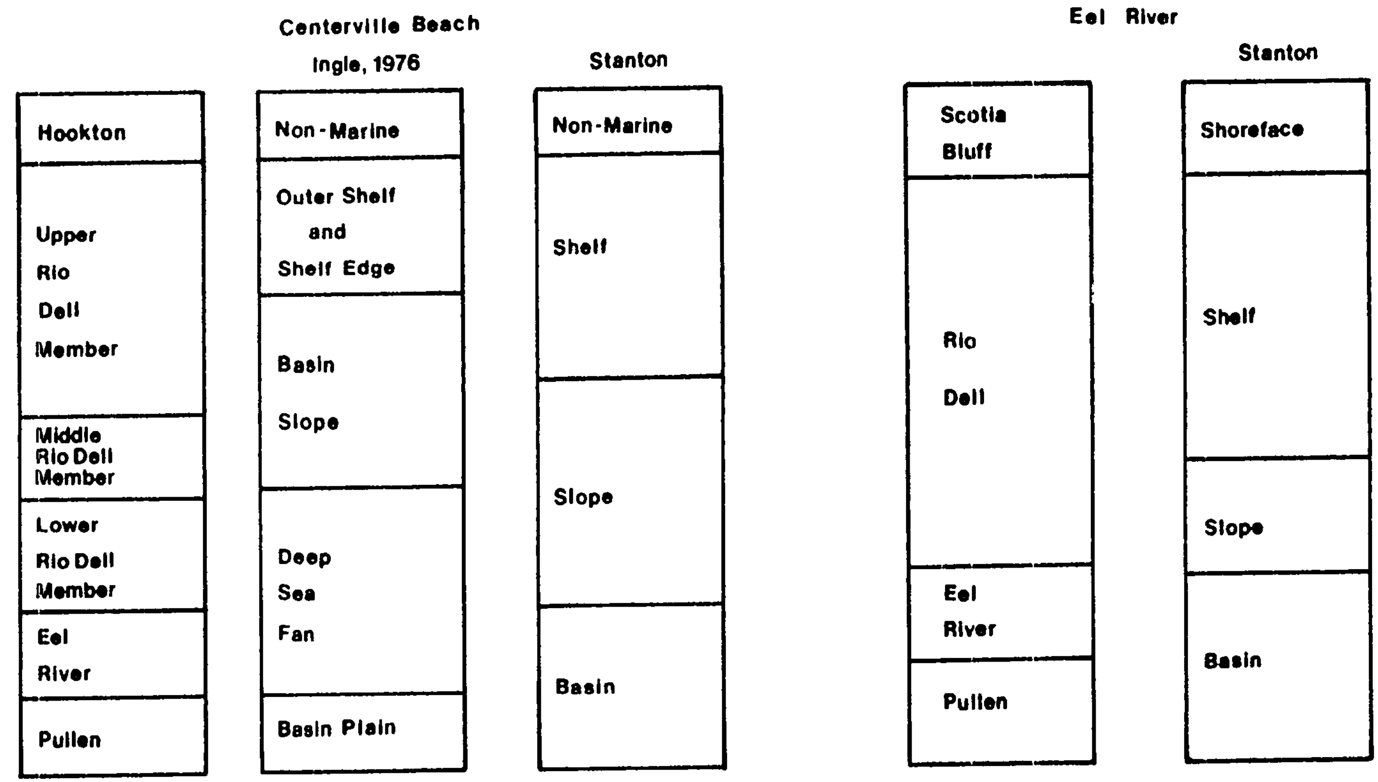


Figure 16. Estimated paleobathymetry of the Humboldt Basin sections as determined by Ingle (1976) and Stanton (unpublished).

deposited basin slope environments and the upper two-thirds of the Upper Rio Dell Member was deposited in shelfal conditions. The unconformity at the top of the Rio Dell Formation removes the shoreface environments, and the sediments of the Hookton are non-marine.

At the Eel River section, Stanton's interpretation of the environments of the Pullen and Eel River Formations is the same as at Centerville Beach, that of basinal sedimentation. The lower fourth of the undifferentiated Rio Dell Formation represents basin slope, and the remainder of the Rio Dell was deposited in a shelf setting. The shelf/shoreface boundary occurs around the contact between the Rio Dell and Scotia Bluffs Formations. After inspection of the samples, the author feels that the interpretations of Stanton are probably the most correct and that his environmental interpretations will be used in the formulation of the conclusions of this study.

Paleontologic Analyses

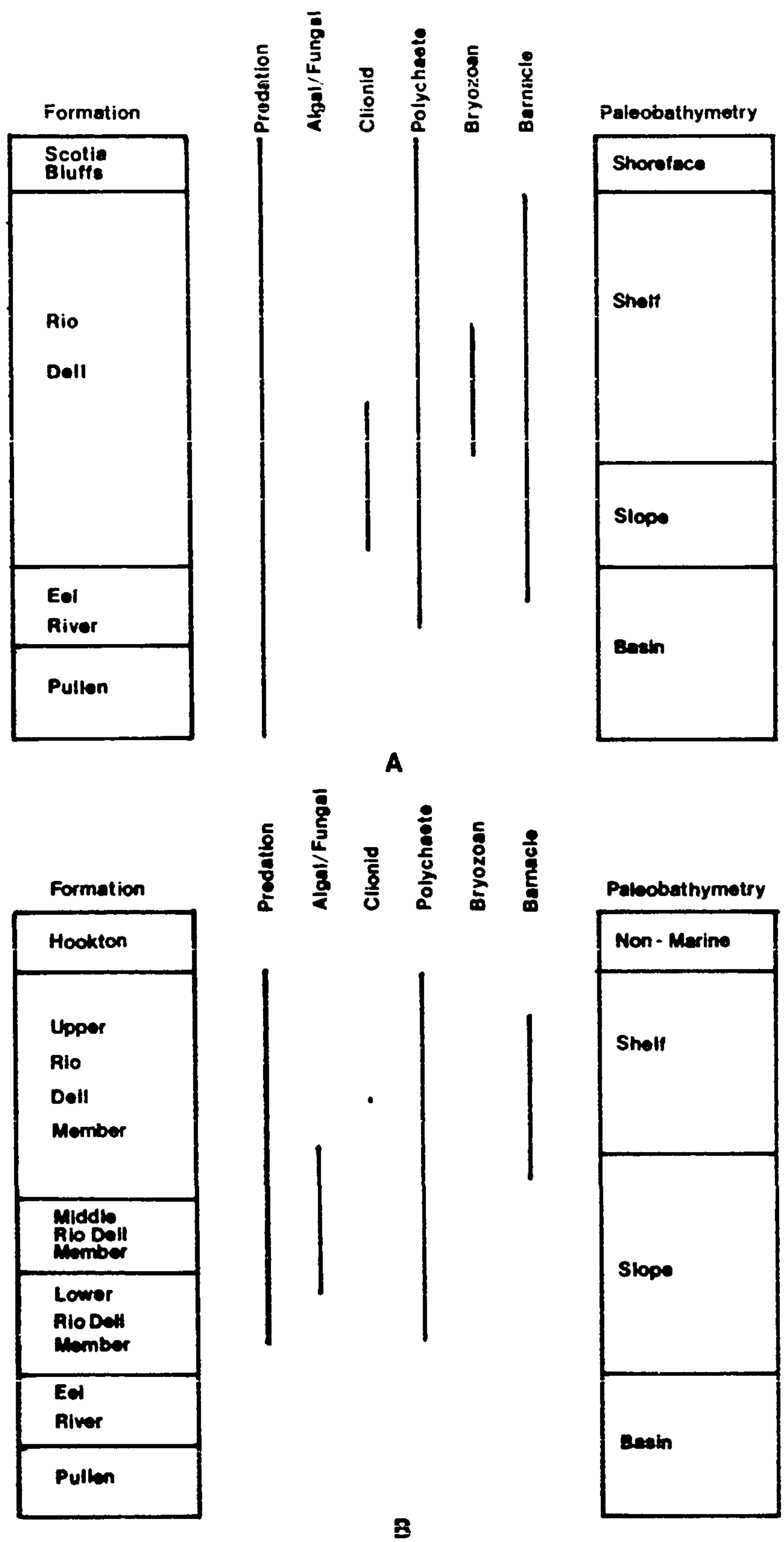
With the exception of bivalve epibionts, examples of each of the major types of interactions identified in the Gulf Coast study were observed in the samples from the Humboldt Basin. These types of interactions include gastropod predation, algal/fungal borings, clionid borings, polychaete borings, encrusting bryozoans, and encrusting barnacles. The number of interactions, in general, was low throughout both Humboldt Basin sections. Figure 17 shows the stratigraphic distribution of the interaction types for the Centerville Beach and Eel River sections.

The majority of shells collected from this area have fair to poor preservation, and identification below the generic, and sometimes familial, level was not possible. A listing of the fauna of the Humboldt Basin sections can be found in Appendix III. An additional listing of the samples, fauna, and interactions is included in Appendix IV.

The faunal collection from the Humboldt Basin include materials collected by Dr. R. J. Stanton, (Texas A & M University), Dr. J. R. Dodd (Indiana University), and the author. These samples comprise one of the most complete collections from the Centerville Beach and Eel River sections.

Fossil abundance was low throughout the lower two-thirds of the section (the Pullen, Eel River, and lower Rio Dell Formations) at each of the locations (plates I and II provide a summary of the data for each locality). The samples that were available, in the lower portions of the section, were very sparse. The samples from these units represent the original fauna as best as can be obtained. These samples will be

Figure 17. Stratigraphic and paleobathymetric distribution of guest organisms at the A. Eel River section and B. Centerville Beach section.


Formation
Scotia Bluffs
Rio Dell
Eel River
Pullen
Predation
Algal/Fungal
Clionid
Polychaete
Bryozoan
Barnacle
Paleobathymetry
Shoreface
Shelf
Slope
Basin
A
Formation
Hookton
Upper Rio Dell Member
Middle Rio Dell Member
Lower Rio Dell Member
Eel River
Pullen
Predation
Algal/Fungal
Clionid
Polychaete
Bryozoan
Barnacle
Paleobathymetry
Non - Marine
Shelf
Slope
Basin
B

treated as being representative of an original depauperate fauna and analyzed as such. The conclusions reached in this section are those justified by the sample and do not include conjectural species compositions.

Relative to the number of shells in the collection, the percentage which contains interactions is small. The numbers of interactions in individual samples range from 5 % to 20+ % of the shells present. In samples of fewer than ten specimens, the percentages of each type of interaction appear to be arbitrarily high. As sample size increases upwards in the section, the percentage of the total that each type of interaction comprises becomes less. These relationships indicate that the percentage of each interaction type in the small samples should be viewed as being the upper limit for that type of interaction within that sample. The extreme variability in sample size, from one to more than 100 per sample, caused concern about the relationship between the interaction intensities and sample size. The samples from the Centerville Beach and Eel River sections were placed into groups based on stratigraphic position and lithologic character to allow for the comparison of interaction intensity trends and sample size (figs. 18 and 19). As figures 20a and 20b show, the number of

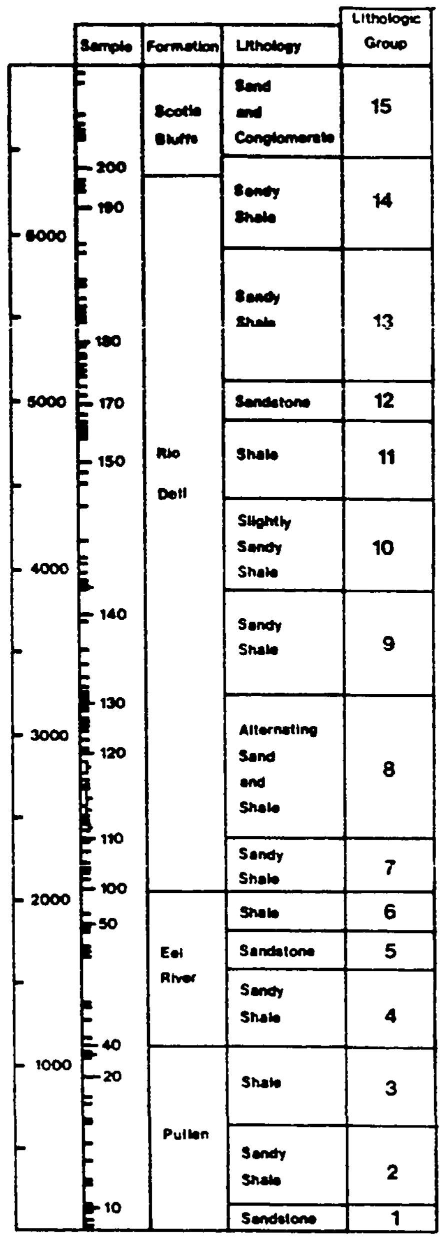


Figure 18. Lithologic groups as defined for the Eel River section.

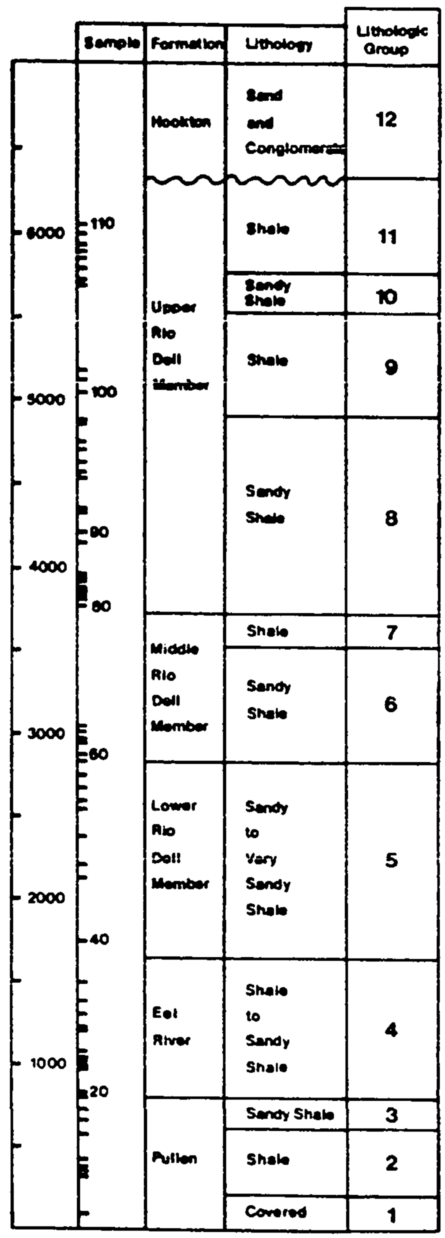


Figure 19. Lithologic groups as defined for the Centerville Beach section.

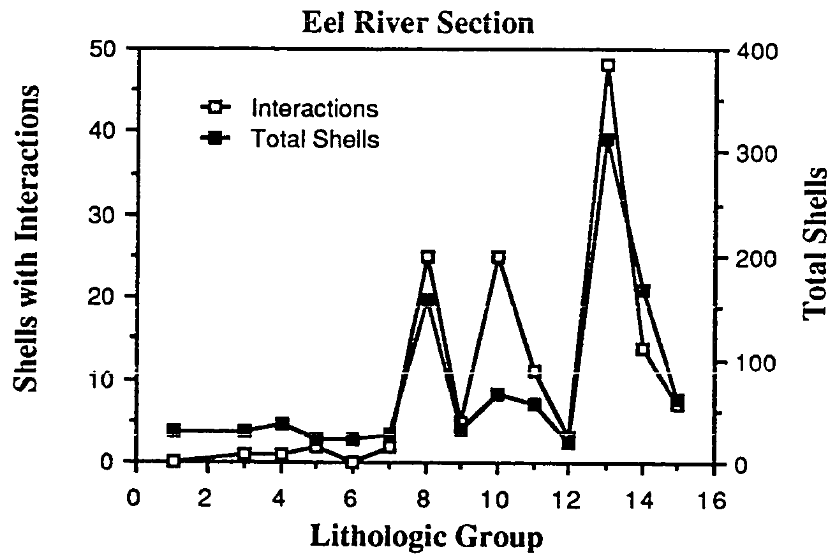


Figure 20a. Sample size (total shells) and number of interactions by lithologic groups for the Eel River section. (Note different Y-axis scales.)

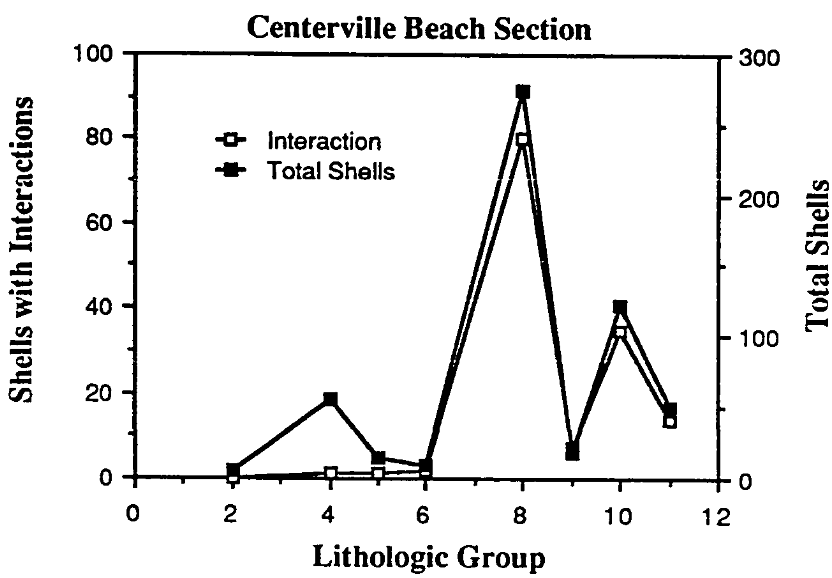


Figure 20b. Sample size (total shells) and number of interactions by lithologic group for the Centerville Beach section. (Note different Y-axis scales.)

shells with interactions varies with the total number of shells within each lithologic group.

The distribution of samples within the section and the low total number of shells within some of the units do not allow for normal statistical comparison. Figures 21a and 21b display the relationship between the total numbers of shells and the interaction intensities. It is clear from these figures that the interaction intensity is not simply a function of sample size. The similarity of patterns within the two sections indicates that common ecologic controls on interactions play a part in the distribution of guests.

Organism Interactions

Gastropod Predation

The gastropod predators are represented in the Humboldt Basin section by the borings of members of the families Naticidae and Muricidae. The bivalve Macoma elimata was the first utilized prey of naticids at both sections. The first naticid boring, at the Eel River section, occurs 700 feet below the first appearance of naticids. The lowest occurrence of a naticid boring was at the top of the Pullen. The first naticid, Natica (Cryptonatica) clausa, appears at the top of the Eel River Formation. The first naticids of the Centerville Beach section appear at the base of the Eel River Formation, while the first naticid boring was not

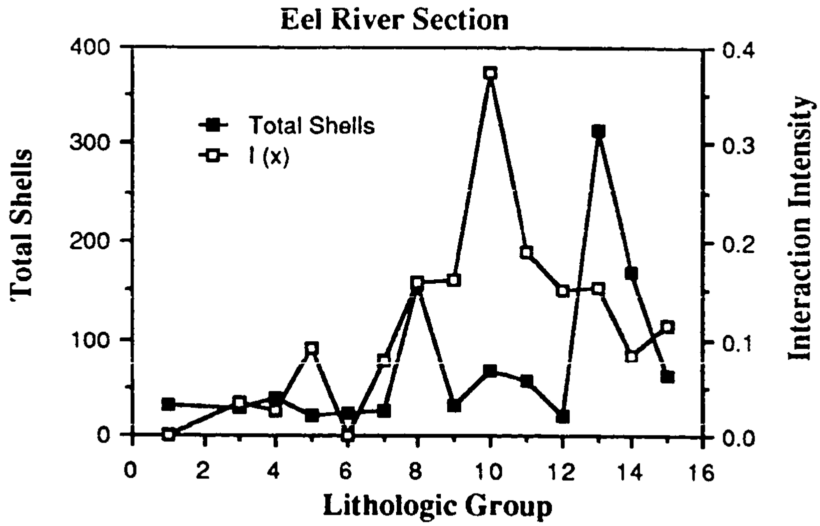


Figure 21a. Total shells vs. interaction intensity by lithologic group for the Eel River section.

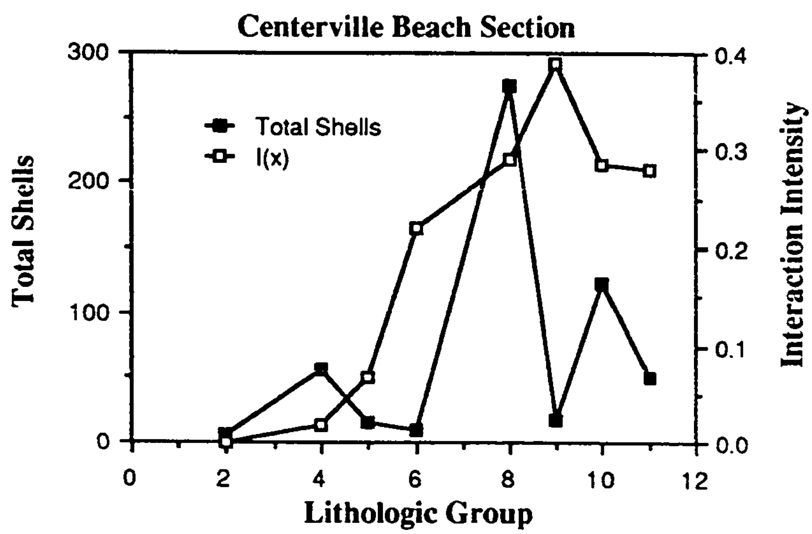


Figure 21b. Total shells vs. interaction intensity by lithologic group for the Centerville Beach section.

found until 1100 feet higher in the section, in the Lower Rio Dell Member. At both sections, muricids and muricid borings occur higher in the section.

To determine general prey preference, the dominance ratio of bored bivalves to bored gastropods in each section was computed. Figures 22 and 23 show the dominance ratio of prey selected between bivalves and gastropods. This dominance ratio is presented along with the dominance ratio of potential bivalve to gastropod prey. To determine values for total shell and prey dominance, the following formulas were used:

if bivalves were dominant,

$$\text{Dominance Ratio} = -\frac{\text{Bivalves}}{\text{Total (Bivalve+Gastropod)}}$$

if gastropods were dominant,

$$\text{Dominance Ratio} = +\frac{\text{Gastropods}}{\text{Total (Bivalve+Gastropod)}}$$

(The dominance ratio was developed solely for the display of data, and no inherent significance of the values should be assumed.) The pattern of prey preference of the gastropods is different between the two sections. The Eel River and lower portion of the Rio Dell Formations at the Eel River section (fig. 22), have a dominance ratio of bivalve to gastropod prey of -1. This ratio begins to change at the shelf slope break. From one-quarter of the way into the Rio Dell

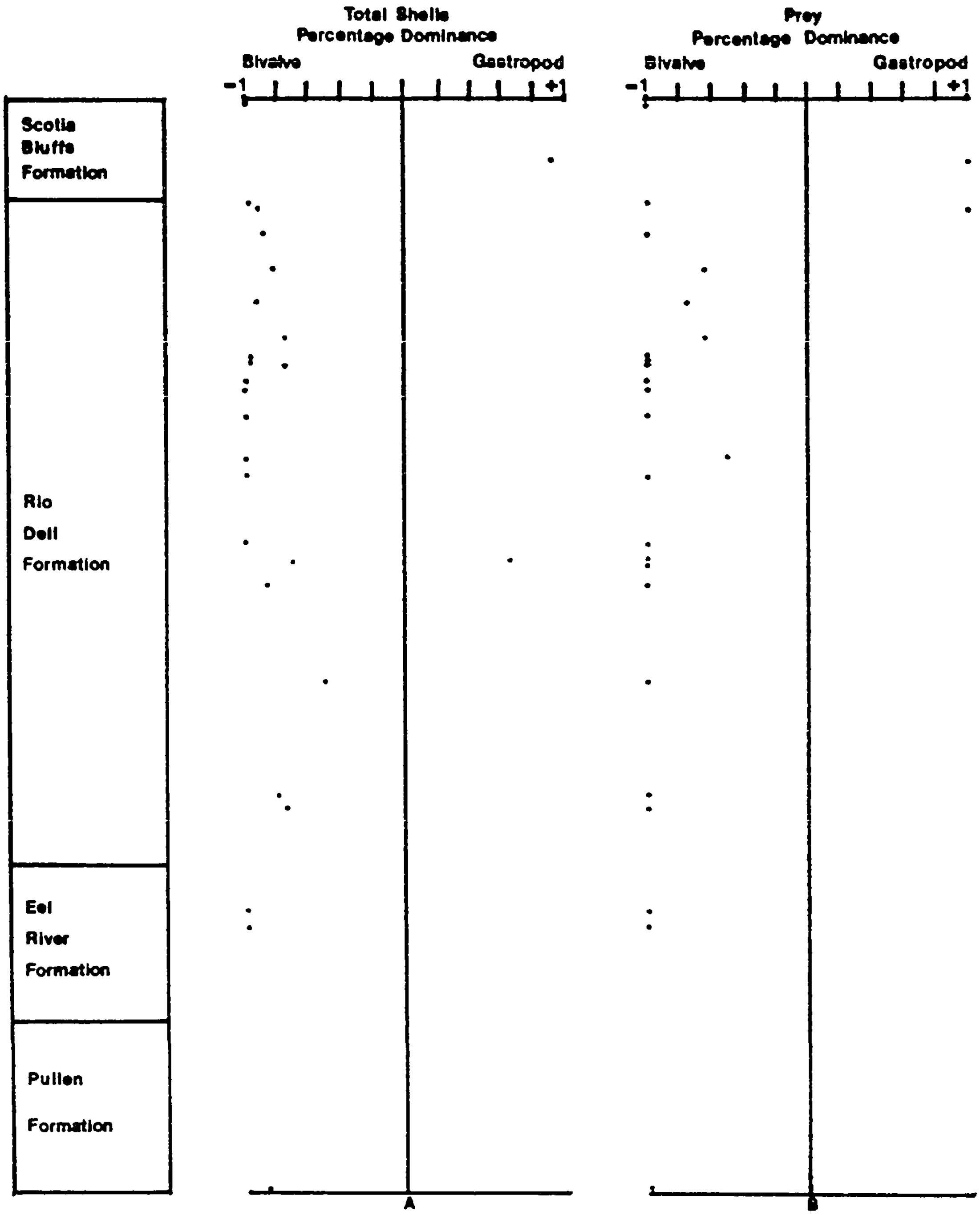


Figure 22. A. Total shell bivalve/gastropod dominance for samples with gastropod boreholes at the Eel River section. B. Prey bivalve/gastropod dominance percentages within samples with boreholes.

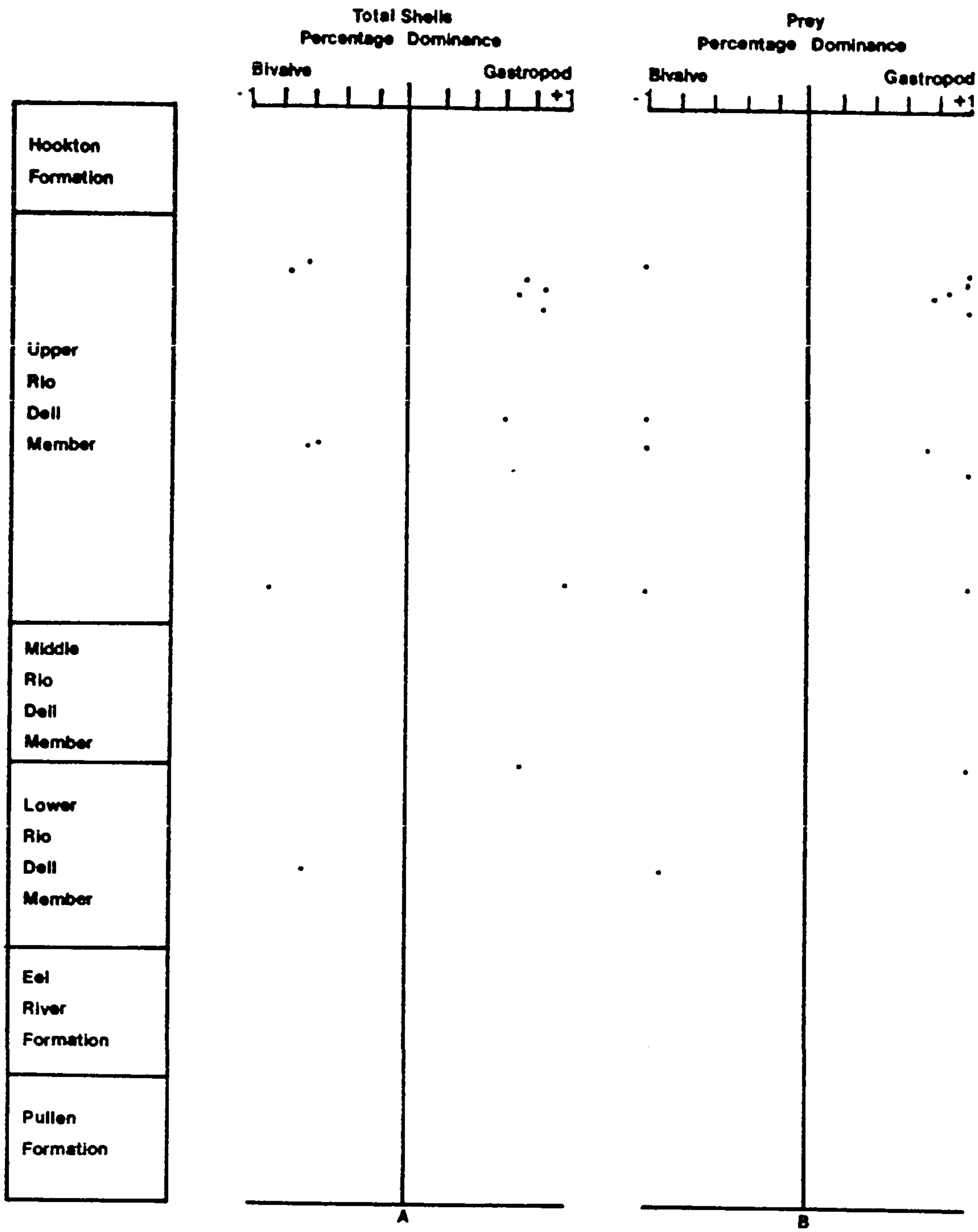


Figure 23. A. Total shell bivalve/gastropod dominance for samples with gastropod boreholes at the Centerville Beach section. B. Prey bivalve/gastropod dominance percentages within samples with boreholes.

to the top, the bivalves were utilized to the exclusion of all gastropod prey species except for instances of continued predation on Natica (Cryptonatica) clausa (fig. 24). Predation incidents increase upward in the section with naticids being the dominant borer throughout. The total number of specimens increases upward in the section but is not paralleled by an increase in the number of incidents of predation. The increase in number of bored individuals is a reflection of the appearance of key bivalve prey species. Near the Rio Dell and Scotia Bluffs contact the number of specimen and borings decrease. The shells collected from the Scotia Bluffs Formation were found in lag deposits. Because the material was brought into the area from elsewhere, no environmental interpretation can be presented.

The character of the dominance ratio of bivalve to gastropod prey at the Centerville Beach section was different (fig. 23). Throughout the section the dominance ratio fluctuates as the number of incidents of predation increases upward throughout the Rio Dell. Although the dominance ratios vary widely throughout the section, the gastropod borers show no change in overall preference as the inferred water depths decrease. The deeper water prey species (gastropod) continue their range into shallower waters and continue

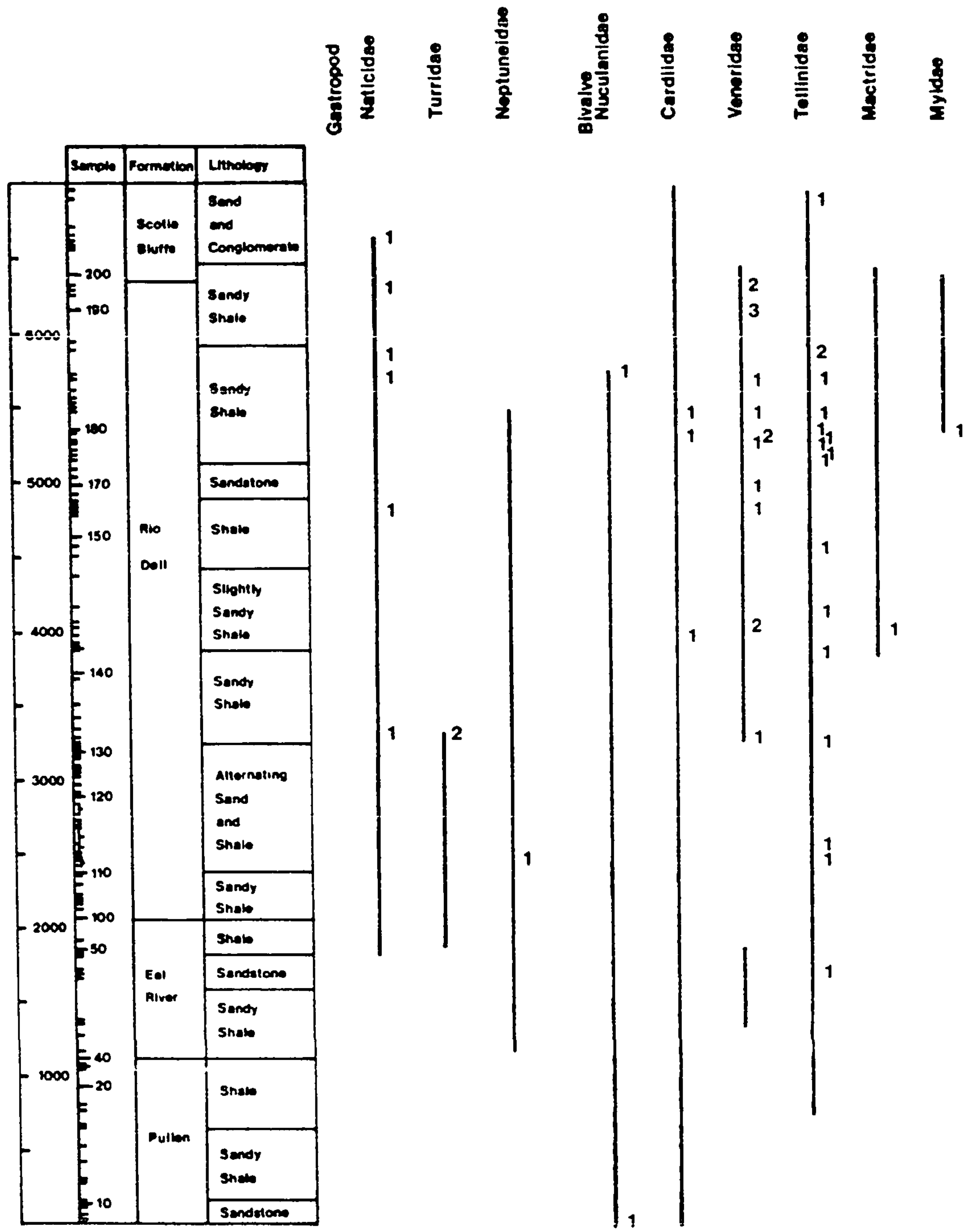


Figure 24. Distribution of prey gastropods and bivalves for the Eel River section. The numbers represent bored shells. The black lines show the range of the prey within the section.

to be preferred over bivalves (which become more abundant upward). The amount of gastropod predation does not diminish upwards in the Rio Dell, and the record was abruptly terminated at the contact between the Rio Dell Formation and the non-fossiliferous, continental, Hookton Formation(fig. 25).

The preferred gastropod as gastropod prey at the Eel River section was the naticid Natica (C.) clausa. Predation on N. (C.) clausa begins at the shelf/slope break and continues into the Scotia Bluffs, shoreface portion of the section. Other gastropods found bored at the Eel River section are Antiplanes (A.) major, Antiplanes perversa, and Beringius (?), each of which have only one specimen with a borehole within the section. As with Polinices at the Texas Gulf Coast, the naticids appear to have been a preferred prey of themselves. At the Centerville Beach section, the number of specimen with boreholes was greater. The majority of the gastropods as their own prey are found within the naticids, muricids, and turrids with a slight preference towards the muricids and turrids in the upper portion of the section. Latisipho hallii was the only neptuneid species preyed upon within the section. Other members of the family are present throughout the section but were not attacked.

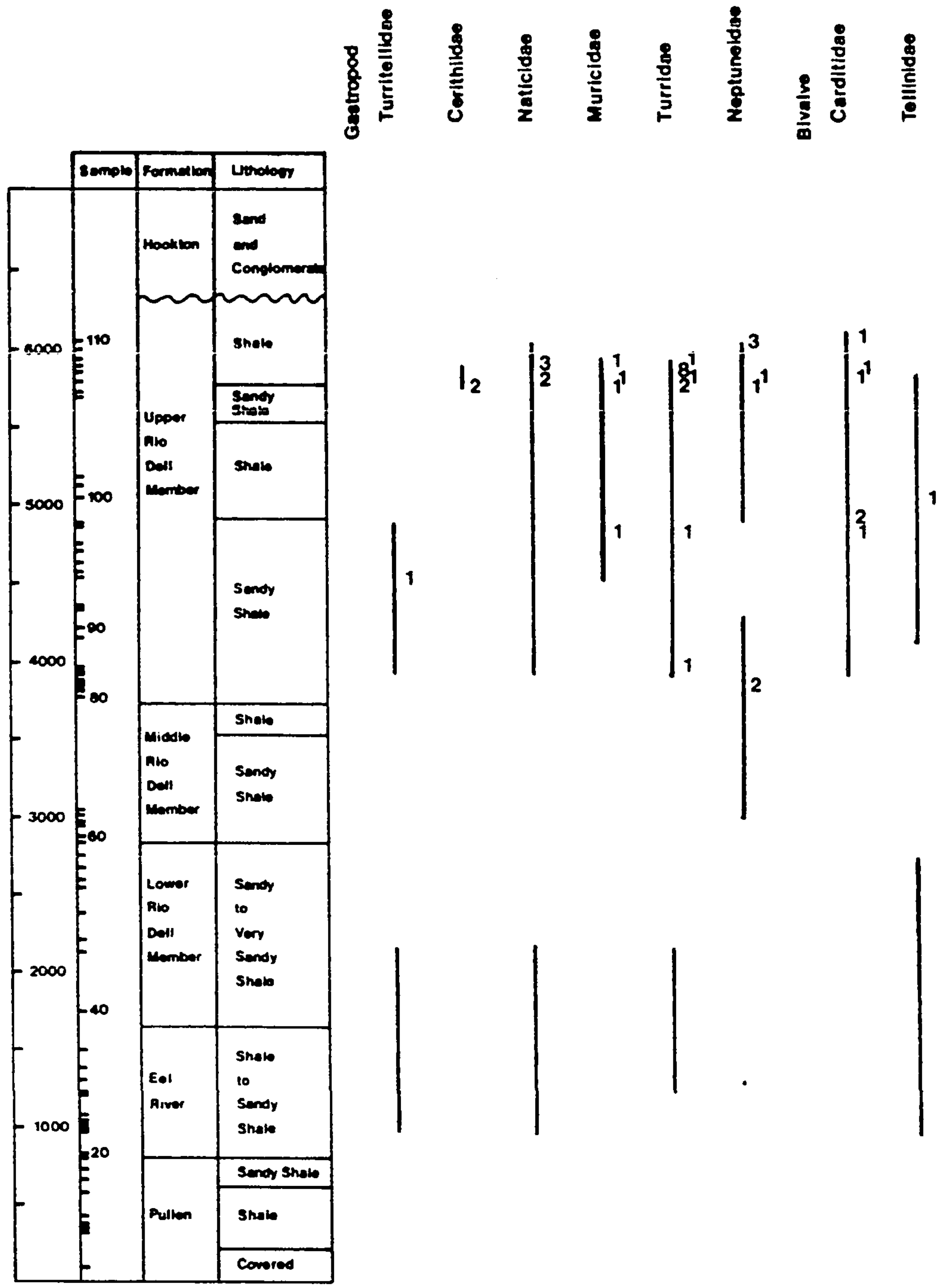


Figure 25. Distribution of prey gastropods and bivalves for the Centerville Beach section. The numbers represent bored shells. The black lines show the range of the prey within the section.

A disproportionally larger number of reports of gastropod borings in the shells of the bivalves was found at the Eel River section. The preferred bivalves as gastropod prey at the Eel River section are from the order Veneroida and are concentrated in the families Veneridae and Tellinidae. Table 13 lists the bivalve prey.

Table 13. Bivalve species bored by gastropods at the Eel River section and number of incidents of predation.

Bivalve Prey	# of shells attacked
Protothaca staylei hannibali	7
Psephidea lordi ovalis	5
Macoma elimata	5
Macoma inquinata arnheimi	4
Macoma nasuta	2
Clinocardium meekianum	1
Nuculana fossa	1
Cryptomya (?)	1

At the Centerville Beach section the reverse condition is true; the number of bivalves with gastropod boreholes is much fewer than those in gastropods. The bivalve most commonly preyed upon was the carditid *Cyclocardia ventricosa*. Predation on this Cartididae did not occur below the base of the Upper Rio Dell Member even though specimen of *C. ventricosa* were abundant below this horizon. The primary predatory gastropod on *C. ventricosa* was of the naticid type and the onset of boring occurs at the same level as the first appearance of the naticid species *Polinices* (*Euspira*) *pallidus*. The only other bivalves with boreholes were a sample of *Macoma elimata* in the Lower Rio Dell Member and a sample of *Macoma* aff. *M. inquinata arnheimi* in the middle of the Upper Rio Dell Member.

Other types of interactions are more abundant when compared to the number of incidents of gastropod predation. This finding was especially true at the Eel River section. The control mechanism determining the preference between bivalves and gastropods as gastropod prey is complex. A possible control on the preference is the species composition as controlled by the location of each of the sections with reference to their place in the depositional settings of the basin itself. The sediments at the Eel River section are more varied than at the Centerville Beach section. The Rio Dell sediment types at the Eel River section fluctuate rapidly as would be expected under shallower water, more terrestrially controlled conditions. The sediments in the Centerville Beach section reflect the stability of deeper-water conditions, separated from fluctuating terrestrial conditions. The differences in the stability of the environments and the conditions of the substrate (firmness, organic content, etc.) would produce different faunas and potentially different prey availability.

Borings (Non-predatory)

In the Humboldt Basin there were few occurrences of borings of algae, fungi, and clionid sponges. Because of the few reports of these types of borings, few conclusions can be made about these types of interactions for this area. The following material briefly summarizes their occurrence:

Algal:

Centerville Beach
Compsomyax subdiaphana -middle of the Upper Rio Dell Member.

Fungal:

Centerville Beach
Yoldia scissurata -Lower Rio Dell Member

Neptunea (Sulcosipho) tabulata -in lowermost Middle Rio Dell Member

Natica sp. -lowermost portion of the Upper Rio Dell Member

Clionid:

Eel River
Beringius arnoldi -lowermost Rio Dell Formation

Protothaca staleyi hannibali -in middle portion of the Rio Dell Formation

Centerville Beach
bivalve fragment -middle portion of the Upper Rio Dell Member

Polychaete borings were abundant in the shells from the upper portion of the Eel River section. There were few occurrences below the lower portion of the Rio Dell Formation. This level is interpreted as being on the middle of the basin slope. At the Centerville Beach section the polychaete borings were sparse below the Upper Rio Dell Member, again located on the middle of the basin slope region as defined by Stanton.

Table 14 lists the gastropod species from the Eel River section which were preferentially bored by worms. These gastropods have relatively thick shells in which the worms could bore without penetrating the inner shell surface. Other than the general lack of worm borings in the deeper water deposits, there are no depth related trends for these borings in the gastropods at the Eel River section. The bivalve/worm interactions were concentrated within the Pectinidae,

Table 14. Gastropod species bored by polychaete worms at the Eel River section and number of incidents of utilization.

Gastropod Hosts	# of shells utilized
Natica (C.) clausa	14
Neptunea (S.) tabulata	1
Neptunea (G.) smirna	3
Beringius arnoldi	3

Veneridae, and Tellinidae. The most utilized bivalves were *Pecten* sp., *Patinopecten* (*P.*) *caurinus*, *Clinocardium meekianum*, and *Protothaca staleyi hanniballi*.

Polychaete worm borings do not appear until the lower Middle Rio Dell Member at the Centerville Beach section and were widespread to the upper boundary unconformity. The pattern of the borings shows no preference between gastropod or bivalve shells for boring with deeper water host shells continuing to be bored, even after new, shallower water forms become abundant. At the Centerville Beach section the gastropod species which were the most consistently bored are *Natica* (*C.*) *clausa*, *Antiplanes* (*A.*) *major*, and *Latisipho hallii*. The bivalve species which was the most consistently bored was *Patinopecten* (*P.*) *caurinus*, *Cyclocardia ventricosa*, and *Pandora grandis*.

The increase in the number of specimen and species with epibiontic and endolithic interactions at the mid-slope level of both sections indicates that there was some common control over the intensity of these borings. There were an adequate number of shells in the lower section for the lack of borings to be merely a function of shell availability. The mid-slope level may represent the first level of substantial food supply to support a diverse interactive fauna. At the

Eel River section the number of non-predatory borings is reduced as the transition between the Rio Dell and the Scotia Bluffs Formations is reached as are the number of other types of interactions. The higher energy nature of the shoreface environments with their periods of potential exposure could prohibit the settlement of some larvae or the development of an epifaunal community (such as at the Gulf of Mexico beach locality from the Texas Gulf Coast).

Host as a Substrate

Several types of encrusting organisms were found on the shells from the Humboldt Basin (Table 15).

Table 15. Epibiontic guest abundance in the samples from the Humboldt Basin.

Guest	# of incidents
barnacles	30
bryozoans	2
serpulid worms	1
total available shells	1534

The number of incidents of encrustation was few in comparison to the total number of shells. The lithology of the lower units of the Wildcat Group would indicate that the substrate was not firm and that there were no natural surfaces present which would have supported the epibiontic guests. The encrusting organisms which were present would have been relegated to locations on shells of organisms specifically adapted for the environment.

To interpret the epibiontic interactions in the Humboldt basin, the controls on distribution of this type of interaction must be addressed. For recruitment to be successful, there must be surfaces on which the larvae of the epibionts may land. If shell material is lacking or spread out over a broad area, species with short planktic larval stages will not remain viable. For this reason, even if shallow water forms were introduced downslope by turbidity or grain-flow mechanisms, these forms would not be able to populate deeper water environments and would appear as single (or low) report occurrences. These occurrences would not be indicative of the presence of characteristic epibiontic associations within the particular environment. Another control on the distribution of epibiontic organisms would be the availability of non-living surfaces to populate. Modern epibiontic invertebrates will grow on most smooth surfaces, even man-made ones. The growths of barnacles on the hulls of ships would be of prime example. If there were other surfaces for the epibionts to colonize, such as rocks or firm sedimentary substrates (firm sand or gravel), the epibionts which did not derive vital benefits from the interactions with the host could exist on these surfaces in times when living substrates were uncommon. A third factor controlling the presence of epibiontic organisms would be the stability of the environment. Environments with periods of rapid sedimentation or sediment bypass would experience a periodic killoff of the standing crop of epibionts and possibly hosts. The need for continuous repopulation would keep the communities present within these environments from reaching stability and organism integration.

Very few incidents of epibiontic interaction occur within the samples from the Eel River section. With the exception of one sample from the Eel River Formation, there were no basin or slope epibiontic interactions at the this section. This sample contains a fragment of Clinocardium encrusted by barnacles. The fragment of Clinocardium was transported into the deeper water environment, as attested to by abrasion of the shell. One-third of the way into the Rio Dell Formation two neptuneid gastropod species, Neptunea cf. N. (Golikovia) smirna and Latisipho hallii, have epibiontic interactions. The epibionts are barnacles and encrusting bryozoans. The majority of the interactions with epibionts occur in the middle and upper Rio Dell Formation and within the shelfal environment as defined by Stanton. The mactrid bivalve Spisula hemphilli was the only bivalve species (of note) with epibiontic interactions. At each level (between samples 141 and 144) S. hemphilli has at least one report with barnacles attached.

At the Centerville Beach location there were no epibiontic interactions below the Upper Rio Dell Member, and barnacles were the only encrusting guest organism present at this locality. Barnacles first appear on shells in sample 87 (coincident with the first appearance of barnacles, attached or not). Barnacles as epizoans extend almost up to the top of the Rio Dell Formation. The barnacles show no preference, at any level, to any one specific host. The barnacles appear to show a concentration within members of the families Pectinidae, Cardiidae, and Veneridae. The infaunal bivalves, such as the Tellinidae, show no encrustation within a rich record of individuals. This absence could be attributed, in the deeper water horizons, to the lack of a mechanism for working these shells to the surface.

There are no relationships between lithology and occurrence of epibionts at either location. The epibionts occur on shells in shales, silty shales, and sandstones. The basinal environments in the Humboldt Basin with a sparse fauna, few non-living surfaces for colonization, and periods of rapid sedimentation have few epibiontic interactions. The slope environments with an even sparser fauna, no surfaces to colonize (non-living), and depositional instability have even fewer epibiontic interactions. The shelf environments have the most varied and abundant fauna and were also the most stable, and it is in the shelf area that the most epibiontic interactions take place. Some of the reports of interaction in deeper waters were transported from shelfal environments. At each section, the first reliable occurrences of epibiontic interactions occur in shelf environments. The shelf conditions would be conducive to keeping a shell exposed long enough to become encrusted.

Summary

The Centerville Beach section presented the broadest range of environments with which to interpret the distribution of specific interactions. The predatory borings first appeared in the slope deposits of the lower Rio Dell Formation and continued to the top of the section. Increasing numbers of bored shells represent the increased faunal abundance and diversity of the shallower water, upper shelf, and slope environments. Prey selection was influenced by the availability of prey species (again a function of water depth). As shallow water species became available, the gastropods added these species to their "menu," but did not remove other species in turn. The termination of gastropod/deep water prey interactions occurred at the stratigraphic termination of the prey organism.

The endolithic and epibiontic interactions of the Centerville Beach section first appeared at the shelf/slope break (low in the Rio Dell) and continued to the upper boundary unconformity with the Hookton. Polychaete borings were the most abundant and pervasive evidence of interactions in the section. The intensity of interaction continued up to the top of the Upper Rio Dell Member without reduction. This would indicate that the shallowest water environments, present at the Eel River section, were lost in the formation of the unconformity at the top of this section.

The Eel River section provided the most complete range of environments, basin to shoreface, of the sections. This section allows us to look at interactions in the shallowest water environments, missing at the Centerville Beach section. Predatory gastropod borings showed the same depth distributions and prey selection here as they did at the beach locality. The larger number of gastropod borings at this section are attributable to the abundant and diverse fauna developed on the shelf.

Endolithic and epibiontic interactions first occur on the slope and increase at the shelf/slope break. There was a sharp decline in the number and types of interactions at the shelf/shoreface transition. Most of the shoreface samples were collected from channel lag deposits and more clearly transported materials.

KETTLEMAN HILLS

If the sediments of the Humboldt Basin were deposited in constantly shallow water depths, would we have seen the same relationships of intensity and types of interactions that were attributed to water depth? How much of the trend was actually attributable to the evolution of interaction relationships through time? It is possible that the appearance of the first interactions at the Humboldt Basin sections corresponds to the time of development of each of the interaction types for the entire California coast.

To test these possibilities, one must study the fossils from deposits reflecting an environment which was relatively constant through time. To test the rate of change in the interactions, if any prove to be present, the deposits of this area should be approximately the same age as the Humboldt Basin material and contain some related genera. If the changes in the interactions were solely related to evolution of interaction sets, the changes seen at the Humboldt Basin would be visible in this setting also. The area of constant environments chosen to test this against was the Kettleman Hills of central California (fig. 26).

The Kettleman Hills are doubly plunging anticlinal hills formed as a portion of the Coastal Ranges. These

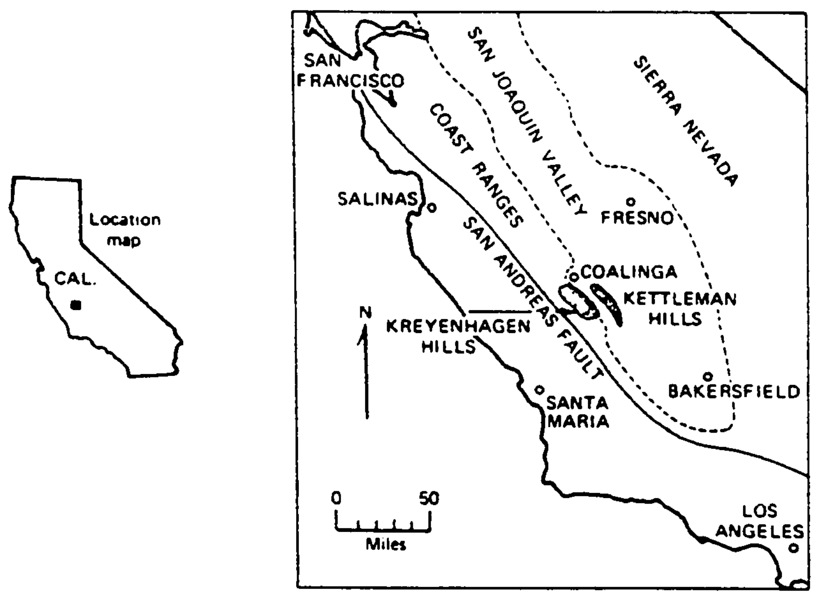


Figure 26. Location of the Kettleman Hills region, California with reference to large-scale nearby structure (from Stanton and Dodd, 1970).

hills extend into, and disappear below, the sediments of the San Joaquin Valley (fig. 27). The Pliocene and Pleistocene strata exposed in the core and flanks of the Kettleman Hills have been subdivided into three formations; Etchegoin, San Joaquin, and Tulare, oldest to youngest respectively (Woodring, Stewart, and Richards, 1940).

Stratigraphy and Sedimentology

The sediments of the Kettleman Hills region were deposited in an embayment which extended to the north as far as San Francisco, to the east into the San Joaquin Valley, westward into the Coastal Ranges, and southward (at least initially) as far as Santa Maria (fig. 28). The control on distribution of sediment types and ecological habitats was primarily tectonic. Formation of the Sierra Nevada mountain range and the Coastal Ranges, along with movement along the San Andreas fault, influenced sediment supply and connection of the embayment with normal marine conditions (Stanton and Dodd, 1970).

The Kettleman Hills and surrounding areas fall within the Coalinga district (Woodring, et. al., 1940), an important petroleum region (now approaching abandonment in the Kettleman Hills proper). Interest in the oil and gas potential of the sediments in the Kettleman Hills structure provided the impetus for the

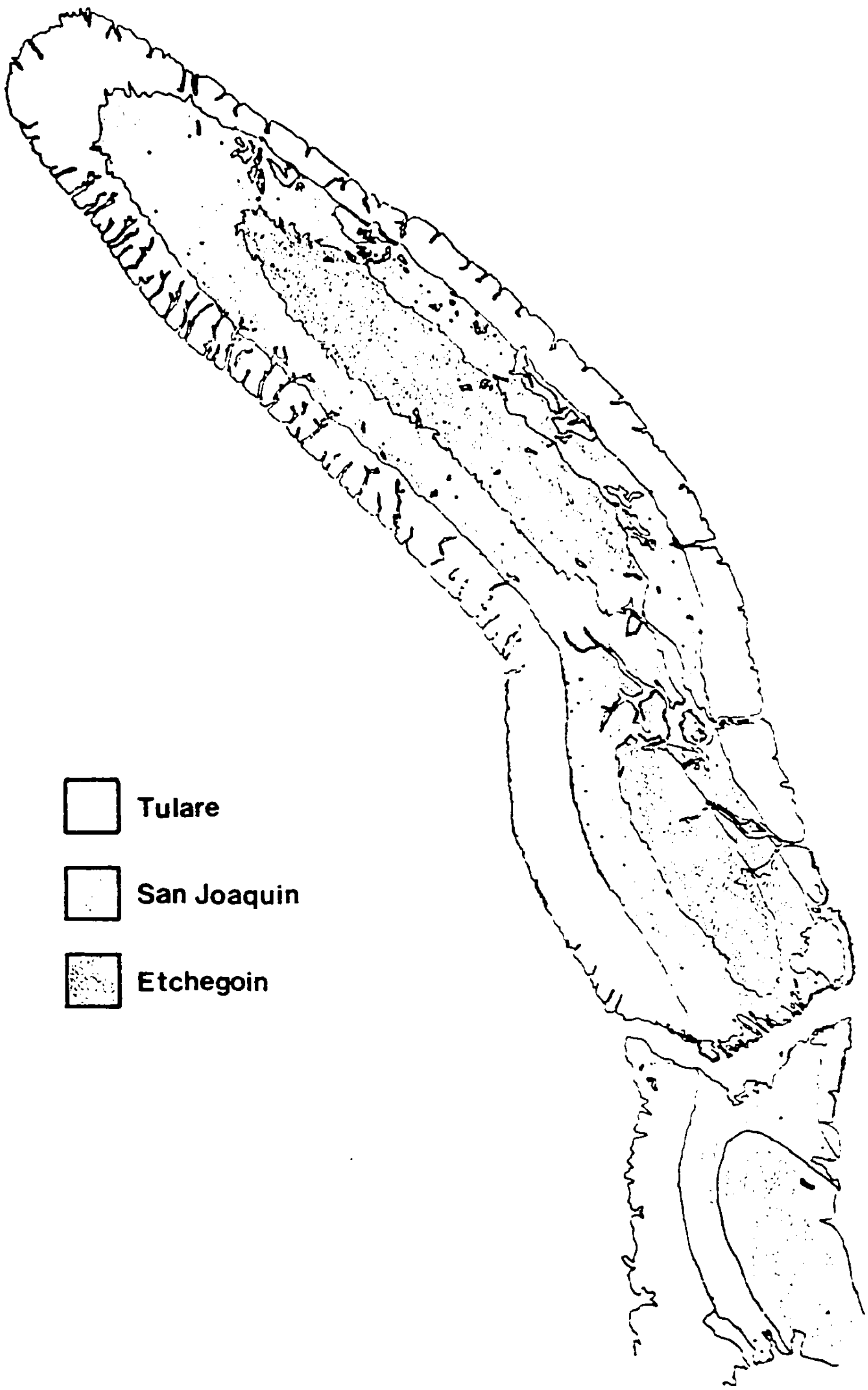


Figure 27. Generalized geologic map of the Kettleman Hills (after Woodring, et al, 1940).

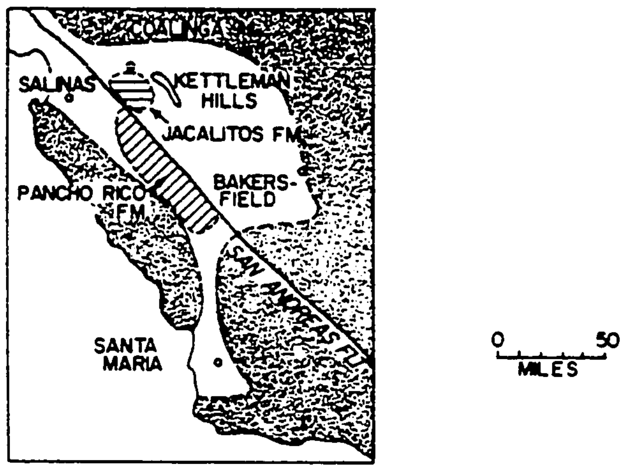


Figure 28. Early Pliocine paleogeography of west central California (after Galehouse [1967], from Dodd and Stanton, 1981).

publication of many stratigraphic (Watts, 1894; Andreson, 1905; Arnold and Anderson, 1910; Musser, 1929; Gestner, 1933; and Kleinpell, 1938) and paleontologic (Cooper, 1894; Arnold, 1910; Hannibal, 1912; Kew, 1920; and Pilsbry, 1934) papers. In 1940, W. P. Woodring, R. Stewart, and R. W. Richards described the detailed stratigraphy, paleontology, and structure of the Kettleman Hills in the United States Geological Survey Professional Paper #195. This work continues to be used as the primary reference for the area. Some of the localities listed in the back of the work are used in this study and are referenced in Appendix III .

Some of the more recent publications on the paleontology of the Kettleman Hills region have looked at paleoecology (Stanton and Dodd, 1970), depositional environments (Stanton and Dodd, 1972, 1976a), paleosalinities (Dodd and Stanton, 1975, 1976a), and trophic structure (Stanton and Dodd, 1976b). It is within the framework established by these previous studies that the question of organism interactions is considered.

Exposed in the eroded crests and flanks of the North, Middle, and South Domes of the Kettleman Hills are the Etchegoin, San Joaquin, and Tulare Formations. During the lower Pliocene, marine waters transgressed inland and covered an area which included the Kettleman Hills. A complete lithologic section is present as the result of continuous deposition in this area. The transgressive portion of the transgressive regressive depositional package includes another formation. The initial deposits of this inland embayment fall within the Jacalitos Formation. The sediments of the Jacalitos are not exposed at the surface in the Kettleman Hills but can be observed in Jacalitos Canyon to the northwest. The deposits of the Jacalitos Formation represent relatively open marine conditions.

By the middle Pliocene, the southern connection of the embayment had closed (fig. 29) restricting the communication of the southern regions with the marine waters to the north (Stanton, pers comm.). The closing of the southern entrant signaled the end of the transgressive phase and the beginning of the regressive phase of deposition represented by the sandstones, siltstones, and conglomerates of the Etchegion, San Joaquin, and Tulare Formations. The regressive phase was punctuated by minor (apparent?) transgressive and regressive cycles. Each of the cycles contains a relatively thin fossiliferous lower unit and a thicker upper nonfossiliferous unit. Each of the fossiliferous units in the Kettleman Hills was named after the

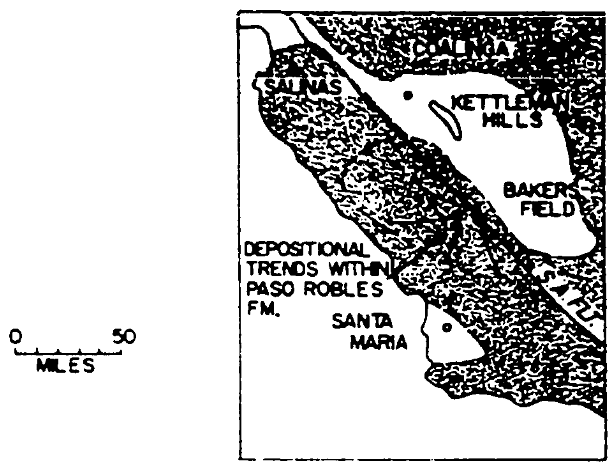


Figure 29. Late Pliocene paleogeography os west central California (after Galehouse [1967], from Dodd and Stanton, 1981.)

characteristic fossil of the unit (fig. 30) (Woodring, et al., 1940).

The middle Pliocene Etchegoin Formation is composed of thin sand stringers, silty sandstones, and sandy siltstones. It is subdivided into five fossil zones; Patinopecten, Macoma, Siphonalia, Upper Pseudocardium, and Littorina. The San Joaquin Formation, late Pliocene, is composed of sandstones and mudstones and is generally composed of finer sediments than the Etchegoin. Two distinctive conglomeratic units occur within the San Joaquin, one at the base of the unit and is termed the Cascajo Conglomerate and the other (approximately one-half way up the section) is at the base of the Pecten Zone. The six zones of the San Joaquin of the Kettleman Hills are the Cascajo Conglomerate, the Neverita zone, the Pecten zone, the Trachycardium zone, the Acila zone, and the Upper Mya zone. The Tulare Formation, Pleistocene in age, was deposited in essentially non-marine settings and contains the coarsest average grain size. The basic Tulare sediment type is that of a buff sandstone which is frequently interrupted by thin conglomeratic units (Stanton and Dodd, 1970). This unit contains relatively few fossils and will not be analyzed in any great detail in this work.

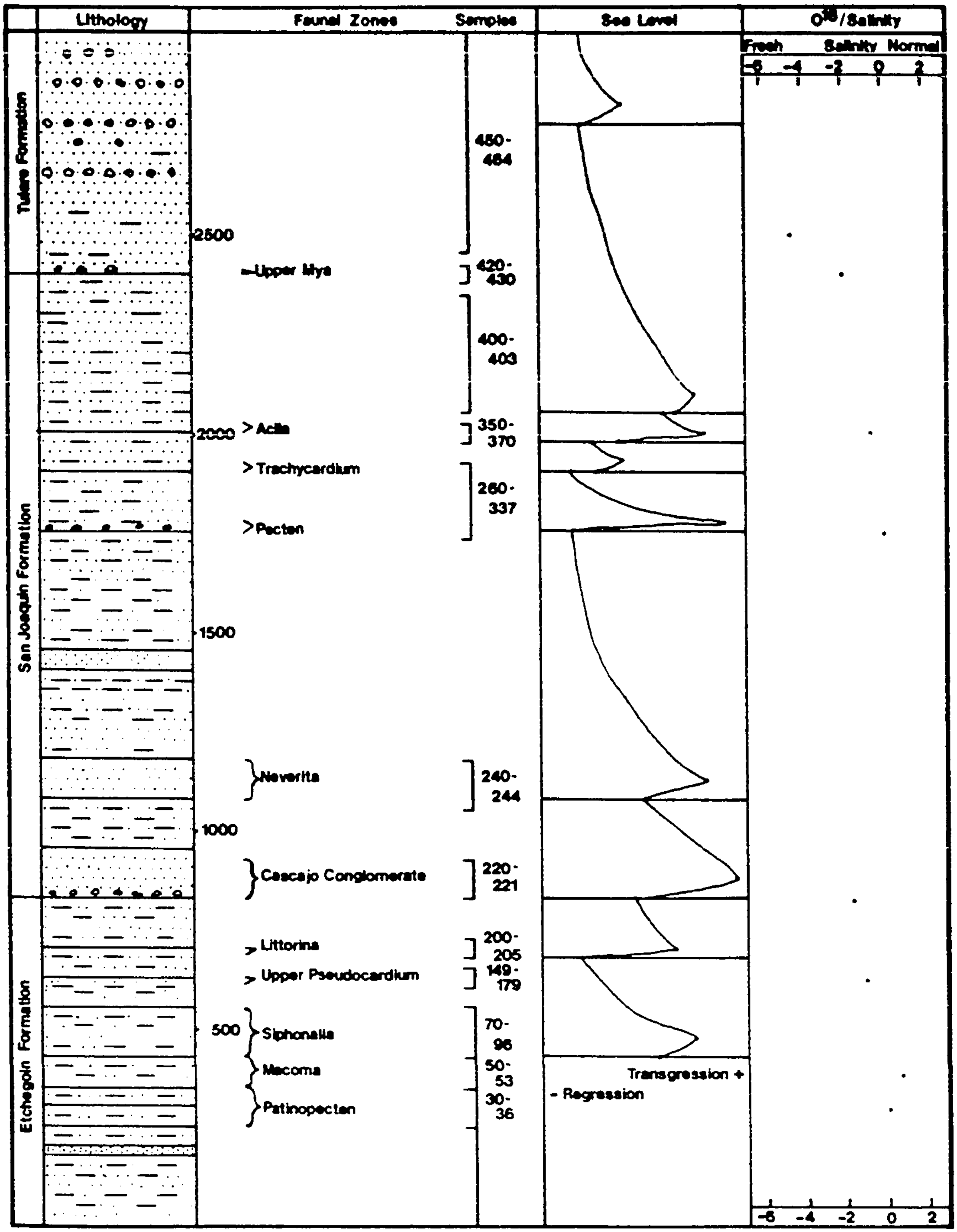


Figure 30. Stratigraphy, sedimentology, faunal zones, transgression/regression curves and oxygen isotope data for the Kettleman Hills from Stanton and Dodd, 1970.

Each of the transgressive/regressive packages represents fluctuations in rates of subsidence of the embayment or changes in the sediment supply with probably no exposure of the units. The depositional environments of the Etchegoin and San Joaquin Formations fluctuated throughout the time of the deposition with minor transgressions and regressions. Most of the fossil zones were deposited in similar conditions, those of the initial transgressive lithology. The samples were treated as representing an essentially stable depositional environment, and the trends of organism interaction found within this area are attributable to changes through time, not changes throught varied environments.

Organism Interactions

Shell dissolution influenced the preservation of interaction evidence in the shells from the Kettleman Hills. Commonly, the shells had signs of point dissolution caused by the pressure of the matrix grains against the shell, making the detection of microborers difficult or impossible. The outer shell layers, where most of the interactions would have occurred, were missing in some genera. *Chama* and *Mytilus*, were consistently missing their outer shell layers. In order to be consistent throughout the study, questionable traces of interaction were not noted and will not enter into the formulation of the conclusions for this section. Even with all of the difficulties in the identification of potential interaction traces, clearly over one-third of the shells collected from the Kettleman Hills contain some sign of organism interaction.

The localities sampled in the Kettleman Hills are listed in Appendix III by zone. Data obtained from the fauna recovered from the Kettleman Hills is presented in tabular form in this section and is available from the author by request. The interpretation of depositional environments for the strata of the Kettleman Hills that was used in this study is that of Stanton and Dodd (1970) and is summarized in figure 31. The analysis of Kettleman Hills organism interactions was performed primarily on the host gastropod and bivalve components of the fauna. Corals, barnacles, and echinoderms are mentioned as hosts where important. Gastropod predation of the fauna is considered separately from the other types of shell penetrants because of the inherent differences in primary motive.

Table 16 provides a display of the major fossil groups found in this study with their number of occurrences listed by zone. Table 17 provides, by host group, a display of the distribution of the seven types of recognized interactions; predation by gastropods,

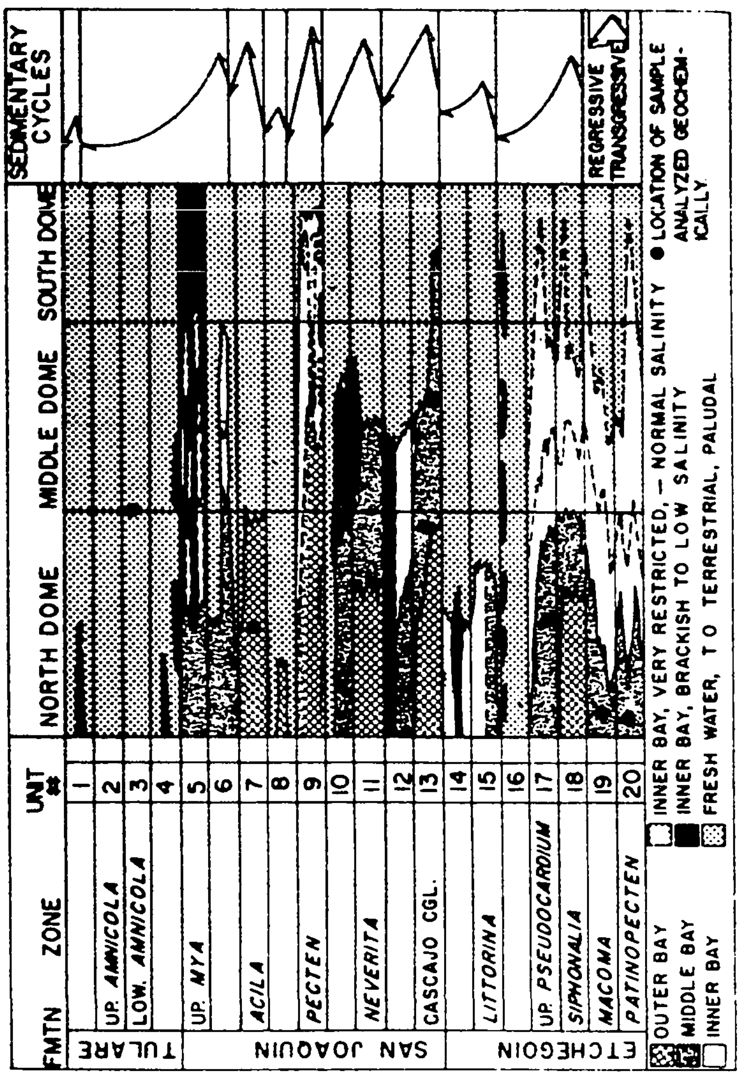


Figure 31. Stratigraphic section showing cyclic sedimentation and north-south environmental facies patterns, from Stanton and Dodd, 1970.

Table 16. Stratigraphic faunal distribution for the Kettleman Hills.
a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryozoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation								14	3		4		2	4		6	1		2
Upper Mya Zone											15		4	1					
Acila Zone						2		2	2	1	1		19	6		2	1		2
Pecten/Trachycardium Zone	8	13		4	2	1	1	142	31	3	71		25	75		54	4	5	3
Neverita Zone								1					1	12	9		466		
Cascajo Conglomerate			1											18			1		
Littorina Zone								1			3		7						
Upper Pseudocardium Zone			1			1		8	5	2	8	4	19	7		5			
Siphonalia Zone				1				8	14				23	13		9			13
Macoma Zone								8	1				5	4		2			
Patinopecten Zone								1					2						

Table 16. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation	5			6	6	5	17	7	2		3	22	6				2	2			
Upper Mya Zone				8			59	1				3	10				7	39			
Acila Zone	8	33		113	4	11	23	9			8	4	6			19	1	3		1	
Pecten/Trachycardium Zone	72	37	1	277	1	69	148	204	16		12	41	67	2	1	12	11	42	1	6	94
Neverita Zone	2			5	1	4										1					
Cascajo Conglomerate				21		1	1					2	1				1	6			
Littorina Zone	4			3		1					1	1	8			1	1	13			
Upper Pseudocardium Zone	13			33	20	4	192			6	33	13	24			310	11	17			
Siphonalia Zone	14			35	13	69	162	8		1	19	33	14	1	1	312	5	12			4
Macoma Zone	2			2	9	3							21		1	12	2				
Patinopecten Zone	10			2		12	52	13			1	18	12			33		3			

Table 16. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation		9		3	1		3	4		1					3	
Upper Mya Zone										1						
Acila Zone		6	15		4		28			1					3	
Pecten/Trachycardium Zone	3	126	5	19	17	4	219	10	6	12	8	1			29	1
Neverita Zone	1			1			2						1			
Cascajo Conglomerate		1					1							1		
Littorina Zone																
Upper Pseudocardium Zone		3	2	1	3	2	18									
Siphonalia Zone		26	7	1			56									
Macoma Zone	4	2	1	2			31									
Patinopecten Zone		4	11	1	1	1	66								2	

Table 17. Distribution of interactions within major faunal divisions for the Kettleman Hills samples. The total number of specimen is listed for each division. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Algal/Fungal Borings								*	*		*		*	*		*	*		
Clinoid borings								*					*	*		*			
Encrusting Bryozoa	*	*						*	*				*	*			*		*
Gastropod Predation								*	*		*		*	*	*	*	*	*	
Attached Bivalves	*																		
Barnacles		*		*				*	*					*			*	*	*
Polydoran Borings	*							*	*		*		*	*		*		*	*
Total Samples:	8	13	2	5	2	4	1	155	56	6	102	4	108	141	9	78	473	5	22

Table 17. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Chamidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae
Algal/Fungal Borings	*	*		*		*	*	*	*				*	*			*	*	*		*
Clinoid Borings	*			*		*	*	*			*	*	*				*				
Encrusting Bryozoa	*			*		*	*	*			*	*	*				*		*		
Gastropod Predation	*	*		*	*		*	*					*	*		*	*		*		*
Attached Bivalves				*		*	*	*			*		*				*				
Barnacles	*			*		*	*	*			*	*	*	*	*		*	*			
Polydoran Borings	*	*		*	*	*	*	*			*	*	*	*			*	*	*		
Total Samples:	141	70	1	506	54	180	687	242	18	7	98	77	139	169	3	3	703	41	127	1?	7

Table 17. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Algal/Fungal Borings	*	*	*													
Clionid Borings		*	*													
Encrusting Bryozoa		*	*													
Gastropod Predation	*						*									
Attached Bivalves		*	*													
Barnacles		*	*	*			*	*		*				*	*	
Polydoran Borings		*	*	*	*		*	*	*	*			*		*	
Total Samples:	8	177	41	29	26	7	431	14	13	15	1?	3	1	11	39	29

algal/fungal borings, clionid sponge borings, encrusting bryozoans, encrusting bivalves, and encrusting barnacles. The total number of specimens of each type that was studied is also presented. Twenty-six of the fifty-five "host" categories have fewer than ten specimens each, six of the categories are affected by all of the interaction types, two additional categories have all types of interaction except for predation by gastropods, and two of the categories have all types of interaction except for attached bivalves. The importance of each of these observations will be discussed in the following sections. The interactions will be studied with regard to: 1) the types of host organisms involved, 2) types of interaction related to the life habit of the hosts (ie. epifaunal/ infaunal), and 3) types of interactions which show a change in preference relative to stratigraphic level. The life habits and the environmental ranges used for the host species are those of the closest modern analogues (Keen, 1971, Keen and Coan, 1974, and Ricketts and Calvin, 1968).

Gastropod Predation

As evidenced by the data, gastropod predation pressure was relatively mild in the Kettleman Hills (Table 18). With one notable exception, there are no more than six instances of gastropod predation per prey

Table 18. Stratigraphic distribution of incidents of gastropod predation for the Kettleman Hills samples. The upper number is the number of specimen with the interaction, the lower (in parenthesis) is the cell percent. Muricid borings are indicated with an "*".
a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone													1 (5)	1 (16)					
Pecten/Trachycardium Zone								2 (1)	5 (16)		1 (1)			2 (3)		1/1* (2)-(2)		1 (20)	
Neverita Zone														1 (8)	1 (11)		105 (22)		
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone											1* (12)								
Siphonalia Zone									4 (7)					1 (7)		1 (11)			
Macoma Zone																1 (50)			
Patinopecten Zone																			

Table 18. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation																					
Upper Mya Zone																					
Acila Zone		1. (3)										1 (25)									
Pecten/Trachycardium Zone				6 (2)			1 (1)					1 (2)	2 (3)								
Neverita Zone				4 (80)		3 (75)															
Cascajo Conglomerate																					
Littorina Zone	1 (25)																				
Upper Pseudocardium Zone					1 (3)								1* (4)								
Siphonalia Zone				1 (3)	2 (1)		1 (1)								1* (100)						
Macoma Zone					1 (11)										1 (100)						
Patinopecten Zone												2 (11)	1 (4)								

Table 18. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation																
Upper Mya Zone																
Acila Zone																
Pecten/Trachycardium Zone		1 (1)					2 (1)									
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone																
Siphonalia Zone																
Macoma Zone																
Patinopecten Zone																

organism type at any one horizon, even though the total numbers of shells within some of the families was high. Each of the gastropod families that were without signs of predation had few total specimens.

The number of times that gastropods occur as gastropod prey were higher than the number of times that bivalves were (130 for the gastropods and 38 for the bivalves). The reason for the high number of bored gastropods was that from locality 244, in the Neverita zone, 105 specimen (out of a total of 466 shells) of Olivella cf. O. pedroana had been bored by a naticid predator, probably Neverita reclusiana (6 specimen were collected along with the prey). This locality is the only sample collected from the Neverita Zone. The significance of this locality, as being representative of the zone, can not be determined. The sample is unique in its composition and, compared to other localities, represents an abnormal set of environmental/biological circumstances. If this anomalous sample is removed from consideration because of its indeterminate nature, the bivalves have a slightly higher number of incidents of gastropod predation.

The families of gastropods which were preyed upon did not fall into any pattern of life habit or environment. They include members of infaunal and epifaunal, attached and mobile, shallow and deeper water gastropod families. The percentage of bored shells, when related to the total numbers of shells in each zone, show no overall stratigraphic trend. Within the Etchegoin Formation, samples with borings were distributed across the faunal zones. The concentration of the borings around the Pecten/Trachycardium zone in the San Joaquin Formation is an artifact of sampling. The largest number of specimen and sample localities for this portion of the study were from this zone.

The total number of all bivalve specimen with gastropod borings is less than one percent of the total number of bivalve shells studied from the Kettleman Hills. None of the families in the superfamily Carditacea (Diplodontidae, Lucinidae, Chamidae, and Cardiidae) were found with gastropod borings. The diplodontids, lucinids, and cardiids were infaunal, although this could have made them harder for the naticids to find; other infaunal bivalves such as the mactrids were preyed upon. With the exception of the Tulare samples, species from these families occurred in large samples. At some of these localities, naticids were relatively abundant, yet no carditacean was bored. Members of the family Chamiidae were epifaunal, yet no genus from the family was preyed upon.

All but three occurrences of gastropod borings occurred in what were considered to be localities with normal salinity. With the exception of the Chamidae, all of the bivalve families without gastropod borings were infaunal (most were only shallow burrowing). The presence of large numbers of gastropods and epifaunal bivalve species (in great abundance in some zones) and the lack of large numbers of borings is another indication that predation pressure on the preservable fauna was low. Some of these samples included a large naticid component in the fauna, yet borings were rare or absent.

The number of instances of predation was low, without regard to the total number of shells (with the exception of the borings in the shells of the Olivella). If the number of predatory borings found in a rare species was one specimen of a total of ten specimens per sample or stratigraphic level, it was one in one hundred specimens in an abundant species per sample or stratigraphic unit. The fact that the number of borings does not vary with sample size indicates that predation pressure was low. Unless the chances for preservation of shells with gastropod borings was low, the naticid gastropods collected from the Kettleman Hills must have utilized soft-bodied and non-preservable food resources, such as worms. This same situation, too many predatory gastropods for the amount of preserved food resource, has been noted in the Eocene Stone City Formation (Clairborne Group, Middle Eocene, Central Texas; Stanton, et al., 1981). Studies by Stanton, et al.,(1981) have come to a similar conclusion that the missing food resource must be soft-bodied organisms.

Micro-borings

Shell corrosion made the detection of microborings difficult. Pressure dissolution pitting from the matrix grains and groundwater destroyed most of the smaller borings from this area. The activities of algal and fungal microborers (seen in Table 17) was pervasive and affected members of almost half of the host categories present. Table 19 shows the occurrences of microborers by stratigraphic zone. The one algal/fungal interaction with gastropods in the Littorina zone was in a normal marine, inner bay environment. The Neverita, Pecten/Trachycardium, and Acila zone interactions all occurred within the outer bay localities, and none were within brackish or restricted environments.

Host selection by the algal/fungal guests differed between the Etchegoin and San Joaquin Formations. In the Etchegoin Formation, the venerids, tellinids, and mactrids (all infaunal) were preferentially bored. In

Table 19. Stratigraphic distribution of algal/fungal borings for the Kettleman Hills samples. The upper number is the number of specimen with the interaction, the lower (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone													1 (5)						
Pecten/Trachycardium Zone								1 (1)	6 (19)		1 (1)			4 (1)			1 (1)	1 (25)	
Neverita Zone														3 (25)					
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone																			
Siphonalia Zone													1 (3)						
Macoma Zone																			
Patinopecten Zone																			

Table 19. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation																					
Upper Mya Zone							8 (13)										1 (14)				
Acila Zone		1 (12)																			
Pecten/Trachycardium Zone	4 (5)	3 (3)				2 (3)	6 (4)	4 (2)	2 (12)				2 (3)					1 (1)		1 (16)	
Neverita Zone																					
Cascajo Conglomerate																					
Littorina Zone																					
Upper Pseudocardium Zone												2 (15)				2 (1)					
Siphonalia Zone																					
Macoma Zone													2 (9)			1 (8)					
Patinopecten Zone							1 (2)					1 (5)									

Table 19. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation																
Upper Mya Zone																
Acila Zone			1 (7)													
Pecten/Trachycardium Zone	3 (100)	5 (4)														
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone																
Siphonalia Zone																
Macoma Zone	1 (25)															
Patinopecten Zone																

the San Joaquin Formation, the nuculanids, mytilids, ostreids, pectenids, and solenids were bored by these microborers. With the exception of the solenids, all of the San Joaquin host species were epifaunal. With the exception of the difference in life habit between the Etchegoin and San Joaquin hosts, this type of interaction does not follow any trend in salinity, sediment type, or station potential host composition.

Clionid Sponge Borings

The clionid sponge borings (*Entobia*) are intermediate in abundance between the algal/fungal and polychaete types of borings. The clionid borings occur in the shells of gastropods, bivalves, and barnacles (Table 20). Only four species of gastropods possess clionid borings; *Calyptraea filiosa*, *Crepidula princeps*, *Neverita reclusiana*, and *Nassarius* sp. *Calyptraea filiosa* and *Crepidula princeps* are epifaunal attached gastropods whose shell surfaces were available for colonization throughout the life of the individual. Specimen of *Crepidula princeps*, from the *Macoma* zone of the North Dome (a middle bay locality), and of *Calyptraea filiosa*, from an outer bay locality in the *Aclia* zone, were bored. This difference in concentration of interactions is the result of the lower numbers of *Crepidula* in the San Joaquin Formation, not a change in actual preference. *Neverita*

Table 20. Stratigraphic distribution of clionid sponge borings for the Kettleman Hills samples. The upper number is the number of specimen with the interaction, the lower (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone													1 (5)						
Pecten/Trachycardium Zone													1 (4)	6 (9)					
Neverita Zone														1 (8)	1 (11)				
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone																			
Siphonalia Zone								2 (25)											
Macoma Zone								1 (12)					2 (40)						
Patinopecten Zone																			

Table 20. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation																					
Upper Mya Zone							2 (3)														
Acila Zone				3 (3)		1 (9)					1 (12)					1 (5)					
Pecten/Trachycardium Zone	5 (7)			5 (2)		4 (6)	2 (1)	4 (2)				3 (7)				1 (8)					7 (7)
Neverita Zone																					
Cascajo Conglomerate																					
Littorina Zone																					
Upper Pseudocardium Zone	1 (8)						22 (11)									21 (7)					
Siphonalia Zone	1 (7)					7 (10)	4 (2)	1 (12)				2 (6)				16 (5)					
Macoma Zone																1 (8)					
Patinopecten Zone	1 (10)							3 (23)								3 (9)					

Table 20. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation		2 (22)														
Upper Mya Zone																
Acila Zone			2 (13)													
Pecten/Trachycardium Zone		2 (2)														
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone																
Siphonalia Zone		1 (4)	2 (28)													
Macoma Zone																
Patinopecten Zone			1 (9)													

reclusiana and Nassarius sp. are infaunal gastropods whose shells contain borings of clionid sponges. Basic sponge ecology indicates that boring into the shells of these genera would not have occurred while the shells were buried in the mud (ie. alive host), but while the shell was exposed at the surface (after or near death). Specimen of bored Neverita were found in both the Neverita and Pecten/Trachycardium zones. The clionid bored, infaunal Nassarius shell was found in the Neverita zone in a normal salinity, outer bay locality.

The clionid-bivalve interactions greatly outnumber those with gastropods. The interactions found within the Etchegoin Formation occur evenly between and including the Patinopecten and Upper Pseudocardium zones. The number of clionid interactions was greater in the Etchegoin Formation with a peak in the Upper Pseudocardium zone in the species Ostrea atwoodi and Pseudocardium densatum at localities throughout middle bay environments. The interactions found in the San Joaquin Formation are within the zones between and including the Neverita and Upper Mya zones. The greatest number of different types of bivalves involved in clionid-bivalve interactions occurs in the Pecten/Trachycardium zone. Most of the bivalves involved in this type of interaction were either epifaunal or shallowly infaunal. Almost all of the clionid-bivalve interactions are in normal salinity, middle to outer bay environments. The only two exceptions are the occurrence of clionid borings in the shells of *Ostrea vespertina sequens* from brackish water localities in the Upper *Mya* zone. These occurrences are like those found between *Crassostrea virginica* and clionid sponges as noted earlier in Nueces Bay, Texas.

The barnacles with clionid borings show a similar distribution to that between the clionids and the bivalves (most of the barnacles were located on bivalve shells). The exception to this is the appearance of two bored barnacles in the Tulare Formation. The ecologic implications of these and other interactions in the Tulare Formation are discussed in the section summary.

Polychaete Borings

The borings produced by the polychaetes are pervasive throughout the formations in the Kettleman Hills, and these are the most abundant type of interaction present (Table 21). Polychaete interactions occur throughout the section. The polychaete borings occur within each of the affected families with equal likelihood in each zone and formation, and no change in preference was noted in the samples.

Table 21. Stratigraphic distribution of polychaete worm borings for the Kettleman Hills samples. The upper number is the number of specimen with the interaction, the lower (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone								1 (50)					1 (5)						
Pecten/Trachycardium Zone	1 (12)							4 (3)	3 (10)		1 (1)		3 (12)	18 (24)		1 (2)		2 (40)	
Neverita Zone																			
Cascajo Conglomerate														2 (11)					
Littorina Zone													2 (28)						
Upper Pseudocardium Zone											1 (12)		1 (5)	1 (14)					1 (50)
Siphonalia Zone								1 (12)					1 (4)			1 (11)			9 (69)
Macoma Zone								1 (12)											
Patinopecten Zone																			

Table 21. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation					1 (16)	1 (16)	7 (41)					2 (9)									
Upper Mya Zone							7 (12)														
Acila Zone	1 (12)	3 (9)		46 (41)		4 (36)	7 (30)	2 (22)			3 (37)					12 (63)					
Pecten/Trachycardium Zone	11 (15)	1 (3)		68 (24)		21 (30)	46 (31)	45 (45)			2 (16)	10 (24)	1 (1)			4 (33)		3 (7)			37 (39)
Neverita Zone				1 (20)																	
Cascajo Conglomerate				1 (5)														2 (33)			
Littorina Zone																		1 (8)			
Upper Pseudocardium Zone	1 (8)			5 (15)	3 (15)		125 (65)					2 (15)				27 (9)					
Siphonalia Zone	2 (14)			14 (40)	2 (15)	14 (20)	90 (55)	2 (25)			2 (10)	7 (21)	2 (14)			53 (16)		2 (16)			2 (50)
Macoma Zone	1 (50)				1 (11)								2 (9)			2 (16)					
Patinopecten Zone	2 (20)			1 (50)		1 (8)	29 (55)	7 (53)								15 (45)					

Table 21. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation		3 (33)														
Upper Mya Zone																
Acila Zone		1 (16)	4 (26)													
Pecten/Trachycardium Zone		29 (23)		2 (10)	1 (6)		4 (2)	1 (10)	2 (33)	2 (16)					3 (10)	
Neverita Zone												1 (100)				
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone		1 (33)	1 (50)													
Siphonalia Zone		7 (26)	3 (42)													
Macoma Zone	1 (25)						2 (6)									
Patinopecten Zone			7 (63)				4 (6)									

The majority of the gastropod families were involved in interactions with the boring polychaetes. Three of the four families without interactions, Turritellidae, Cerithidae, and Collumbellidae, are represented by fewer than 10 specimens. The fourth family, the Olividae, has 473 specimen present, 466 of them at one locality in the Neverita zone. Very few specimen from this locality were involved in interactions. The polychaete borings present at this locality were widely distributed among gastropod and bivalve hosts. Of the four families, the Olividae species were the only ones which could be considered infaunal.

The Siphonalia zone had the highest number of polychaete interactions in the Etchegion Formation with the highest number interacting with the cancellariids. The cancellarids with borings were widespread throughout the localities within outer bay enironments. The Pecten/Trachycardium zone had the highest number of polychaete interactions in the San Joaquin Formation with six of the gastropod families with borings (three or fewer families were represented in any of the other zones). The naticids have the highest number of interactions with the boring polychaetes within the Pecten/Trachycardium zone. These interactions occur along the Kettleman Hills at localities from the North, Middle, and South Domes. These environments include inner to outer bay, normal salinity conditions.

The polychaete/bivalve interactions are numerous and widespread in families with many specimen. The bivalve families with few or no polychaete borings are infaunal. At least one specimen of every epifaunal species of bivalve was affected to at least some extent. The only infaunal bivalve family with a significant number of polychaete borings was the mactrids with most of the interactions (≈75%) occurring within the Etchegoin Formation where the mactrids are the most abundant. The most frequently bored host bivalve species are: Anadara trilineata with 123 interactions, Ostrea atwoodi with 170 interactions, Ostrea vespertina sequens with 126 interactions, and Pseudocardium densatum with 92 interactions.

There are no readily visible trends to the bivalve interactions with the polychaetes. This finding includes the number of interactions as well as the distribution of their occurrences. With most of the other types of interactions, there were many fewer interactions of that type in the Etchegoin Formation than there were in the San Joaquin Formation. This was not true of the polychaete borings. The boring polychaetes extend throughout the range of environmental conditions while interactions of the other types of boring organisms (the algal/fungal group and the clionids) tended toward the open marine conditions. The polychaete borings were found in environments with normal salinities, "fresh" and brackish waters, and occurred within a range of substrate types.

The borings of the polycheates were so pervasive in the Pecten/Trachycardium zone that their borings are found in the shells of barnacles and echinoderms as well as shark and ray teeth (the enamel bases), fish bones, and animal bones.

Bryozoa

Encrusting, cheilostome bryozoans occur on slightly less than 0.1% of the shells from the Kettleman Hills. The largest percentage of shells encrusted by bryozoans (=70%) belonged to bivalves (Table 22).

The bryozoans were found on both infaunal and epifaunal gastropod shells, possibly indicating that the bryozoans had encrusted the shells after the host organisms had died, and not before. The bivalve shells with bryozoan encrustations were scattered throughout the section with no visible trends. The arcids and ostreids were the only families which were consistently encrusted, and these occurrences were in low numbers. Nearly eighty percent of the encrusted bivalves were

Table 22. Stratigraphic distribution of encrustation by bryozoans for the Kettleman Hills samples. The upper number is the number of specimen with the interactions, the lower number (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone																			
Pecten/Trachycardium Zone	1 (12)	3 (23)											1 (4)	1 (1)					1 (33)
Neverita Zone																	4 (1)		
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone																			
Siphonalia Zone									1 (7)										1 (8)
Macoma Zone								1 (12)											
Patinopecten Zone																			

Table 22. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation																					
Upper Mya Zone																					
Acila Zone	1 (12)			2 (12)																	
Pecten/Trachycardium Zone	3 (4)			14 (5)			6 (4)	15 (7)			2 (16)	3 (7)									4 (4)
Neverita Zone																					
Cascajo Conglomerate																					
Littorina Zone																					
Upper Pseudocardium Zone	1 (8)						3 (1)									8 (2)					
Siphonalia Zone				3 (8)		2 (3)	3 (2)									1 (.)		1 (8)			1 (25)
Macoma Zone																					
Patinopecten Zone							1 (2)									1 (3)					

Table 22. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation																
Upper Mya Zone																
Acila Zone																
Pecten/Trachycardium Zone		1 (1)	2 (40)													
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone																
Siphonalia Zone																
Macoma Zone																
Patinopecten Zone																

infaunal, and their shells had to have been exposed at the surface at the time of interaction. Chama pellucida might have been more extensively encrusted than the four times recorded for the species. Most of the shells of this species were found without the outer shell layer attached. The intensity of bryozoan encrustation found in the Pecten/Trachycardium zone indicates that the shells had remained at the surface, or were brought up to and maintained at the surface, for a longer period of time in this zone than in the other zones.

Bivalves

The epifaunal attached bivalves made up the least abundant type of interaction (Table 23). They occurred on shells of few hosts, most of which were within bivalve families. Three genera of attached bivalves occurred within the Kettleman Hills area. They are Ostrea, Chama, and Mytilus (in decreasing order of abundance).

There were no instances of gastropod shells being encrusted with bivalves. This differs from the results of the Gulf Coast study where the shells of Polinices and Busycon were often covered with small oyster spats. Comparatively speaking, the gastropod shells from the Kettleman Hills were relatively small. The only Kettleman Hills species to grow to a fairly large size

Table 23. Stratigraphic distribution of attached bivalve guests for the Kettleman Hills samples. The upper number is the number of specimen with the interaction, the lower (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation																			
Upper Mya Zone																			
Acila Zone																			
Pecten/Trachycardium Zone	3 (37)	4 (31)																	
Neverita Zone																			
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone																			
Siphonalia Zone																			
Macoma Zone																			
Patinopecten Zone																			

Table 23. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation							1 (6)														
Upper Mya Zone							11 (18)														
Acila Zone				1 (1)			8 (34)														
Pecten/Trachycardium Zone				7 (2)		1 (1)	18 (12)	1 (.)													11 (12)
Neverita Zone																					
Cascajo Conglomerate																					
Littorina Zone																					
Upper Pseudocardium Zone							4 (2)					1 (8)				1 (.)					
Siphonalia Zone						7 (10)	21 (13)														
Macoma Zone						1 (33)															
Patinopecten Zone						1 (8)	3 (6)					1 (5)									

Table 23. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation																
Upper Mya Zone																
Acila Zone			2 (13)													
Pecten/Trachycardium Zone		3 (2)														
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone																
Siphonalia Zone																
Macoma Zone																
Patinopecten Zone																

were *Neverita reclusiana* and *Siphonalia kettlemanensis*. The use of bivalve shells, to the exclusion of the shells of gastropod shells (at locations where there were abundant), indicates that the epibiontic bivalves either could not get to, or could not set on, the gastropod shells.

The number of bivalve families acting as hosts to the encrusting bivalves was relatively few in number with four of the seven families (Arcidae, Mytilidae, Ostreidae, and Chamidae) possessing almost all of the recorded interactions, most of them on the shells of *Ostrea*. The bivalve epibionts occurred on either epifaunal or shallowly infaunal bivalves with no preference to location on the shell. The ostreid epibionts have a tendency to set on shells of their own species even when they co-occur within a locality.

Ostrea atwoodi and *Ostrea vespertina sequens* co-occur at five localities within the section in the North Dome. There are no localities where both *Ostrea* species co-occurred in abundance. Biological differences between these two species may have allowed them to competitively exclude each other within their respective environments.

Chama pellucida never occurred attached to other members of its own species. This absence might be related to the roughened texture of the outside of the right (upper) valve. Chama is only found encrusting host bivalves in the deposits of the Pecten/Trachycardium zone in outer bay localities. Mytilus occurred encrusted on only three shells, and no conclusions could be derived from this data.

Barnacles

The barnacles were second only to the boring polychaetes in the number of zones affected in the Kettleman Hills (Table 24). The identification of barnacles as guest organisms was often made from their fragmentary remains or base plates which were found attached to shells. Identification of the guest barnacles, either balanid or coronulid, was not possible on this basis. The coronulid barnacles have been recorded only as host organisms. Their presence indicated that there were attached coronulid barnacles present at the Kettleman Hills localities, but that no identifiable pieces were found on any of the host shells. This absence may indicate some type of bias toward preservation of the balanid barnacle interactions over those of the coronulid. The coronulid host shells are listed in Appendix IV.

The occurrence of barnacles on gastropod hosts is relatively rare with four or fewer occurrences in only five of eleven families with an even ratio of epifaunal to infaunal gastropod species. Of the total of eleven

Table 24. Stratigraphic distribution of attached barnacle guests for the Kettleman Hills samples. The upper number is the number of specimen with the interactions, the lower (in parenthesis) is the cell percent. a. Coelenterates to Neptuneidae.

	Coelenterates (General)	Rhizopsammia	Bryzoans (General)	Encrusting Bryozoans	Branching Bryozoans	Family Discinidae	Family Dallininae	Gastropod (General)	Family Trochidae	Family Turritellidae	Family Littorinidae	Family Cerithidae	Family Calyptraeidae	Family Naticidae	Family Collumbellidae	Family Nassariidae	Family Olividae	Family Cancellariidae	Family Neptuneidae
Tulare Formation														1 (25)					
Upper Mya Zone																			
Acila Zone																			
Pecten/Trachycardium Zone		1 (8)						3 (2)	1 (3)					3 (4)				2 (40)	1 (33)
Neverita Zone																	1 (.)		
Cascajo Conglomerate																			
Littorina Zone																			
Upper Pseudocardium Zone																			
Siphonalia Zone																			2 (15)
Macoma Zone								1 (12)											
Patinopecten Zone																			

Table 24. Continued. b. Bivalve to Chamidae.

	Bivalve (General)	Family Nuculidae	Family Nuculanidae	Family Arcidae	Family Glycymeridae	Family Mytilidae	Family Ostreidae	Family Pectinidae	Family Diplodontidae	Family Lucinidae	Family Cardiidae	Family Veneridae	Family Tellinidae	Family Semelidae	Family Psammobiidae	Family Mactridae	Family Solenidae	Family Myidae	Family Corbulidae	Family Hitellidae	Family Chamidae
Tulare Formation				2 (33)			2 (12)	1 (14)													
Upper Mya Zone																					
Acila Zone	1 (12)			6 (5)		1 (9)	1 (4)	2 (22)								1 (5)					
Pecten/Trachycardium Zone	5 (7)			16 (6)		5 (7)	11 (7)	28 (14)				3 (7)		1 (50)			2 (13)				7 (7)
Neverita Zone																					
Cascajo Conglomerate																					
Littorina Zone																					
Upper Pseudocardium Zone	3 (23)						1 (1)				1 (3)					5 (2)					
Siphonalia Zone	4 (28)			3 (8)		14 (20)	17 (10)	1 (12)				2 (6)	2 (14)			11 (3)					1 (25)
Macoma Zone	1 (50)					2 (66)															
Patinopecten Zone	3 (30)					4 (43)	2 (4)				1 (100)	1 (5)									

Table 24. Continued. c. Pholadidae to Serpula.

	Family Pholadidae	Barnacle (General)	Family Balanidae	Family Cancrinae	Echinoderm (General)	Order Clypeasteroida	Family Dendrasteridae	Fish Teeth	Fish scales and plates	Skate and shark teeth	Fish bone	Fish vertebra	Fish otolith	Vertebrate: vertebra	Vertebrate: bone	Family Serpula
Tulare Formation		1 (11)		1 (33)												
Upper Mya Zone																
Acila Zone		2 (33)	6 (40)													
Pecten/Trachycardium Zone		27 (21)	2 (40)					1 (10)		1 (8)	1 (11)				1 (3)	
Neverita Zone																
Cascajo Conglomerate																
Littorina Zone																
Upper Pseudocardium Zone			1 (50)													
Siphonalia Zone		6 (23)	2 (28)													
Macoma Zone	1 (25)	1 (50)	1 (100)													
Patinopecten Zone		3 (75)	1 (9)													

recordings of barnacles attached to gastropods, only four occur outside of the Pecten/Trachycardium zone. There does not appear to be any preference to any one gastropod host by the barnacles, but the number of samples was too small to be certain.

Most of the barnacle interactions occur with bivalves and with other barnacles. Over half of the bivalve families have recordings of barnacle interactions; the ones with few occurrences are infaunal bivalves which would only be encrusted when brought to the surface after or near death. The "usual" bivalve host species, the arcids, mytilids, ostreids, and pectenids are the most heavily utilized hosts for the barnacles with stratigraphic concentrations of the interactions between the Littorina and Upper Pseudocardium zones of the Etchegoin Formation and between the Pecten/ Trachycardium and Acila zones of the San Joaquin Formation. Barnacles found attached to other barnacles show the same general relationships as to stratigraphic location as the ostreids and pectinids. Several barnacles within the Pecten/Trachycardium zone were found attached to fish and vertebrate remains (along with some of the polychaete borings noted earlier).

There were several occurrences of barnacles on shells in the Tulare Formation, a supposedly fresh to brackish water unit. Most of the barnacles from the brackish water localities from the Gulf Coast study were small and thin shelled. The barnacles on the shells from the Tulare of the Kettleman Hills were not thin shelled or small (relative to the size of the shells that they were on).

Summary

The most abundant guest types (polychaete borers, and barnacles) were found on shells of many different animate and inanimate (fish teeth and bones) objects. This would indicate that in their interactions with the "host" shells, the boring polychaetes and encrusting barnacles of the Kettleman Hills were not using the attributes of the live hosts. The host shell provided substrate, and the conditions of the host, alive or dead, may not have had any effect on the guest.

Although epifauna are normally selected by guest organisms as attachment sites or as substrate to bore into, shallow infauna were made available (on the surface) at many of the Kettleman Hills localities. The Siphonalia zone of the Etchegoin Formation and the Pecten/Trachycardium zone of the San Joaquin Formation are similar in that interactions seem to have been unusually abundant at these horizons. Both were relatively open marine times with open bay conditions in the North Dome and fresh water conditions in the

South Dome. The shells must have stayed at the surface for a longer time through either bioturbation or lower rates of sedimentation, although neither zone was lithologically distinctive enough within the section to support this hypothesis.

No clear trends of change in the preferences appear within the interactions. The nature of host types and specificity remain fairly constant between the Patinopecten zone at the base of the Etchegoin Formation and the Upper Mya zone of the San Joaquin Formation. This would indicate that interaction pairs did not evolve within the time span represented by these units (approximately 4 million years). The significance of this observation is that, within a geologically short time span, change does not occur in interactions and basic interaction pairs through time within a stratigraphic section. Changes in interactions and pairings represent directed changes in the environment, not changes in the guest organism's capabilities.

Some types of organisms showed a tendency towards interaction with epibiontic and endolithic organisms, termed "guest" organisms in this study. The gastropod families most commonly found in interactions were the Calyptraeidae and the Naticidae. The naticids were preferentially utilized by all of the guest types with the exception of attached bivalves (the naticids of the Gulf Coast study includes bivalves as guest organisms). The calyptraeids were affected by a wide variety of guest organisms, but not to the same numerical extent as the naticids.

Five of the bivalve families have records of interaction with every type of guest organism present. They are the Arcidae, Ostreidae, Pectenidae, Veneridae, and Mactridae. Instances of interaction with the arcids, ostreids, and pectinids were the most numerous of all host organisms studied from the Kettleman Hills. The barnacles showed similar trends of interactions and numbers of instances of interaction as did the ostereids and pectinids, the shells to which they were commonly attached.

CONCLUSIONS

1. The sites of interaction of epibiontic and endolithic guests with the gastropod shells from beach and nearshore localities in the Laguna Madre and Redfish Bay exhibit shell surface distributions which do not relate to the life position of the gastropod hosts. The shells of dead gastropods have been removed from the shallow nearshore and sea grass areas and are brought to the beach by the hermit crabs (pagurid crustaceans). The distributions of the host-guest interactions are related to the way that hermit crabs orient and move the shells (see fig.5). The epibionts (barnacles, bryozoans, and serpulid worms) colonize the highest shell surface (that provided while the shells are being used by the hermit crab) to stay above the sediment-water interface and utilize water currents at that level above the sediment. No interactions exist, including those of boring guests, at the site where the shell is in contact with the sediment surface.

2. The guest organisms at the Texas Gulf Coast localities show no preference interactions on host shells which could be related to the life habit of a live host Samples with similar location of interactions on the shells of epifuanal and infaunal organisms are indicative of environments where shells

are brought to, and maintained, at the surface after or near the death of the host.

3. The fewest interactions occurred at the Gulf Coast localities in which the environmental conditions at the sediment-water interface are the most severe. All of the live host organisms at these locations were infaunal and not involved in interactions until the shells were brought to the surface at or near death of the host. The highest numbers of interactions occurred at the oyster bank localities, each of which exhibit well integrated systems of organism interactions. The epibiontic and endolithic interactions were complex and varied, representing the degree of interdependence developed within the fauna which form the banks.

4. Patterns of predation selection in the Humboldt Basin do not show depth dependence. Samples from the Humboldt Basin indicate that new species are added (as they appear) to the types of prey as water depths decrease while deeper water prey are retained (throughout their depth ranges). It appears that some species are preferentially preyed upon (although this can not be statistically proven).

5. The Pullen, Eel River and lower portion of the Rio Dell Formations in the Humboldt Basin contain few epibiontic interactions. These basin and slope environments have an extremely sparse fauna and were

sedimentologically unstable. Transport of sediment in turbidity and grain flow movements prevented the establishment of integrated pairs of host and guest organisms and lack of available shell surfaces keep shallow water guests from populating the deeper waters that they may be carried down into.

6. The environmental dependence of interactions and interaction pairs is evident at the Humboldt Basin sections. The interactions of the Eel River section show an increase in intensity with decreasing water depth. The number of interactions with epibiontic and endolithic guests increase upwards from the base of the Pullen to the middle of the Rio Del Formation (slope to shelf break) at the Eel River section. The number of these interactions, particularly with the polychaete worms, decreases from this level upwards to the boundary between the Rio Dell and the Scotia Bluffs where the depositional environment changes from shelf to shoreface. Failure of the interactions to decrease in the Upper Rio Dell at the Centerville Beach locality indicates that shoreface conditions are absent at that section and as much as 1500 feet of the Rio Dell may potentially be missing at the upper boundary unconformity.

7. At the Kettleman Hills, with the exception of the intense predation on Olivella cf. O. pedroana by a

naticid predator in the Neverita Zone of the Etchegoin Formation, no particular type of interaction (epibiontic, endolithic, or predatory) becomes favored within a zone as the number of potential host shells increases. This indicates that the intensity of interactions must reflect a quality of the environment, independent of the host fauna. Most interactions occur at open outer bay or unrestricted inner bay localities. Host specificity, when it does occur, is a function of available host shells as controlled by the processes which bring shells to the surface and maintain them there.

8. The molluscan families Naticidae, Ostreidae, and Pectinidae are heavily utilized at the Texas Gulf Coast, Humboldt Basin, and Kettleman Hills localities. The intensity of interactions is lower in the fossil material but the predelection of these families to be involved in interactions of all types is maintained.

9. Barnacles, as hosts, show the same types and stratigraphic distributions of interactions as did their bivalve hosts. In the bivalve host shells with barnacles and other endolithic guests, the shells of the barnacles were bored as a continuation of the host shell. The barnacle's ecologic characteristics were not being utilized by the individual guest organism types.

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APPENDIX I

Gulf Coast Taxonomy

Life habit, as defined in the Introduction, for the fauna is provided (in parenthesis).

E - Epifaunal

I - Infaunal

Phylum Mollusca
- Class Gastropoda
  - Order Mesogastropoda
    - Family Littorinidae
      - Genus *Littorina*
        - Species *L.* (*Littoraria*) *irrorata* (E)
    - Family Turritellidae
      - Genus *Vermicularia*
        - Species *V. fargoi*
    - Family Cerithiidae
      - Genus *Cerithium*
        - Species *C.* (*Thericium*) *floridanum* (E)
    - Family Strombidae
      - Genus *Strombus*
        - Species *S. alatus*
    - Family Calyptraeidae
      - Genus *Crepidula*
        - Species *C.* (*Janacus*) *plana* (E)
    - Family Naticidae
      - Genus *Polinices*
        - Species *P.* (*Neverita*) *duplicatus*
  - Order Neogastropoda
    - Family Muricidae
      - Genus *Thais* (E)
        - Species *T.* (*Stramonita*) *haemastoma floridana*
        - Species *T.* (*Stramonita*) *haemastoma haysae*
      - Genus *Murex*
        - Species *M.* (*Phyllonotus*) *pomum* (E)

Family Columbellidae
Genus *Anachis*
Species *A. avara semiplicata*
Family Buccinidae
Genus *Cantharus*
Species *C.* (*Pollia*) *cancellarius*
Family Melongenidae
Genus *Busycon*
Species *B. contrarium*
Species *B. spiratum plagosus*
Family Olividae
Genus *Oliva*
Species *O.* (*Ispidula*) *sayana* (I)
Family Terebridae
Genus *Terebra*
Species *T.* (*Strioterebaum*) *dislocata*

Class Bivalvia
Order Arcoida
Family Arcidae (E)
Genus *Barbatia*
Genus *Anadara*
Species *A.* (*Cunearca*) *brasiliana*
Species *A.* (*Lunarca*) *ovalis*
Family Noetiidae (I)
Genus *Noetia*
Species *N.* (*Eontia*) *ponderosa*
Order Mytiloidae
Family Mytilidae (E)
Genus *Brachidontes*
Species *B.* (*Brachidontes*) *exustus*
Species *B.* (*Ischadium*) *recurvus*
Family Pinnidae (E)
Genus *Atrina*
Species *A. serrata*
Order Pterioida
Family Pectinidae (E)
Genus *Aequipecten*
Species *A.* (*Plagioctenium*) *amplicostatus*

Family Plicatulidae (E)
Genus *Plicatula*
Species *P. gibbosa*
Family Anomiidae (E)
Genus *Anomia*
Species *A. simplex*
Family Ostreidae (E)
Genus *Crassostrea*
Species *C. virginica*
Genus *Ostrea*
Species *O. equestris*
Order Veneroida
Family Ungulinidae (E)
Genus *Diplodonta*
Species *D.* (*Phlyctiderma*) *semiaspera*
Family Carditidae
Genus *Cardita* (E)
Species *C.* (*Carditamera*) *floridana*
Family Mactridae (I)
Genus *Rangia*
Species *R. cuneata*
Family Donacidae (I)
Genus *Donax*
Species *D. variabilis texasiana*
Family Tellinidae
Family Solecurtidae
Genus *Tagelus*
Species *T.* (*Mesopleura*) *plebeius* (I)
Family Veneridae (I)
Genus *Dosinia*
Species *D.* (*Dosinidia*) *discus*
Genus *Chione*
Species *C. cancellata*
Genus *Mercenaria*
Species *M. campechiensis*
Species *M. campechiensis texana*
Order Myoida (I)
Family Corbulidae
Genus *Corbula*
Order Pholadomyoida
Family Periplomatidae (I)
Genus *Periploma*
Species *P. inequale*

Phylum Arthropoda
    Class Cirripedia
        Order Thoracia
            Family Balanidae (E)
    Class Malacostraca
        Order Decopoda
            Infraorder Brachyurra
                Crab claw
              Family Cancridae (E)
                Genus _Arenaeus_
                    Species _A. cribarius_

Phylum Echinodermata
    Class Echinoidea
        Order Clypeasteroidea
            Genus _Mellita_ (I)
                Species _M. quinquiesperforata_

Phylum Annelida
    Class Polychaetia
        Order Sedentaria
            Family Serpulidae
                Genus _Serpula_ (E)

APPENDIX II

California Taxonomy

The specimens from the California locations were coded for computer analysis. The coding folows each species name or pertinent classification level (in parenthesis.)

Kingdom Protista
- Phylum Protozoa
  - Class Sarcodina
    - Order Foraminifera
      - (010001)

Kingdom Plantae
- General (020001,020002)
- Coal (020003)
- Wood (020004)

Kingdom Animalia
- Phylum Coelenterata
  - Class Anthozoa
    - Subclass Zoantharia
      - Order Scleractinia
        - General (210001)
        - *Rhizopsammia arnoldi* (211121)
- Phylum Ectoprocta
  - General (310001)
  - Cheilostome, encrusting (311111)
  - Ctenostome?, branching (312111)
- Phylum Brachiopoda
  - Class Inarticulata
    - Order Acrotretida
      - Suborder Acrotretidina
        - Superfamily Discinacea
          - Family Discinidae
            - Subfamily Discininae
              - *Discinscia* sp. (411111)
              - *Discinscia cumingii* (411112)

Class Articulata
Order Terebratulida
General (420001)
Suborder Terebratellidina
Superfamily Terebratellacea
Family Dallinidae
Subfamily Dallininae
Terebratalia sp. (421111)
Terebratalia arnoldi etchegoini (421112)

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Order Archaeogastropoda
Superfamily Trochacea
Family Trochidae
Trochidae ? (511101)
Calliostoma sp. (511111)
Calliostoma sp. A (511112)
Calliostoma sp. B (511113)
Calliostoma coalingensis (511114)
C. coalingense privum (511115)
Calliostoma kerri (511116)
Margarites johnsoni (511121)
Order Mesogastropoda
Superfamily Turritellacea
Family Turritellidae
Turritellid (512101)
Turritellid ? (512102)
Turrid sp. A (512103)
Turritella (512111)
Turritella ? (512112)
Turritella cooperi (512113)
Family Caecidae
Micranellum sp. (512211)
Superfamily Littorinacae
Family Littorinidae
Littorina sp. (512311)
Littorina ? (512312)
Littorina mariana (512313)
Superfamily Cerithiacae
Family Cerithiidae
Bittium ? (512411)
Bittium aperum (512412)
Bittium lacteolum (512413)

Superfamily Calyptraeacea
Family Calyptraeidea
Calyptraea sp. (512511)
Calyptraea ? (512512)
Calyptraea filosa (512513)
Calyptraea inorata (512514)
Calyptraea cf. *C. inorata* (512515)
Crepidula sp. (512521)
Crepidula onyx (?) (512522)
Crepidula cf. *C. onyx* (512524)
Crepidula princeps (512523)
Superfamily Naticacea
Family Naticidae
Naticid (512601)
Naticid ? (512602)
Natica sp. (512611)
Natica (*Cryptonatica*) *clausa* (512612)
Natica cf. *N.* (*C.*) *clausa* (512614)
Polinices (512621)
Polinices (*Euspira*) *pallidus* (512622)
Lunatia sp. (512631)
Lunatia ? (512632)
Lunatia cf. *L. lewissi* (512633)
Neverita sp. (512641)
Neverita reclusiana (512642)
Order Neogastropoda
Superfamily Muricacea
Family Muricidae
Muricid (513101)
Jaton ? (513111)
Trophonopsis (*Nodulotrophon*) *dalli* (513121)
Trophonopsis (*T.*) *fleenerensis* (513122)
Trophonopsis cf. *T.* (*T.*) *fleenerensis* (513123)
Forreria magister (513131)
Ocenebra praenominata (513141)

Superfamily Buccinacea
  Famliy Buccinidae
    Buccinid ? (513201)
    Buccinum saundersi (513211)
    Buccinum cf. B. alerticum (513212)
  Family Collumbellidae
    Columbellid ? (513301)
    Mitrella gausapata (513311)
    Mitrella ? (513312)
  Famliy Nassariidae
    Nassarius sp. (513411)
    Nassarius ? (513412)
    Nassarius (Caesia) grammatus (513413)
    Nassarius (Caesia) coalingensis (513414)
    Nassarius cf. N. stocki (513415)
    Nassarius (Demondia) californianus (513418)
    Nassarius (Caesia) coalingensis (513419)
    Nassa ? (513421)
Superfamily Volutacea
  Family Olividae
    Olivid ? (513501)
    Olivella sp. (513511)
    Olivella pedroana (513512)
    Olivella cf. O. pedroana (513513)
Superfamily Mitracea
  Family Cancellariidae
    Cancellariid (513601)
    Calcellariid ? (513602)
    Cancellaria sp. (513611)

Superfamily Conacea
Family Turridae
Oenopota harpularia (510015)
"*Pseudomelatoma*" *fleenerensis* (510017)
Propebela cf. *P. fidicula* (510018)
Propebela sp. aff. *fidicula* (510019)
Turrid (513701)
Turrid sp. A (513702)
Antiplanes (*A.*) *major* (513711)
Antiplanes voyi (513713)
Antiplanes cf. *A. voyi* (513714)
Antiplanes peversa (513715)
Antiplanes (*Rectisulcus*) *strongi* (513716)
Pseudomellatoma fleenerensis (513727)
Mangellia sp. (513731)
Superfamily Neptunacea
Famliy Neptuneidae
Neptuneid (513801)
Neptuneid ? (513802)
Neptunea sp. (513811)
Neptunea smirna (513812)
Neptunea smirna ? (513813)
Neptunea tabulata (513814)
Neptunea (*N.*) *lyrata altispira* (513815)
Neptunea (*N.*) *pribiloffensis pribiloffensis* (513816)
Neptunea cf. *N.* (*Golikovia*) *smirna* (513817)
Neptunea (*Suclosipho*) *tabluata* (513818)
Neptunea (*Golikovia*) *smirnia* (513819)

Beringius arnoldi (513821)
Beringius ? (513822)
Clinopegma scotiaensis (513831)
Latisipho hallii (513841)
Colus cf. *C. halibrectus* (513851)
Siphonalia sp. (513861)
Siphonalia ? (513863)
Siphonalia kettlemanensis (513862)
Subclass Opisthobranchia
Order Cephalaspidea
Superfamily Acteonacea
Family Acteonidae
Rictaxis punctocaelatus (514111)
Superfamily Bullacea
Family Bullidae
Bulla ? (514211)
Gastropod:
General (510005, 510006, 510007)
Freshwater (510004)

Phylum Mollusca
Class Bivalvia
Subclass Paleotaxodonta
Order Nuculoida
Superfamily Nuculacea
Family Nuculidae
Nuculana sp. (521111)
Acila sp. (521121)
Acila ? (521122)
Acila castrensis (521123)
Superfamily Nuculanacea
Family Nuculanidae
Nuculanid (521201)
Nuculana (521210)
Nuculana ? (521211)
Nuculana sp. A (521212)
Nuculana fossa (521213)
Yoldia sp. (521221)
Yoldia ? (521222)
Yoldia cooperi (521223)
Yoldia cooperi (?) (521224)
Yoldia (*Portlandella*) *karagensis* (521225)
Yoldia scissurata (521226)
Yoldia seminuda (521227)

Subclass Pteromorpha
  Order Arcoida
    Superfamily Arcacae
      Family Arcidae
        Arcidae ? (522101)
        Anadara sp. (522111)
        Anadara ? (522112)
        Anadara sp. ? (522113)
        Anadara canalis (522114)
        Anadara trilineata (522115)
        Bathyarca ? (522121)
    Superfamily Limopsacea
      Family Glycymerididae
        Glycymeris sp. (522211)
        Glycymeris ? (522212)
        Glycymeris grewingki (522213)
  Order Mytiloida
    Superfamily Mytilacea
      Family Mytilidae
        Mytilus sp. (523111)
        Mytilus ? (523112)
        Mytilus coalingensis (523113)
        Mytilus edulis (523114)
        Mytilus cf. *M. edulis* (523115)
        Mytilus (*Mytilis*) (523116)
        Crenomytilus sp. (523121)
        Modiolus sp. (523131)
        Modiolus cf. *M. capai* (523132)
        Modiolus cf. *V. recta* (523133)
        Megacrenella cf. *M. snarlyi* (523151)
  Order Pteroida
    Superfamily Ostracea
      Family Ostreidae
        Ostreid (524101)
        Ostreid ? (524102)
        Ostrea sp. (524111)
        Ostrea ? (524112)
        Ostrea atwoodi (524113)
        Ostrea vespertina sequens (524114)
        Ostrea vespertina sequens (dwarf) (524116)
        Ostrea perversa (524117)

Superfamily Pectinacea
Family Pectinidae
Pectinid (524201)
Pecten sp. (524211)
Pecten ? (524212)
Pecten (*Pecten*) sp. (524213)
Patinopecten (*P.*) *caurinus* (524214)
Pecten coalingensis (524215)
Delectopecten randolphi (524221)
Delectopecten pedroanus (524222)
Lituyapecten dilleri (524231)
Patinopecten sp. (524241)
Patinopecten ? (524242)
Patinopecten (*P.*) *lohri* (524244)
Patinopecten cf. *P.* (*L.*) *dilleri* (524245)
Patinopecten (*L.*) *falorensis* (524246)
Flabellipecten coalingensis (524251)
Aequipecten ? (524261)
Aequipecten impostor (524262)
Chlamys (*S.*) *parmeleei privum* (524271)
Hinnites sp. (524281)
Hinnites multirugosus crassiplicatus (524282)
Superfamily Limacea
Family Limidae
Lima sp. (524311)
Limatula aff. *L.* "*subariculata* (*montagu*)" (524321)
Subclass Heterodonta
Order Veneroida
Superfamily Carditacea
Family Carditidae
Cyclocardia sp. (525111)
Cyclocardia cf. *C.* (*T.*) *ventricosa* (525112)
Cyclocardia ventricosa (525114)
Superfamily Lucinacea
Family Diplodontidae
Thyasira flexiosa (525211)
Thyasira disjuncta (525212)
Anodonta sp. (525221)
Anodonta ? (525222)
Anodonta kettlemanensis (525223)
Family Lucinidae
Lucinid (525301)
Lucina sp. (525311)
Lucinoma annulata (525321)

Superfamily Chamacea
Family Chamidae
Chama sp. (525411)
Chama ? (525412)
Chama pellucida (525413)
Superfamily Cardiacea
Family Cardiidae
Cyclocardium (520008)
Lydocardium (520009)
Cardiid (525501)
Cardiid ? (525502)
Cardium sp. (525511)
Trachycardium sp. (525521)
Trachycardium ? (525522)
Laevicardium sp. (525531)
Clinocardium sp. (525541)
Clinocardium ? (525542)
Clinocardium meekianum (525543)
Clinocardium nuttallii (525544)
Clinocardium ventricosa (525545)
Superfamily Veneracea
Family Veneridae
Venerid (526101)
Venerid ? (526102)
Chione sp. (526111)
Protothaca sp. (526121)
Protothaca ? (526122)
Protothaca grata tarda (526123)
Protothaca lacineata hannibali (526124)
Protothaca staleyi hannibali (526126)
Protothaca cf. _P. s. hannibali_ (526127)
Protothaca staminea (526128)
Compsomyax sp. (526131)
Compsomyax subdiaphana (526132)
Psephidea sp. (526141)
Psephidea lordi ovalis (526142)
Psephidea lordi (?) (526143)
Transenella sp. (526151)
Transenella tantilla (526152)
Transenella californica (526153)
Saxidomus sp. (526161)
Saxidomus ? (526162)
Saxidomus nuttali latus (526163)

Superfamily Tellinacea

Family Tellinidae

Tellinid (526201)

Tellinid ? (526202)

Tellina sp. (526211)

Tellina ? (526212)

Tellina _oldryodi_ (526213)

Tellina _woodringi_ (526214)

Tellina _modesta_ (526215)

Macoma sp. (526221)

Macoma ? (526222)

Macoma _affinis_ (526223)

Macoma _affinis_ _plena_ (526224)

Macoma _astori_ (526225)

Macoma cf. _M._ _astori_ (526226)

Macoma cf. _M._ _calcarea_ (526227)

Macoma _lipari_ (526228)

Macoma sp. X (526230)

Macoma _elimata_ (526231)

Macoma cf. _M._ _elimata_ (526232)

Macoma _inquinata_ _arnheimi_ (526233)

Macoma aff. _M._ _inquinata_ (526234)

Macoma _nasuta_ (526235)

Macoma sp. aff. _M._ _a._ _plena_ (526237)

Macoma _yoldiformis_ (526238)

Macoma _siligua_ (526239)

Family Semelidae
- *Semele* sp. (526311)
- *Semele* cf. *S. rupropiota* (526312)

Family Psammobiidae
- *Sanguinolaria* sp. (526411)
- *Sanguniolaria nuttalli* (526412)
- *Sanguinolaria* cf *S. nuttalli* (526413)

Superfamily Mactracea

Family Mactridae
- Mactrid (526501)
- Mactrid ? (526502)
- *Mactra* sp. (526511)
- *Spisula* sp. (526521)
- *Spisula* ? (526522)
- *Spisula albaria coosensis* (526523)
- *Spisula hemphilli* (526524)
- *Spisula voyi* (526525)
- *Pseudocardium* sp. (526531)
- *Pseudocardium* ? (526532)
- *Pseudocardium densatum* (526533)
- *Pseudocardium densatum* var. *gabbi* (526534)
- *Tresus* sp. (526541)
- *Tresus* ? (526542)
- *Tresus nuttali* (526543)

Superfamily Solenacea

Family Solenidae
- *Solen* sp. (526611)
- *Solen* ? (526612)
- *Solen perrini* (526613)
- *Solen perrini* (?) (526614)
- *Ensis* sp. (526621)
- *Siligua* sp. (526631)
- *Siligua alta* (526632)
- *Siligua alta* = *S.* cf. *S. oregonia* (526633)
- *Siligua oregonia* (526634)
- *Siligua* cf. *S. oregonia* (526635)

Order Myoida
 Suborder Myina
  Superfamily Myacea
   Family Myidae
    Mya sp. (527111)
    Mya ? (527115)
    Mya arenaria (527112)
    Mya cf. *M. arenaria* (527113)
    Mya dickersoni (527114)
    Cryptomya sp. (527121)
    Cryptomya ? (527122)
    Cryptomya californica (527123)
    Cryptomya quadrata (527124)
   Family Corbulidae
    Corbula sp. (527211)
  Superfamily Hiatellacea
   Family Hitellidae
    Panomya sp. (527311)
    Panomya ? (527312)
    Panopea (527321)
    Panopea ? (527322)
    Panopea generosa (527323)
 Suborder Pholdaina
  Superfamily Pholadina
   Family Pholadidae
    Pholad (527401)
    Pholad ? (527402)
    Zirafaea gabbi (527411)
    Penitella (527421)
Subclass Anomalodesmata
 Order Pholadomyoida
  Superfamily Pandoracea
   Family Pandoridae
    Pandora sp. (528110)
    Pandora grandis (528111)
   Family Thraciidae
    Thracia trapezoides (528211)
   Family Periplonatidae
    Periploma sp. (528311)

General:
 Bivalve (520001, 520002, 520003, 520004)
 Bivalve X (520005)
 Bivalve Y (520006)
 Bivalve AA (520007)
 Taxodont (520010)

Phylum Mollusca
  Class Scaphopoda
        Scaphopod (531001, 531002)
      Family Dentaliidae
        Cadulus sp. (531111)
        Dentalium sp. (531121)
        Dentalium n. sp. (531122)
        Dentalia sp. (531131)

Phylum Arthropoda
  Superclass Crustacea
    Class Cirripedia
        Barnacle (611111, 611112, 611113)
      Order Thoracica
        Suborder Balanomorpha
          Family Balanidae
            Subfamily Balaninae
              Balanid barnacle (611211)
              Balanus sp. (611221)
              Balanus (*Tamiosoma*) cf. *B.* (*T.*) *gregarius* (611222)
            Subfamily Coronulinae
              Coronulid barnacle (611311)

    Class Malacostraca
      Subclass Eumalacostraca
        Superorder Eucarida
          Order Decopoda
            Suborder Pleocyemata
              Infraorder Brachyurra
                Crab (621111)
                Crab claw (621121)
                Crab leg (621122)
                Crab claw ? (621123)
                Crab carapace ? (621124)
                Section Cancridea
                  Family Cancridae
                    Subfamily Cancrinae
                      Cancer sp. (621131)
                      Cancer ? (621112)

Phylum Echinodermata
Subphylum Echinozoa
Class Echinoidea
Subclass Euechinoidea
Superorder Gnathostomata
General (700001, 700002, 700003, 700004)
Order Holectypoida
General (711111)
Order Clypeasteroida
General (712001, 712101)
Suborder Scutellina
Family Dendrasteridae
Merriamaster sp. (712111)
Merriamaster perrini (712112)
Merriamaster sp. aff *M. perrini* (712113)
Merriamaster arnoldi (712114)
Merriamaster ? (712115)
Scutellaster sp. (712121)
Scutellaster major (712122)
Dendraster sp. (712131)
Dendraster ? (712132)
Dendraster coalingensis (712133)
Dendraster coalingensis ? (712134)
Dendraster gibbsii humilis (712135)

Phylum Annelida
Class Polychaetia
Order Sedentaria
Family Serpulidae
Serpula (911111)
Serpulid (911112)
Tube worm (911113)

Fish Remains Classification
Crushing tooth (810001)
Tooth (810002)
Tooth ? (810003)
Dermal plate (821001)
Scales (821002)

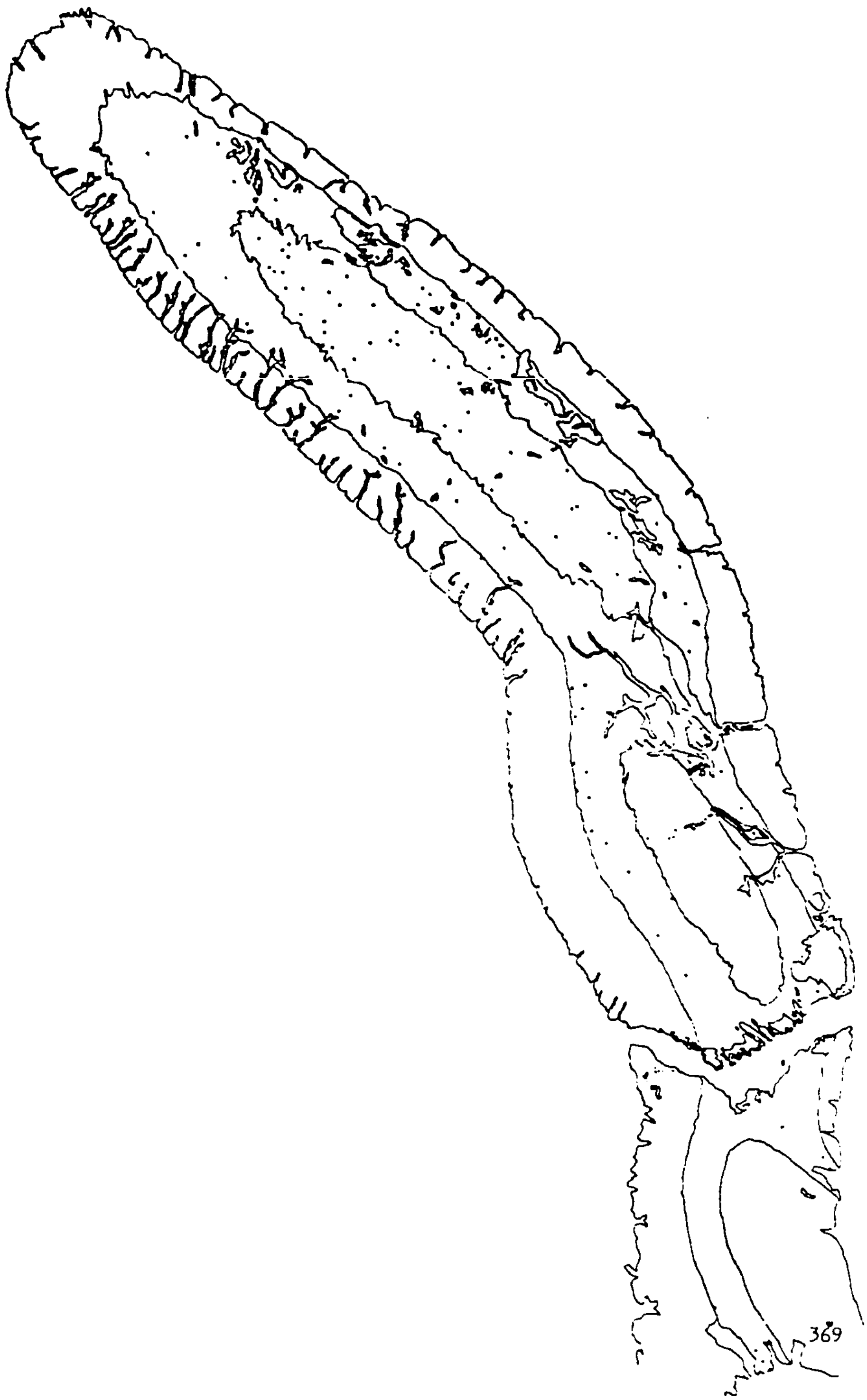
"Dog brains" tooth (822001)
Skate teeth (822003)
Shark teeth (822011)
Shark teeth ? (822012)
Bone (823001)
Vertebra (823002)
Otolith (824001)

Vertebrate Remains Classification
Vertebra (830001)
Bone (850001)

APPENDIX III

Kettleman Hills Sample Localities

Etchegoin Formation (Middle and South Domes)
WSR# 369


369

Etchegoin Formation North Dome

Patinopecten Zone

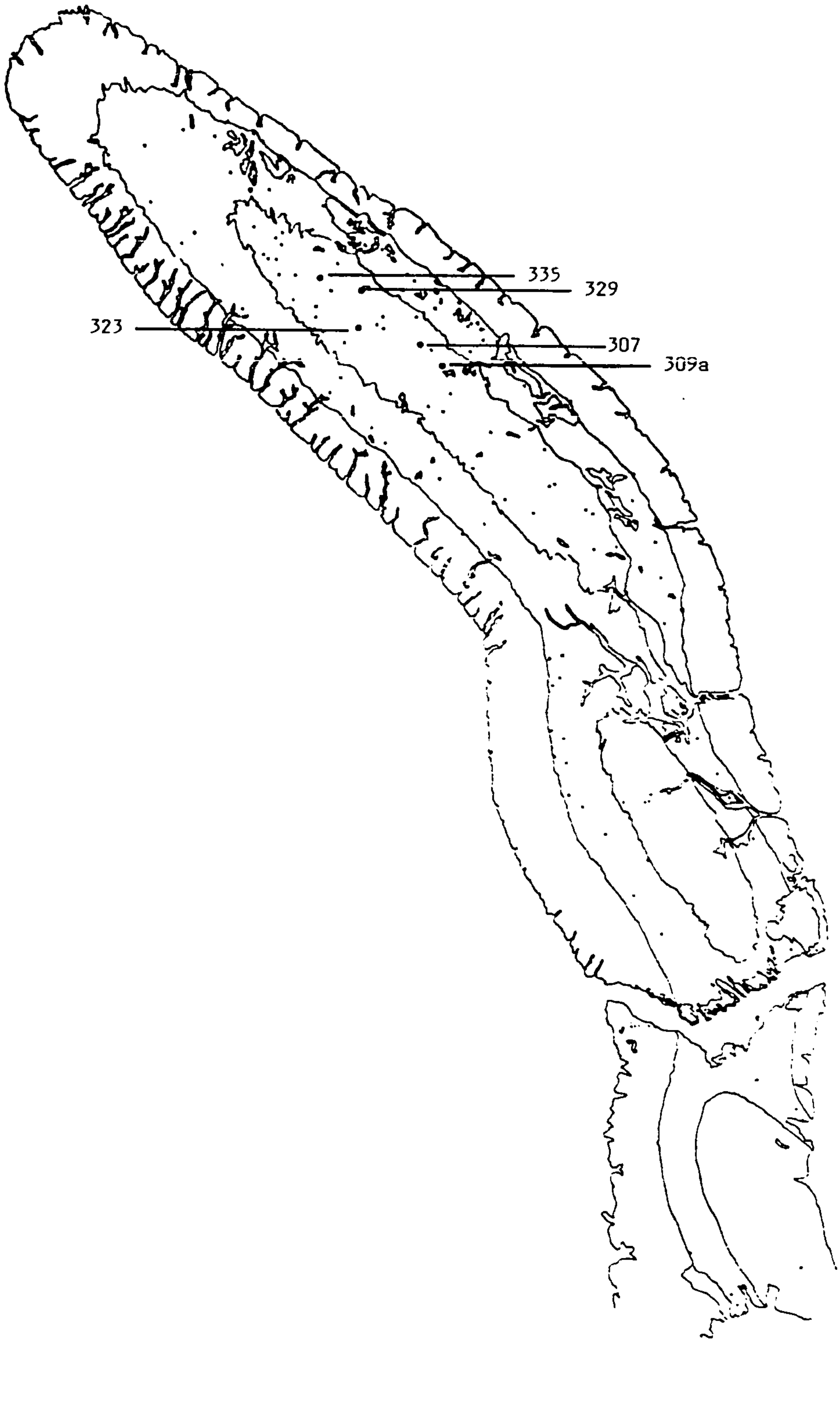
WSR# 307

WSR# 309a

WSR# 323

WSR# 329

WSR# 335


335
329
323
307
309a

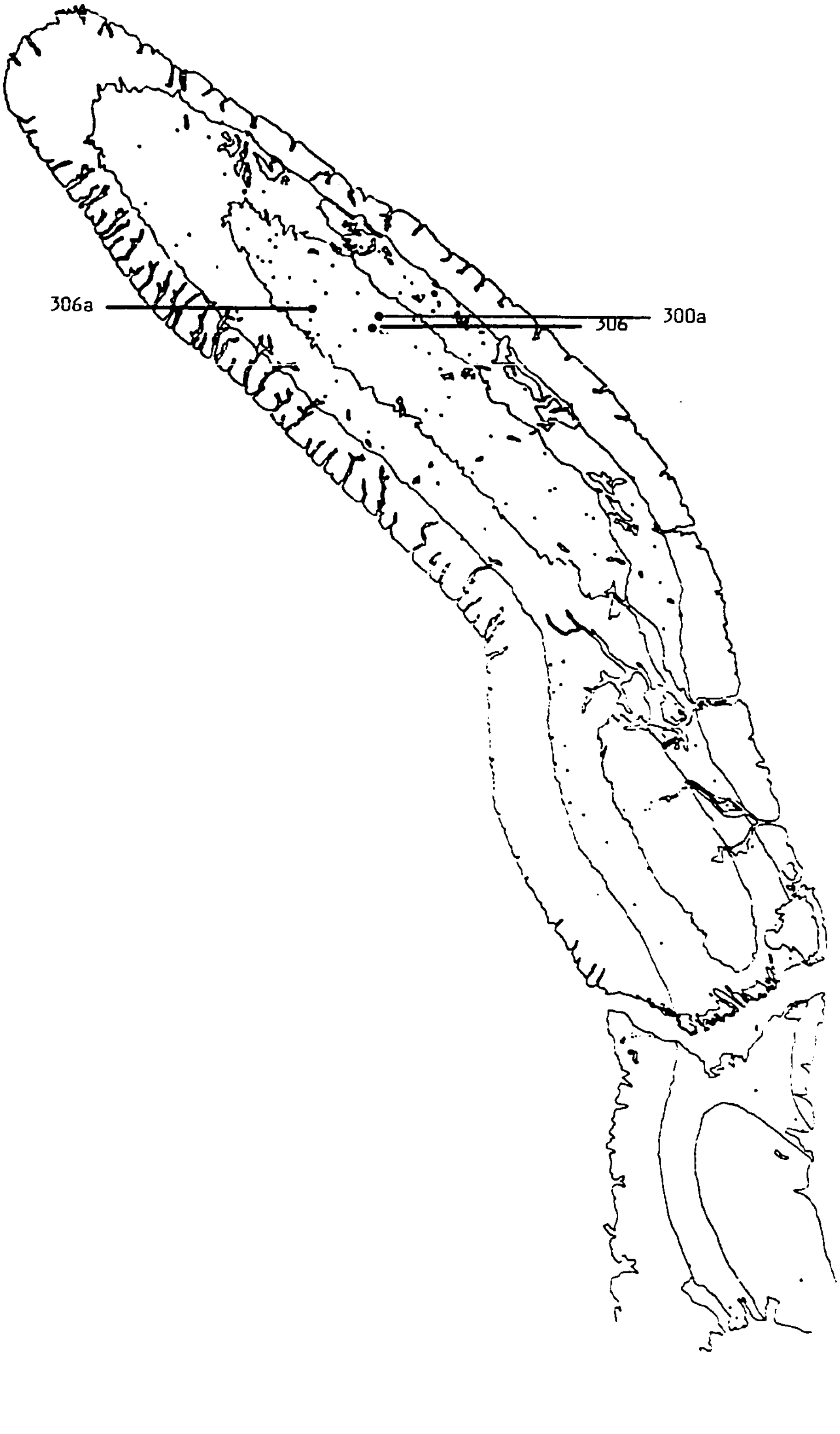
Etchegoin Formation North Dome

Macoma Zone

WSR# 300a

WSR# 306

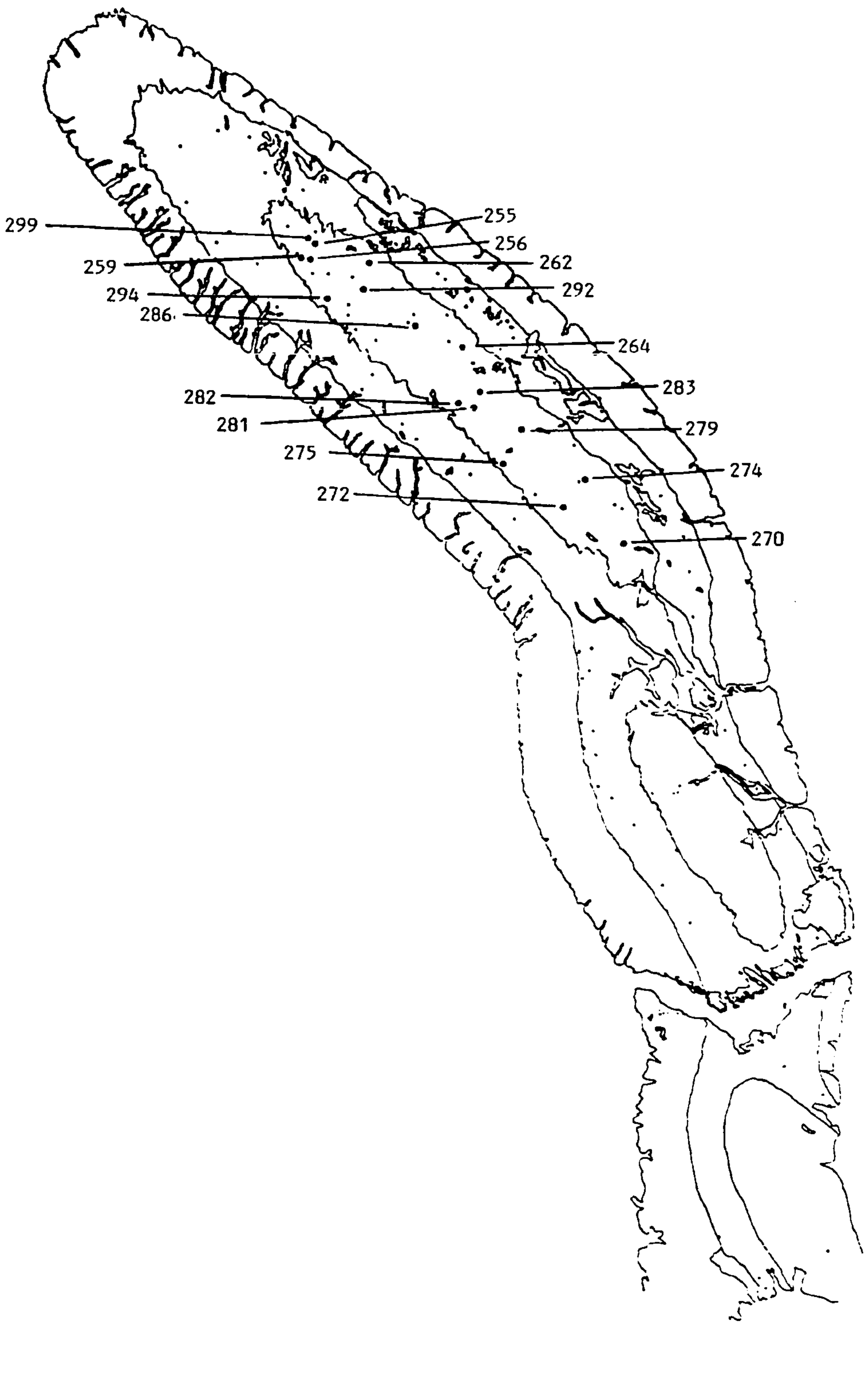
WSR# 306a


306a
300a
306

Etchegoin Formation North Dome

<u>Siphonalia</u> Zone

WSR# 255
WSR# 256
WSR# 259
WSR# 262
WSR# 264
WSR# 270
WSR# 272
WSR# 274
WSR# 275
WSR# 279
WSR# 281
WSR# 282
WSR# 283
WSR# 286
WSR# 292
WSR# 294
WSR# 299


255
299
256
259
262
294
292
286
264
283
282
281
279
275
274
272
270

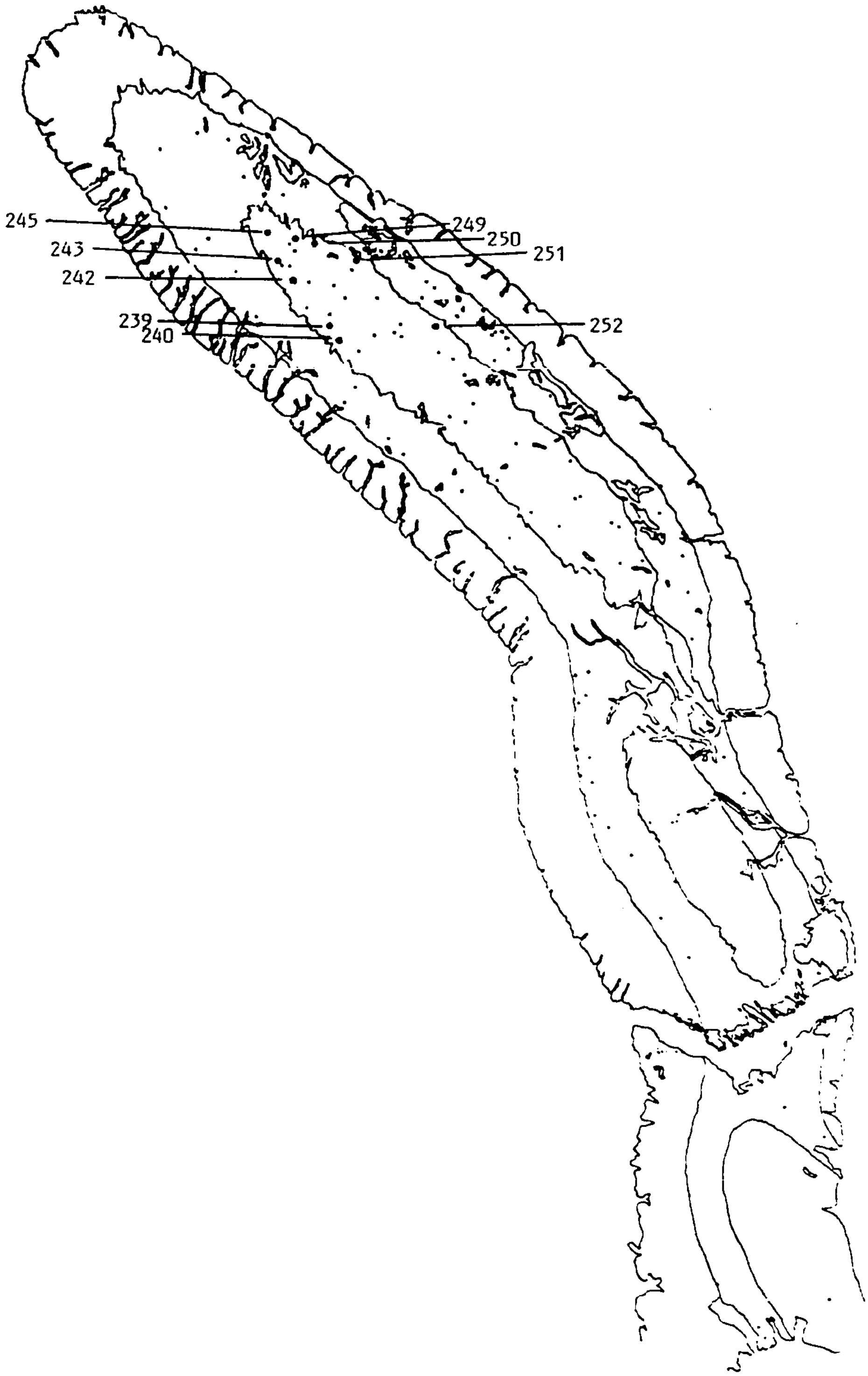
Etchegoin Formation North Dome

Upper *Pseudocardium* Zone

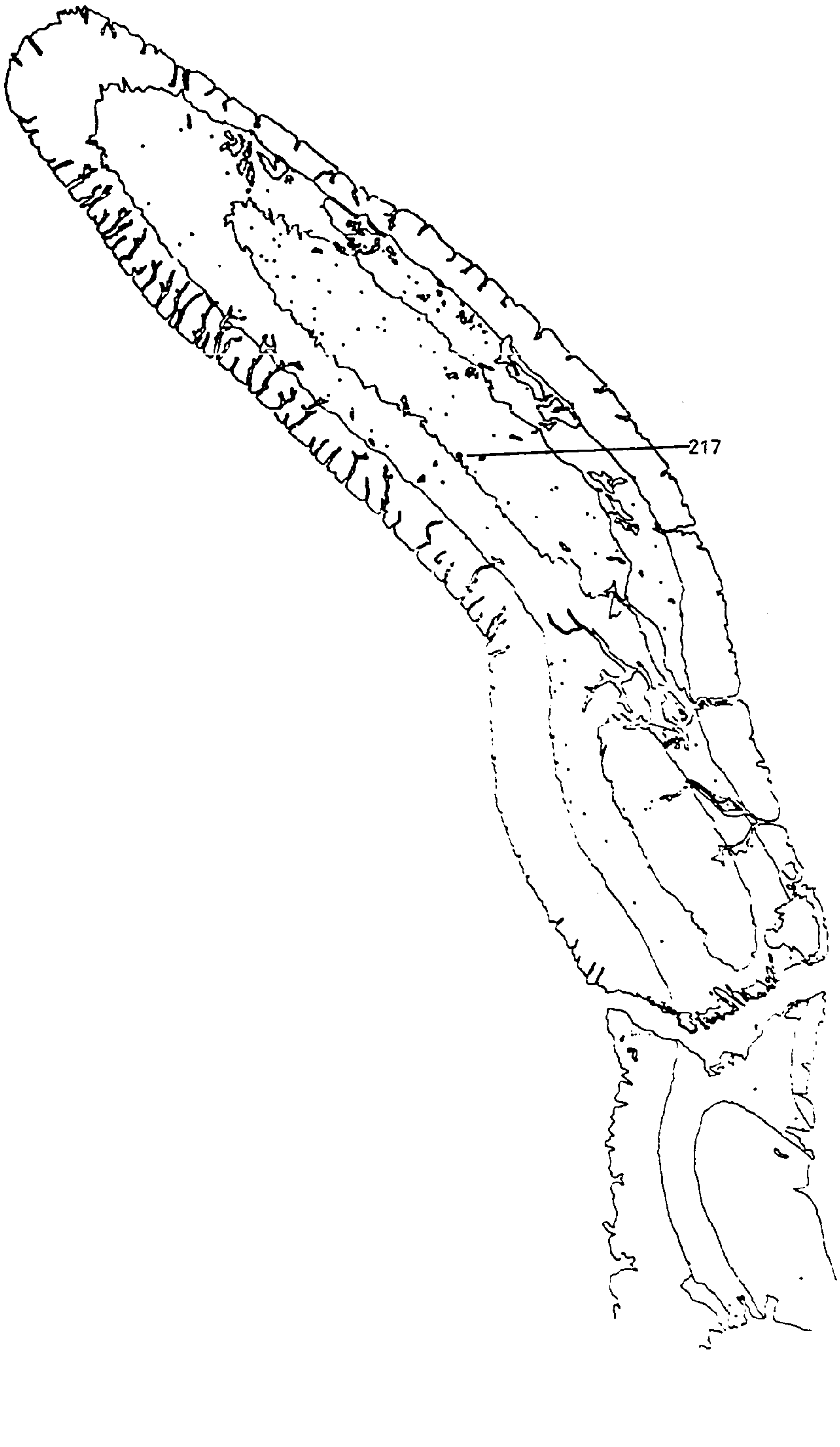
WSR# 239
WSR# 240
WSR# 242
WSR# 243
WSR# 245
WSR# 249
WSR# 250
WSR# 251
WSR# 252

Non-WSR Localities:

Los Junnetes Ridge, East
El Rascador
Arroyo Doblegado
El Chicon
Cuero Alto, South Flank


245
243
242
239
240
249
250
251
252

Etchegoin Formation North Dome
<u>Littornia</u> Zone
WSR# 217

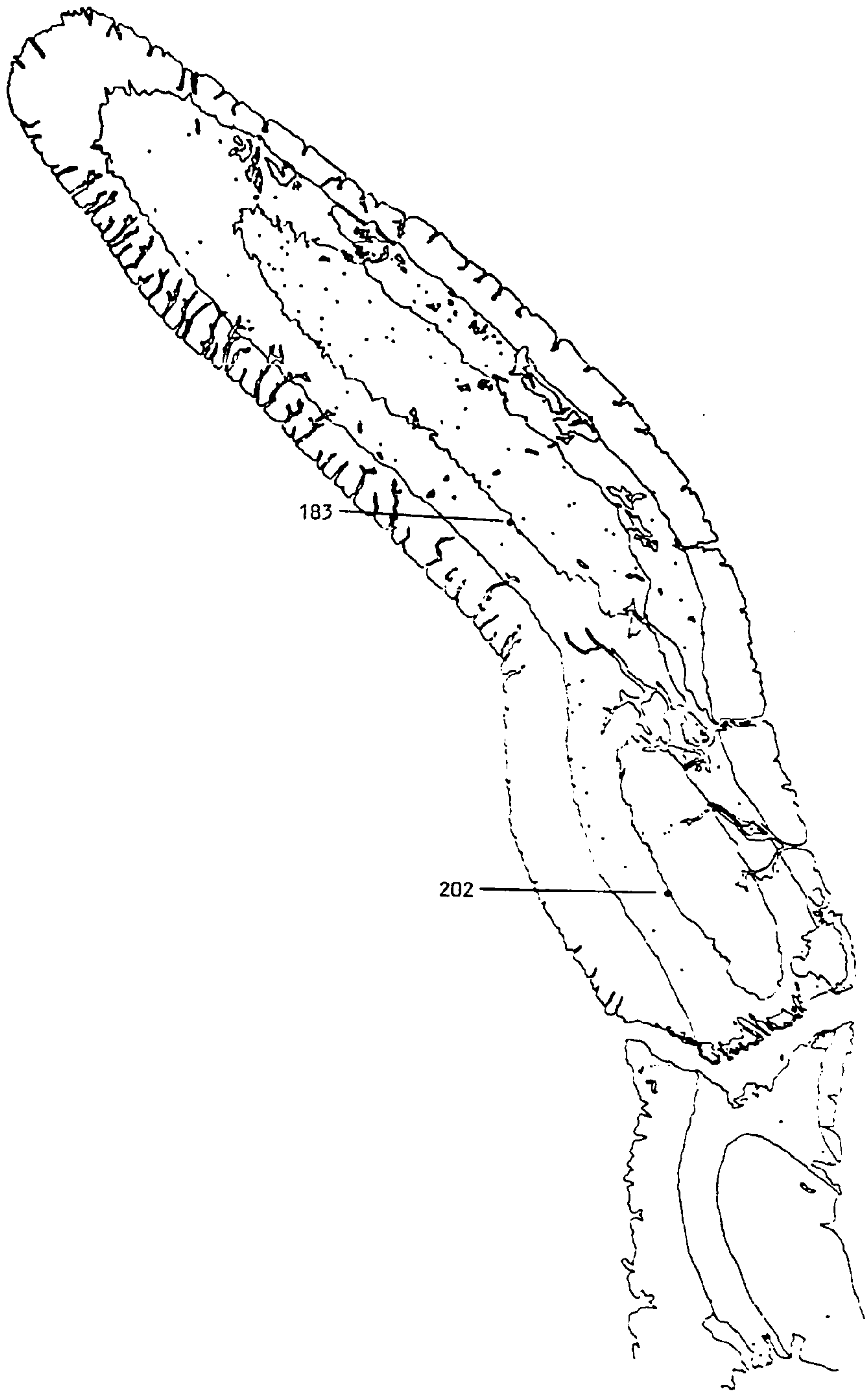

217

San Joaquin Formation

Cascajo Conglomerate

WSR# 183

WSR# 202


183
202

San Joaquin Formation

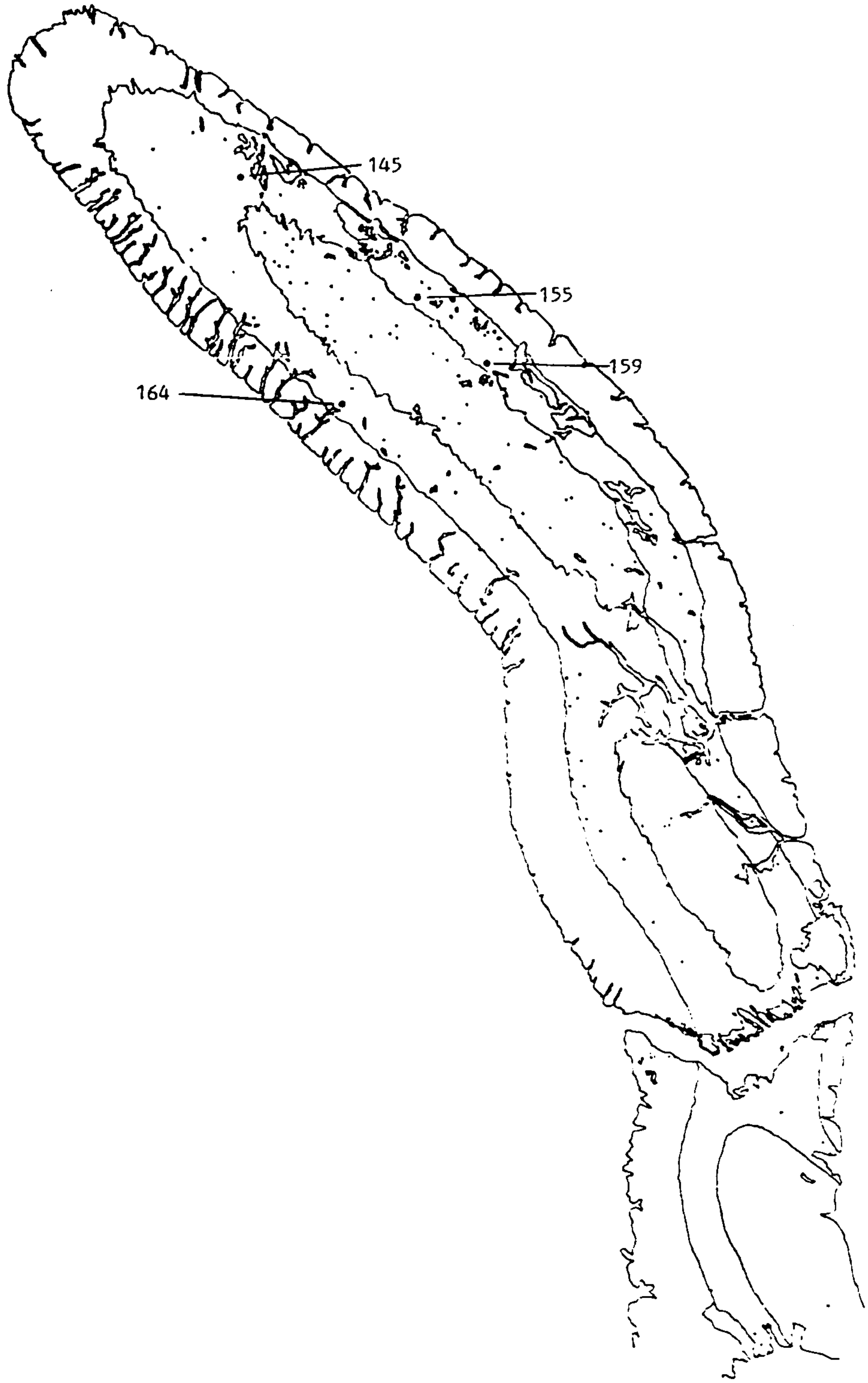
Neverita Zone

WSR# 145

WSR# 155

WSR# 159

WSR# 164


145
155
159
164

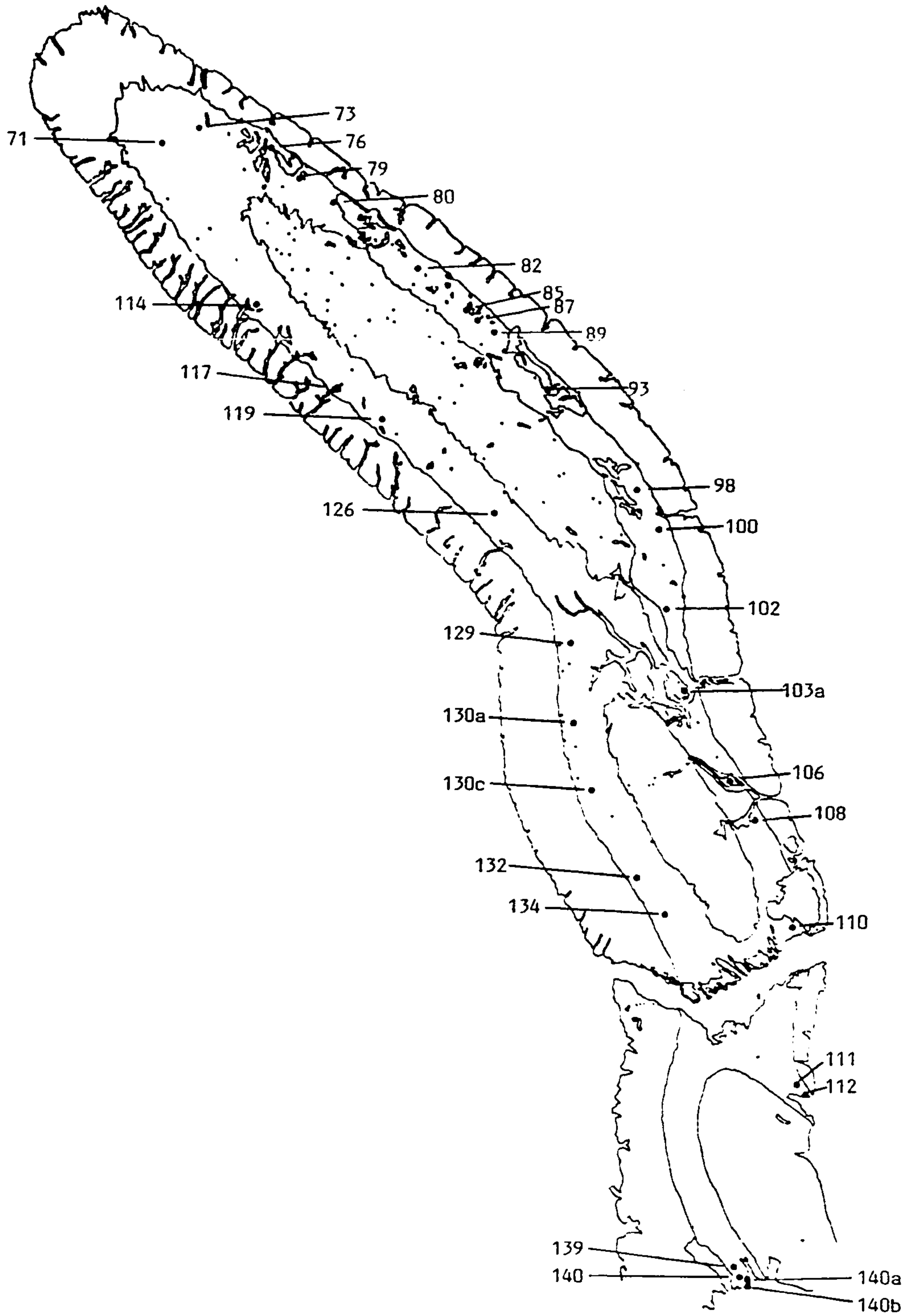
San Joaquin Formation

<u>Pecten/Trachycardium</u> Zone

WSR# 71	WSR#108
WSR# 73	WSR#110
WSR# 76	WSR#111
WSR# 79	WSR#112
WSR# 80	WSR#114
WSR# 82	WSR#117
WSR# 85	WSR#119
WSR# 87	WSR#126
WSR# 89	WSR#129
WSR# 92	WSR#130
WSR# 93	WSR#130a
WSR# 98	WSR#130c
WSR#100	WSR#132
WSR#102	WSR#134
WSR#103a	WSR#139
WSR#105a	WSR#140
WSR#106	WSR#140b
	WSR#140a

Non-WSR Localities:

- Southeast of Hydrill
- La Caldera
- North of La Caldera
- 3rd ridge south of Hydrill
- Badger Hill
- El Prado, Southeast edge
- Arroyo Conchoso area
- Arroyo Recodo
- Ridge North of La Caldera
- Between Arroyo Delgado and Arroyo Ramosa
- El Prado



73
71
76
79
80
82
114
85
87
89
117
93
119
98
126
100
102
129
103a
130a
106
130c
108
132
134
110
111
112
139
140
140a
140b

San Joaquin Formation

Acila Zone

WSR# 60

WSR# 63

WSR# 64

Non-WSR Localities:

El Dombo Area

Northwest corner Sec3, 23S, 18E

Between Arroyo Delgado and Arroyo Ramosa

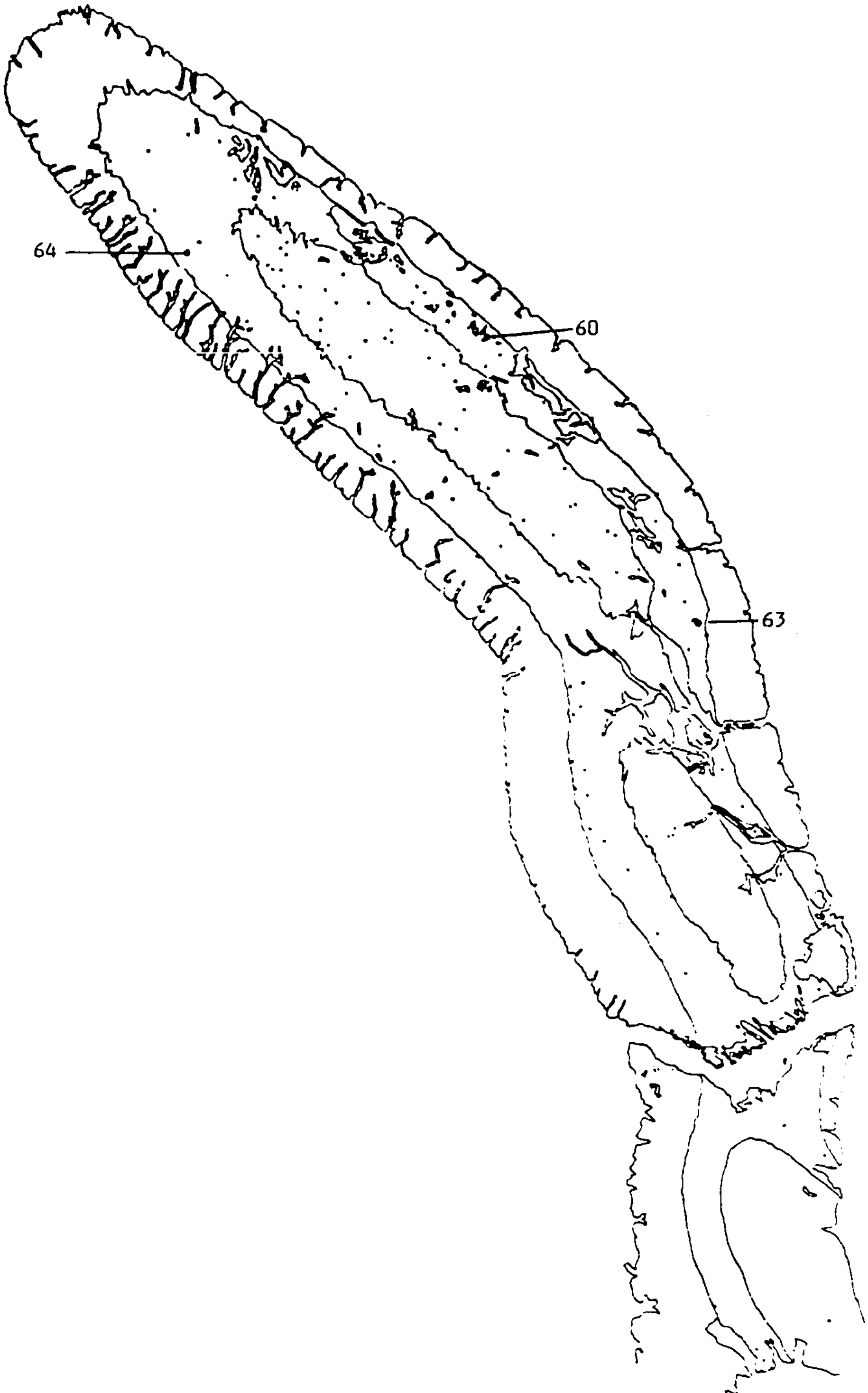
El Prado

Arroyo Pino, northeast of WSR# 96

Arroyo Conchoso area

Hill South of Hydrill

La Caldera


64
60
63

San Joaquin Formation

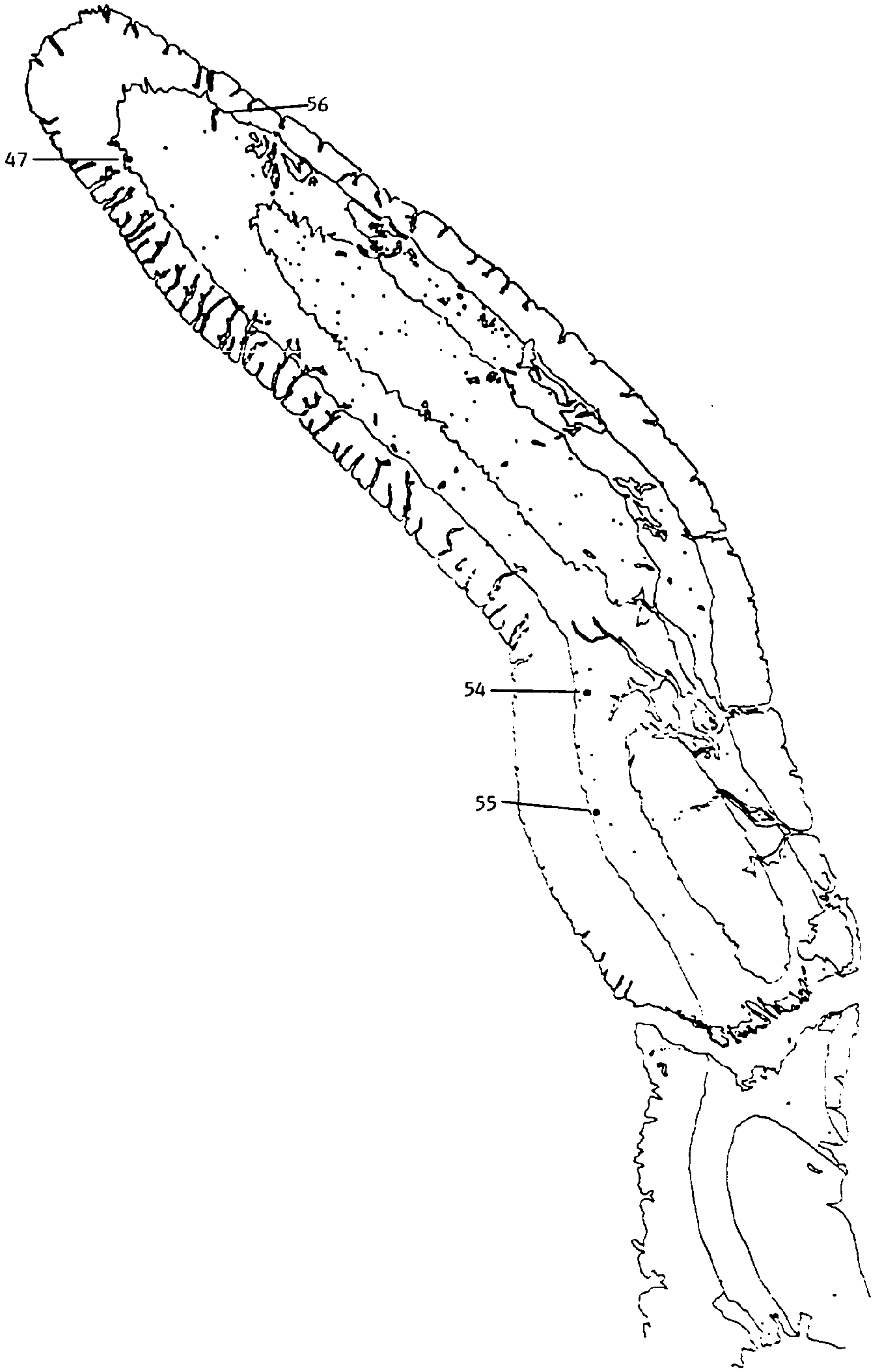
Between *Acila* and Upper *Mya* Zone

WSR# 47

WSR# 54

WSR# 55

WSR# 56

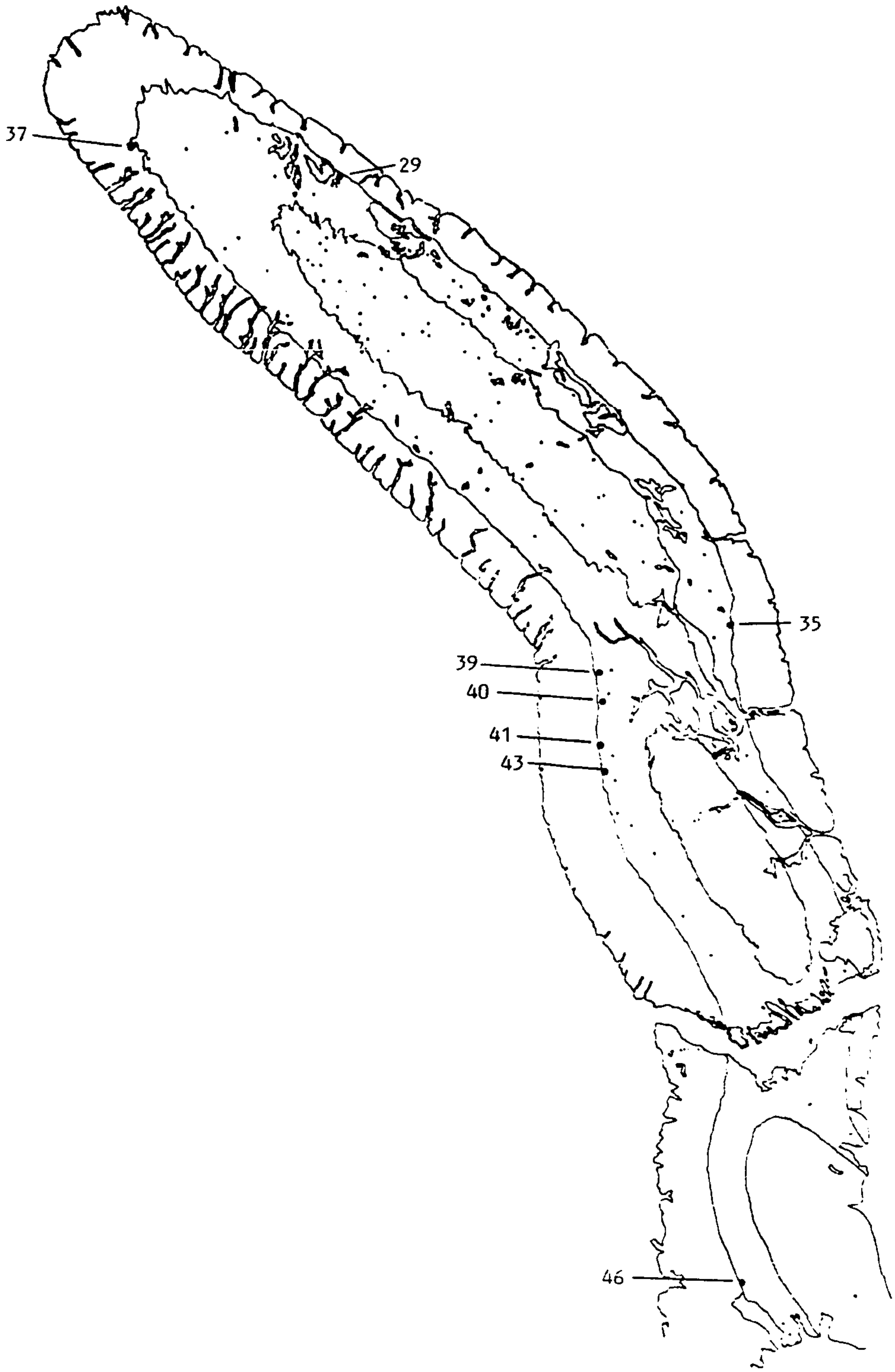


56
47
54
55

San Joaquin Formation

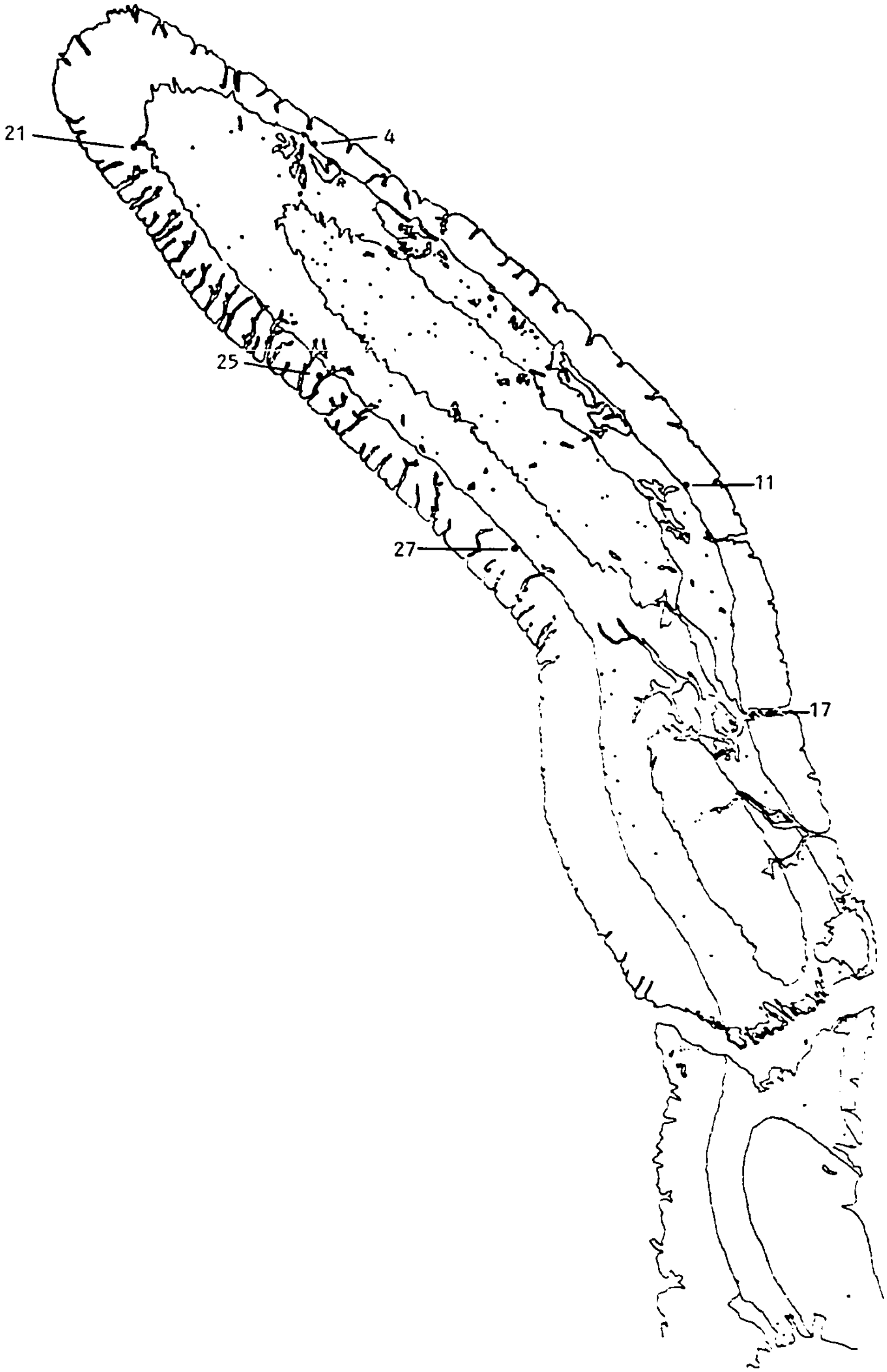
Upper *Mya* Zone

WSR# 29
WSR# 35
WSR# 37
WSR# 39
WSR# 40
WSR# 41
WSR# 43
WSR# 46


37
29
35
39
40
41
43
46

Tulare Formation

WSR# 4
WSR# 11
WSR# 17
WSR# 21
WSR# 25
WSR# 27


21
4
25
11
27
17

APPENDIX IV

Humboldt Basin Sample Data

The following codes are necessary for use of this data:

1) Loc = Location number
   - (2) Eel River Section
   - (3) Centerville Beach Section

2) FM = Formation
   - a. For the Eel River Section
     - (10) Pullen
     - (20) Eel River
     - (45) Rio Dell
     - (55) Rio Dell/Scotia Bluffs (?)
     - (60) Scotia Bluffs
   - b. For the Centerville Beach Section
     - (10) Pullen
     - (20) Eel River
     - (30) Lower Rio Dell Member
     - (40) Middle Rio Dell Member
     - (50) Upper Rio Dell Member

3) SLOC = Sample Level
   Sample numbers refer to those found in Plates I and II.

4) OBS = Computer sort cards

5) HOST = Host organisms
   These numbers refer to the codes provided in Appendix II.

6) GUEST = Guest organisms
   - (23) Fungal boring?
   - (24) Fungal boring
   - (101) Clionid boring
   - (301) Encrusting Bryozoans
   - (513) Muricid boring
   - (514) Naticid boring
   - (515) Naticid boring ?
   - (516) Muricid boring ?
   - (517) Gastropod boring
   - (541) *Teredo* boring ?

(601) Crab breakage
(603) Crab breakage ?
(610) Barnacle
(911) Very small polychaete boring (-0.1mm)
(912) Small polychaete boring (.1-.5mm)
(913) Medium polychaete boring (.5-1mm)
(914) Large polychaete boring (+1mm)
(922) Polychaete boring?

7) CNT = Count variable
1 = single report per shell or first report for a shell
0 = multiple reports per shell
ex.: If CNT = 1, 1, 0, 1, and 0, there were 3 shells.

------ LOC=2 FM=20 SLOC=40 -------

OBS	HOST	GUEST	CNT
5435	513802	0	1

------ LOC=2 FM=20 SLOC=41 -------

OBS	HOST	GUEST	CNT
5436	510005	0	1
5437	511113	0	1
5438	512112	0	1
5439	512601	0	1
5440	513814	0	1
5441	521123	0	1
5442	521123	0	1
5443	521213	0	1
5444	525111	0	1
5445	525541	0	1
5446	526231	0	1
5447	531122	0	1
5448	531131	0	1
5449	621111	0	1

------ LOC=2 FM=20 SLOC=42 -------

OBS	HOST	GUEST	CNT
5450	521123	0	1
5451	521123	0	1

------ LOC=2 FM=20 SLOC=43 -------

OBS	HOST	GUEST	CNT
5452	621121	0	1

------ LOC=2 FM=20 SLOC=44 --------

OBS	HOST	GUEST	CNT
5453	512601	0	1
5454	513201	0	1
5455	513201	912	1
5456	513713	0	1
5457	513801	0	1
5458	513813	0	1
5459	513841	0	1
5460	513841	0	1
5461	520001	0	1
5462	521121	0	1
5463	523111	0	1
5464	526141	0	1

------ LOC=2 FM=20 SLOC=44 -------

OBS	HOST	GUEST	CNT
5465	526221	0	1
5466	526231	0	1
5467	531001	0	1
5468	611211	0	1
5469	621111	0	1
5470	821002	0	1
5471	821002	0	1
5472	850001	0	1
5473	850001	0	1

------ LOC=2 FM=20 SLOC=45 -------

OBS	HOST	GUEST	CNT
5474	20001	0	1
5475	513415	0	1
5476	513801	0	1
5477	525541	0	1
5478	525541	610	1
5479	526231	0	1
5480	611111	0	1
5481	700001	0	1
5482	711111	0	1
5483	711111	0	1
5484	711111	0	1
5485	711111	0	1
5486	712001	0	1
5487	712001	0	1
5488	812001	0	1
5489	830001	0	1
5490	830001	0	1

------ LOC=2 FM=20 SLOC=47 -------

OBS	HOST	GUEST	CNT
5491	520001	0	1
5492	526221	0	1
5493	526221	914	1
5494	526231	0	1
5495	526231	0	1
5496	526231	514	1

------ LOC=2 FM=20 SLOC=48 -------

OBS	HOST	GUEST	CNT
5497	526231	0	1
5498	526231	514	1
5499	531001	0	1
5500	821002	0	1

-------- LOC=2 FM=10 SLOC=4 --------

OBS	HOST	GUEST	CNT
5377	911112	0	1

-------- LOC=2 FM=10 SLOC=6 --------

OBS	HOST	GUEST	CNT
5378	520001	0	1
5379	520001	0	1
5380	520001	0	1
5381	520001	0	1
5382	520004	0	1
5383	520009	0	1
5384	521210	0	1
5385	521210	0	1
5386	531001	0	1

-------- LOC=2 FM=10 SLOC=7 -------

OBS	HOST	GUEST	CNT
5387	513411	0	1
5388	520001	0	1
5389	521213	0	1
5390	521213	514	1
5391	522115	0	1
5392	525501	0	1
5393	526521	0	1
5394	526611	0	1
5395	526614	0	1
5396	531001	0	1
5397	531121	0	1

------- LOC=2 FM=10 SLOC=8 -------

OBS	HOST	GUEST	CNT
5398	520001	0	1
5399	523151	0	1
5400	523151	0	1
5401	526611	0	1

------- LOC=2 FM=10 SLOC=9 -------

OBS	HOST	GUEST	CNT
5402	512521	0	1
5403	520001	0	1
5404	525114	0	1

------ LOC=2 FM=10 SLOC=11 --------

OBS	HOST	GUEST	CNT
5405	525114	0	1
5406	525114	0	1

------ LOC=2 FM=10 SLOC=18 -------

OBS	HOST	GUEST	CNT
5411	513312	0	1
5412	521123	0	1
5413	524222	0	1
5414	526231	0	1
5415	528311	0	1

------ LOC=2 FM=10 SLOC=19 -------

OBS	HOST	GUEST	CNT
5416	20004	0	1
5417	500001	0	1
5418	500001	0	1
5419	510005	0	1
5420	510005	0	1
5421	510007	0	1
5422	512602	0	1
5423	520002	0	1
5424	526202	0	1
5425	526231	0	1
5426	531131	0	1
5427	531131	0	1
5428	531131	0	1
5429	531131	0	1
5430	531131	913	1

------ LOC=2 FM=10 SLOC=20 -------

OBS	HOST	GUEST	CNT
5431	20002	0	1

------ LOC=2 FM=10 SLOC=24 --------

OBS	HOST	GUEST	CNT
5432	526222	0	1

------ LOC=2 FM=20 SLOC=27 --------

OBS	HOST	GUEST	CNT
5433	520001	0	1
5434	526231	515	1

------ LOC=2 FM=20 SLOC=49 -------

OBS	HOST	GUEST	CNT
5501	512612	0	1
5502	521122	0	1
5503	521221	0	1

------ LOC=2 FM=20 SLOC=50 -------

OBS	HOST	GUEST	CNT
5504	512111	0	1
5505	512601	0	1
5506	512614	0	1
5507	512614	0	1
5508	513601	0	1
5509	521111	0	1
5510	521121	0	1
5511	521121	0	1
5512	521213	0	1
5513	522211	0	1
5514	526143	0	1
5515	526231	0	1
5516	621121	0	1

------ LOC=2 FM=20 SLOC=51 -------

OBS	HOST	GUEST	CNT
5517	510005	0	1
5518	526231	0	1
5519	531002	0	1

------ LOC=2 FM=45 SLOC=85 -------

OBS	HOST	GUEST	CNT
5520	513818	912	1

------ LOC=2 FM=45 SLOC=100 -------

OBS	HOST	GUEST	CNT
5521	520002	0	1
5522	521123	0	1
5523	526225	0	1
5524	526231	0	1
5525	526231	0	1
5526	531002	0	1

------ LOC=2 FM=45 SLOC=101 -------

OBS	HOST	GUEST	CNT
5527	527311	0	1

------ LOC=2 FM=45 SLOC=102 -------

OBS	HOST	GUEST	CNT
5528	531001	0	1

------ LOC=2 FM=45 SLOC=103 -------

OBS	HOST	GUEST	CNT
5529	711111	0	1

------ LOC=2 FM=45 SLOC=105 -------

OBS	HOST	GUEST	CNT
5530	512612	0	1
5531	513821	0	1
5532	513821	0	1
5533	513821	101	1
5534	520001	0	1

------ LOC=2 FM=45 SLOC=107 -------

OBS	HOST	GUEST	CNT
5535	10001	0	1
5536	20001	0	1
5537	526231	0	1

------ LOC=2 FM=45 SLOC=108 -------

OBS	HOST	GUEST	CNT
5538	531001	0	1

------ LOC=2 FM=45 SLOC=109 -------

OBS	HOST	GUEST	CNT
5539	513831	0	1
5540	521123	0	1
5541	521213	0	1

------ LOC=2 FM=45 SLOC=110 ------

OBS	HOST	GUEST	CNT
5542	500001	0	1
5543	512612	912	1
5544	520001	0	1
5545	521122	0	1
5546	526232	0	1

------- LOC=2 FM=45 SLOC=111 -------

OBS	HOST	GUEST	CNT
5547	512524	0	1
5548	513821	0	1
5549	521123	0	1
5550	526225	0	1
5551	526231	0	1

------- LOC=2 FM=45 SLOC=112 -------

OBS	HOST	GUEST	CNT
5552	510005	0	1
5553	513822	0	1
5554	520001	513	1
5555	526222	0	1
5556	526231	0	1
5557	526231	0	1
5558	526231	517	0
5559	526231	913	1

------ LOC=2 FM=45 SLOC=113 -------

OBS	HOST	GUEST	CNT
5560	512612	0	1

------ LOC=2 FM=45 SLOC=114 -------

OBS	HOST	GUEST	CNT
5561	520001	0	1
5562	526226	0	1
5563	531001	0	1

------ LOC=2 FM=45 SLOC=115 ------

OBS	HOST	GUEST	CNT
5564	512601	0	1
5565	521213	0	1
5566	521221	0	1
5567	526225	516	1
5568	527311	0	1

------ LOC=2 FM=45 SLOC=116 -------

OBS	HOST	GUEST	CNT
5569	510005	0	1
5570	513821	0	1
5571	513821	0	1
5572	513821	0	1
5573	513821	0	1
5574	520001	0	1
5575	526222	0	1
5576	526222	912	1
5577	526612	0	1

------ LOC=2 FM=45 SLOC=117 -------

OBS	HOST	GUEST	CNT
5578	513821	0	1
5579	513821	0	1
5580	521123	0	1
5581	525501	0	1
5582	526221	0	1
5583	528311	0	1

------ LOC=2 FM=45 SLOC=118 -------

OBS	HOST	GUEST	CNT
5584	513821	0	1
5585	513821	0	1
5586	513821	914	1
5587	520001	0	1
5588	520001	0	1
5589	524201	0	1
5590	524201	912	1

------ LOC=2 FM=45 SLOC=119 -------

OBS	HOST	GUEST	CNT
5591	513821	0	1
5592	521123	912	1
5593	531001	0	1

------- LOC=2 FM=45 SLOC=120 ------

OBS	HOST	GUEST	CNT
5594	513819	0	1
5595	513819	0	1
5596	513819	0	1
5597	513819	912	1
5598	513819	912	1

------- LOC=2 FM=45 SLOC=121 ------

OBS	HOST	GUEST	CNT
5599	513819	922	1

------- LOC=2 FM=45 SLOC=122 ------

OBS	HOST	GUEST	CNT
5600	513821	0	1
5601	513831	0	1

------- LOC=2 FM=45 SLOC=123 ------

OBS	HOST	GUEST	CNT
5602	20004	541	1
5603	513821	0	1
5604	513821	912	1

------- LOC=2 FM=45 SLOC=124 ------

OBS	HOST	GUEST	CNT
5605	510005	0	1
5606	512611	0	1
5607	512611	912	1
5608	512612	0	1
5609	513821	0	1
5610	520001	0	1
5611	520001	0	1
5612	520005	0	1
5613	521123	0	1

------- LOC=2 FM=45 SLOC=125 ------

OBS	HOST	GUEST	CNT
5614	512601	0	1
5615	524241	912	1

------ LOC=2 FM=45 SLOC=126 ------

OBS	HOST	GUEST	CNT
5616	513821	0	1
5617	521123	0	1

------ LOC=2 FM=45 SLOC=127 ------

OBS	HOST	GUEST	CNT
5618	523111	0	1

------ LOC=2 FM=45 SLOC=128 ------

OBS	HOST	GUEST	CNT
5619	524201	0	1

------ LOC=2 FM=45 SLOC=131 ------

OBS	HOST	GUEST	CNT
5620	20001	0	1
5621	20001	0	1
5622	20003	0	1
5623	510005	0	1
5624	512601	0	1
5625	512612	0	1
5626	521226	0	1
5627	521226	0	1
5628	522111	0	1
5629	525211	0	1
5630	526221	0	1
5631	526238	0	1
5632	526611	0	1
5633	526621	0	1
5634	526634	0	1
5635	526635	0	1
5636	531001	0	1

------ LOC=2 FM=45 SLOC=132 -------

OBS	HOST	GUEST	CNT
5637	513812	0	1
5638	513821	0	1

------- LOC=2 FM=45 SLOC=134 -------

OBS	HOST	GUEST	CNT
5639	510005	0	1
5640	524201	0	1
5641	524201	0	1
5642	524201	0	1
5643	524201	0	1
5644	524201	912	1
5645	524201	913	1
5646	524214	0	1
5647	524214	0	1
5648	524214	0	1
5649	524214	0	1
5650	524214	912	1

------- LOC=2 FM=45 SLOC=135 -------

OBS	HOST	GUEST	CNT
5651	20001	0	1
5652	20001	0	1
5653	20001	0	1
5654	510005	0	1
5655	512601	0	1
5656	512601	912	1
5657	512612	0	1
5658	512612	514	1
5659	512612	912	1
5660	513711	514	1
5661	513711	514	1
5662	513715	514	1
5663	513811	0	1
5664	513817	301	0
5665	513817	610	0
5666	513817	912	1
5667	513817	912	1
5668	513818	0	1
5669	513819	0	1
5670	513841	601	1
5671	521221	0	1
5672	524214	0	1
5673	524214	0	1
5674	524214	912	1
5675	524231	0	1
5676	524231	0	1
5677	524231	911	1
5678	524241	0	1
5679	524245	912	1
5680	524246	0	1
5681	524246	0	1
5682	524246	912	1
5683	525114	0	1
5684	525212	0	1
5685	525311	0	1
5686	525311	0	1

------- LOC=2 FM=45 SLOC=135 ------

OBS	HOST	GUEST	CNT
5687	526152	514	1
5688	526215	515	1
5689	531001	0	1
5690	531111	0	1
5691	821002	0	1
5692	823001	0	1
5693	823001	0	1

------- LOC=2 FM=45 SLOC=137 ------

OBS	HOST	GUEST	CNT
5694	526201	0	1

------- LOC=2 FM=45 SLOC=138 ------

OBS	HOST	GUEST	CNT
5695	521226	0	1

------- LOC=2 FM=45 SLOC=139 ------

OBS	HOST	GUEST	CNT
5696	526126	0	1
5697	526126	912	1
5698	526226	0	1

------- LOC=2 FM=45 SLOC=141 ------

OBS	HOST	GUEST	CNT
5699	510005	0	1
5700	512601	912	1
5701	512621	0	1
5702	525501	515	1
5703	525543	0	1
5704	526101	0	1
5705	526126	0	1
5706	526126	0	1
5707	526126	0	1
5708	526126	0	1
5709	526126	0	1
5710	526126	0	1
5711	526126	0	1
5712	526126	0	1
5713	526126	912	1
5714	526131	0	1
5715	526162	101	1
5716	526163	0	1

------ LOC=2 FM=45 SLOC=141 ------

OBS	HOST	GUEST	CNT
5717	526235	0	1
5718	526235	514	1
5719	526501	0	1
5720	526521	0	1
5721	526524	0	1
5722	526524	0	1
5723	526524	610	1
5724	611311	0	1

------ LOC=2 FM=45 SLOC=142 -------

OBS	HOST	GUEST	CNT
5725	524214	912	1
5726	526221	0	1
5727	526231	0	1

------ LOC=2 FM=45 SLOC=143 -------

OBS	HOST	GUEST	CNT
5728	512612	912	1
5729	526126	0	1
5730	526152	0	1
5731	526232	0	1
5732	526523	0	1
5733	526523	0	1
5734	526524	610	1
5735	611311	610	1
5736	611311	912	0

------ LOC=2 FM=45 SLOC=144 -------

OBS	HOST	GUEST	CNT
5737	512612	610	0
5738	512612	912	1
5739	512612	912	1
5740	512612	912	1
5741	512614	0	1
5742	513715	912	1
5743	513819	610	0
5744	513819	912	1
5745	524214	0	1
5746	524214	912	1
5747	524214	912	1
5748	524214	913	0
5749	524214	913	0
5750	525501	0	1
5751	525543	0	1
5752	525543	0	1

------ LOC=2 FM=45 SLOC=144 ------

OBS	HOST	GUEST	CNT
5753	525543	610	1
5754	525543	912	1
5755	526126	0	1
5756	526126	0	1
5757	526126	0	1
5758	526235	0	1
5759	526524	0	1
5760	526524	514	1
5761	526524	610	0
5762	526525	0	1
5763	526525	0	1
5764	526525	0	1

------ LOC=2 FM=45 SLOC=145 ------

OBS	HOST	GUEST	CNT
5765	512612	610	0
5766	512612	913	1
5767	512612	914	0
5768	513821	610	0
5769	513821	912	1
5770	524214	0	1
5771	526126	0	1
5772	526126	514	1

------ LOC=2 FM=45 SLOC=146 -------

OBS	HOST	GUEST	CNT
5773	520001	0	1
5774	520001	0	1
5775	520001	0	1
5776	520008	0	1
5777	524214	0	1
5778	526126	0	1
5779	526126	0	1
5780	526126	0	1
5781	526126	0	1
5782	526126	0	1
5783	526126	0	1
5784	526126	0	1
5785	526126	0	1
5786	526126	912	1
5787	526222	0	1
5788	526222	514	1
5789	526612	0	1
5790	527322	0	1
5791	527322	0	1

------- LOC=2 FM=45 SLOC=148 ------

OBS	HOST	GUEST	CNT
5792	526233	0	1
5793	526233	911	1
5794	526523	0	1

------- LOC=2 FM=45 SLOC=149 ------

OBS	HOST	GUEST	CNT
5795	510005	0	1
5796	510006	0	1
5797	512612	912	1
5798	520001	0	1
5799	520001	0	1
5800	524214	0	1
5801	524214	0	1
5802	524214	912	1
5803	526122	0	1
5804	526221	0	1
5805	526222	0	1
5806	526231	0	1
5807	526231	0	1
5808	526231	0	1
5809	526231	0	1
5810	526231	0	1
5811	526231	514	1

------ LOC=2 FM=45 SLOC=151 ------

OBS	HOST	GUEST	CNT
5812	512612	0	1
5813	521226	0	1
5814	521226	912	1
5815	524214	0	1
5816	524214	0	1
5817	524214	911	1
5818	526126	0	1
5819	526126	0	1
5820	526126	0	1
5821	526126	0	1
5822	526231	0	1
5823	526233	0	1

------ LOC=2 FM=45 SLOC=152 ------

OBS	HOST	GUEST	CNT
5824	520001	0	1
5825	524214	0	1
5826	524214	912	1
5827	526121	0	1

------ LOC=2 FM=45 SLOC=153 ------

OBS	HOST	GUEST	CNT
5828	512612	514	1
5829	525543	0	1
5830	525543	0	1
5831	526126	514	1
5832	526221	0	1

------ LOC=2 FM=45 SLOC=154 ------

OBS	HOST	GUEST	CNT
5833	510006	0	1
5834	512612	912	1
5835	524111	301	0
5836	524111	912	1
5837	524214	0	1
5838	621131	940	1

------ LOC=2 FM=45 SLOC=155 ------

OBS	HOST	GUEST	CNT
5839	512612	0	1
5840	512612	912	1
5841	520001	0	1
5842	524201	0	1
5843	525541	0	1
5844	526126	0	1
5845	526142	0	1
5846	526221	0	1
5847	526221	0	1
5848	526221	0	1
5849	526235	0	1
5850	526612	0	1

------ LOC=2 FM=45 SLOC=170 ------

OBS	HOST	GUEST	CNT
5851	510001	0	1
5852	520001	0	1
5853	524201	912	1
5854	525541	0	1
5855	525541	0	1
5856	526121	0	1
5857	526126	514	1
5858	526202	0	1
5859	526221	0	1
5860	526222	0	1

------- LOC=2 FM=45 SLOC=171 ------

OBS	HOST	GUEST	CNT
5861	512111	0	1
5862	524241	0	1
5863	526221	0	1

------- LOC=2 FM=45 SLOC=172 ------

OBS	HOST	GUEST	CNT
5864	524201	0	1
5865	524201	912	1
5866	524201	913	0
5867	525541	0	1
5868	526121	0	1
5869	526221	0	1
5870	526222	0	1

------- LOC=2 FM=45 SLOC=173 ------

OBS	HOST	GUEST	CNT
5871	525543	0	1
5872	525543	0	1
5873	526126	0	1
5874	526126	0	1
5875	526126	0	1
5876	526234	0	1
5877	526235	0	1
5878	526235	0	1
5879	526235	514	1
5880	526525	0	1
5881	526631	0	1
5882	526634	0	1
5883	621111	0	1

------- LOC=2 FM=45 SLOC=174 ------

OBS	HOST	GUEST	CNT
5884	525543	0	1
5885	526122	0	1
5886	526122	912	1
5887	526233	0	1
5888	526233	0	1
5889	526233	0	1
5890	526233	0	1
5891	526233	0	1
5892	526233	0	1
5893	526233	514	1
5894	526233	514	1
5895	526233	912	1
5896	526233	912	1

------ LOC=2 FM=45 SLOC=175 ------

OBS	HOST	GUEST	CNT
5897	526142	0	1

------ LOC=2 FM=45 SLOC=176 ------

OBS	HOST	GUEST	CNT
5898	526142	0	1
5899	526142	0	1
5900	526142	0	1
5901	526142	0	1
5902	526142	0	1
5903	526142	0	1
5904	526142	0	1
5905	526142	0	1
5906	526142	0	1
5907	526142	0	1
5908	526142	0	1
5909	526142	0	1
5910	526142	0	1
5911	526142	0	1
5912	526142	0	1
5913	526142	0	1
5914	526142	0	1
5915	526142	0	1
5916	526142	0	1
5917	526142	0	1
5918	526142	0	1
5919	526142	0	1
5920	526142	0	1
5921	526142	0	1
5922	526142	0	1
5923	526142	0	1
5924	526142	0	1
5925	526142	0	1
5926	526142	0	1

------ LOC=2 FM=45 SLOC=177 -------

OBS	HOST	GUEST	CNT
5927	520001	0	1
5928	520001	0	1
5929	520001	912	1
5930	524201	0	1
5931	526121	0	1
5932	526221	0	1
5933	526233	0	1

------- LOC=2 FM=45 SLOC=178 ------

OBS	HOST	GUEST	CNT
5934	512612	0	1
5935	512612	0	1
5936	512612	0	1
5937	512612	0	1
5938	512612	0	1
5939	513715	913	1
5940	513841	0	1
5941	520002	610	1
5942	521226	0	1
5943	521226	0	1
5944	524214	912	1
5945	524214	913	0
5946	526126	0	1
5947	526126	0	1
5948	526126	0	1
5949	526126	514	1
5950	526126	514	1
5951	526126	912	0
5952	526142	0	1
5953	526233	0	1
5954	526233	0	1
5955	526233	0	1
5956	526233	0	1
5957	526233	514	1
5958	526412	0	1
5959	526632	0	1
5960	527311	0	1
5961	528211	0	1
5962	528211	0	1
5963	611111	0	1
5964	611111	610	1
5965	611112	610	1
5966	712121	0	1

------ LOC=2 FM=45 SLOC=179 ------

OBS	HOST	GUEST	CNT
5967	512612	0	1
5968	525501	514	1
5969	525543	0	1
5970	525543	0	1
5971	525543	0	1
5972	525543	0	1
5973	525543	0	1
5974	525543	0	1
5975	525543	0	1
5976	525543	0	1
5977	525543	0	1
5978	525543	0	1
5979	525543	0	1
5980	525543	0	1
5981	525543	0	1

------ LOC=2 FM=45 SLOC=179 ------

OBS	HOST	GUEST	CNT
5982	525543	0	1
5983	525543	0	1
5984	525543	0	1
5985	525543	0	1
5986	525543	0	1
5987	525543	0	1
5988	525543	0	1
5989	525543	0	1
5990	525543	0	1
5991	525543	0	1
5992	525543	0	1
5993	525543	0	1
5994	525543	0	1
5995	525543	0	1
5996	525543	0	1
5997	525543	0	1
5998	525543	0	1
5999	525543	0	1
6000	525543	0	1
6001	525543	0	1
6002	525543	0	1
6003	525543	0	1
6004	525543	0	1
6005	525543	0	1
6006	525543	0	1
6007	525543	0	1
6008	525543	0	1
6009	525543	912	1
6010	525543	912	1
6011	526126	0	1
6012	526126	0	1
6013	526126	0	1
6014	526126	0	1
6015	526126	0	1
6016	526126	0	1
6017	526126	0	1
6018	526126	0	1
6019	526126	0	1
6020	526126	0	1
6021	526126	0	1
6022	526126	0	1
6023	526126	0	1
6024	526126	0	1
6025	526126	0	1
6026	526126	0	1
6027	526126	0	1
6028	526126	0	1
6029	526126	0	1
6030	526126	0	1
6031	526126	0	1
6032	526126	0	1
6033	526126	0	1
6034	526126	0	1
6035	526126	0	1

------ LOC=2 FM=45 SLOC=179 ------

OBS	HOST	GUEST	CNT
6036	526126	0	1
6037	526126	0	1
6038	526126	0	1
6039	526126	0	1
6040	526126	0	1
6041	526126	0	1
6042	526126	0	1
6043	526126	514	1
6044	526126	912	1
6045	526126	912	1
6046	526126	912	1
6047	526126	912	1
6048	526126	912	1
6049	526126	912	1
6050	526126	912	1
6051	526126	912	1
6052	526126	912	1
6053	526126	912	1
6054	526126	913	0
6055	526126	913	0
6056	526126	913	0
6057	526126	913	0
6058	526126	913	0
6059	526126	913	0
6060	526126	913	0
6061	526126	913	0
6062	526126	913	0
6063	526221	514	1
6064	526230	0	1
6065	526230	0	1

------ LOC=2 FM=45 SLOC=180 -------

OBS	HOST	GUEST	CNT
6066	512601	0	1
6067	524214	0	1
6068	524214	0	1
6069	524214	0	1
6070	524214	610	1
6071	524214	912	1
6072	524214	912	1
6073	524214	912	1
6074	524214	912	1
6075	524214	913	0
6076	524214	913	0
6077	524214	913	0
6078	524214	913	0
6079	525543	0	1
6080	525543	0	1
6081	526126	0	1
6082	526126	912	1
6083	526132	0	1

------ LOC=2 FM=45 SLOC=180 ------

OBS	HOST	GUEST	CNT
6084	526132	0	1
6085	526132	0	1
6086	526132	0	1
6087	526132	514	1
6088	526132	911	1
6089	526202	517	1
6090	526231	0	1
6091	527122	516	1
6092	528211	0	1
6093	528211	0	1
6094	528211	0	1
6095	528211	0	1
6096	528211	0	1
6097	528211	0	1
6098	528211	0	1
6099	528211	0	1
6100	528211	0	1
6101	528211	0	1
6102	528211	0	1
6103	528211	0	1
6104	528211	0	1
6105	528211	0	1
6106	611111	0	1

------ LOC=2 FM=45 SLOC=181 -------

OBS	HOST	GUEST	CNT
6107	20004	0	1
6108	510007	514	1
6109	511112	0	1
6110	512612	0	1
6111	513816	0	1
6112	513841	922	1
6113	521212	0	1
6114	525114	912	1
6115	525501	0	1
6116	525543	514	1
6117	526132	0	1
6118	526142	0	1
6119	526142	0	1
6120	526142	0	1
6121	526142	0	1
6122	526142	0	1
6123	526142	0	1
6124	526142	0	1
6125	526231	0	1
6126	526231	514	1
6127	528211	0	1
6128	621131	0	1

------ LOC=2 FM=45 SLOC=182 ------

OBS	HOST	GUEST	CNT
6129	512614	0	1
6130	525543	0	1
6131	712122	0	1

------ LOC=2 FM=45 SLOC=185 -------

OBS	HOST	GUEST	CNT
6132	524214	0	1
6133	526132	0	1
6134	526132	0	1
6135	526231	0	1
6136	528211	0	1
6137	528211	0	1
6138	528211	0	1
6139	528211	0	1
6140	528211	0	1
6141	528211	0	1
6142	528211	0	1
6143	528211	0	1
6144	528211	0	1
6145	528211	0	1
6146	528211	0	1

------ LOC=2 FM=45 SLOC=186 -------

OBS	HOST	GUEST	CNT
6147	526126	0	1
6148	526132	0	1
6149	526132	0	1
6150	526132	0	1
6151	526132	0	1
6152	526132	0	1
6153	526132	0	1
6154	526231	0	1
6155	528211	0	1
6156	528211	0	1

----- LOC=2 FM=45 SLOC=187 -------

OBS	HOST	GUEST	CNT
6157	20001	0	1
6158	512612	514	1
6159	521227	514	1
6160	524214	0	1
6161	524214	913	1
6162	525543	0	1
6163	526132	0	1
6164	526142	0	1

------ LOC=2 FM=45 SLOC=187 ------

OBS	HOST	GUEST	CNT
6165	526231	0	1
6166	526231	0	1
6167	526231	514	1
6168	526231	514	1
6169	526523	0	1
6170	527312	0	1

------ LOC=2 FM=45 SLOC=188 ------

OBS	HOST	GUEST	CNT
6171	512612	514	0
6172	512612	912	1
6173	525543	0	1
6174	525543	911	1
6175	526126	0	1
6176	526231	0	1
6177	526231	0	1
6178	526231	514	1
6179	526233	0	1
6180	526233	0	1
6181	526233	0	1
6182	526233	514	1
6183	526238	0	1

------ LOC=2 FM=45 SLOC=189 ------

OBS	HOST	GUEST	CNT
6184	524214	0	1

------ LOC=2 FM=45 SLOC=190 ------

OBS	HOST	GUEST	CNT
6185	20004	0	1
6186	512612	0	1
6187	512612	0	1
6188	512612	912	1
6189	520002	0	1
6190	524214	0	1
6191	524214	912	1
6192	524214	912	1
6193	524214	913	0
6194	524214	914	0
6195	525541	0	1
6196	525543	0	1
6197	525543	0	1
6198	525543	0	1
6199	525543	0	1
6200	525543	0	1

------ LOC=2 FM=45 SLOC=190 -------

OBS	HOST	GUEST	CNT
6201	525543	0	1
6202	525543	0	1
6203	525543	0	1
6204	525543	0	1
6205	526142	514	1
6206	526142	514	1
6207	526142	514	1
6208	526222	0	1
6209	526222	0	1
6210	526532	0	1
6211	526611	0	1
6212	528111	912	1
6213	528111	913	0

------ LOC=2 FM=45 SLOC=191 -------

OBS	HOST	GUEST	CNT
6214	524214	0	1
6215	524214	912	1
6216	525501	0	1
6217	525502	912	1
6218	525543	0	1
6219	525543	0	1
6220	525543	610	1
6221	526142	0	1
6222	526201	0	1
6223	526201	0	1
6224	526201	0	1
6225	526201	0	1

------ LOC=2 FM=45 SLOC=192 -------

OBS	HOST	GUEST	CNT
6226	512612	0	1
6227	512612	0	1
6228	512612	0	1
6229	512612	514	1
6230	520001	0	1
6231	520005	0	1
6232	520006	0	1
6233	520007	0	1
6234	525541	0	1
6235	525543	0	1
6236	525543	0	1
6237	525543	0	1
6238	525543	0	1
6239	525543	0	1
6240	525543	0	1
6241	525543	0	1
6242	525543	0	1

------- LOC=2 FM=45 SLOC=192 ------

OBS	HOST	GUEST	CNT
6243	525543	0	1
6244	525543	0	1
6245	525543	0	1
6246	525543	0	1
6247	525543	0	1
6248	525543	0	1
6249	525543	0	1
6250	525543	0	1
6251	525543	0	1
6252	525543	0	1
6253	525543	0	1
6254	525543	0	1
6255	525543	0	1
6256	525543	0	1
6257	525543	0	1
6258	525543	0	1
6259	525543	0	1
6260	525543	912	1
6261	525543	913	1
6262	526142	0	1
6263	526142	0	1
6264	526142	0	1
6265	526142	0	1
6266	526142	0	1
6267	526142	0	1
6268	526142	0	1
6269	526142	0	1
6270	526142	0	1
6271	526142	0	1
6272	526142	0	1
6273	526222	0	1
6274	526222	0	1
6275	526522	0	1
6276	526611	0	1
6277	526612	0	1
6278	526612	0	1
6279	527111	0	1
6280	527111	0	1
6281	712001	0	1

------ LOC=2 FM=45 SLOC=193 -------

OBS	HOST	GUEST	CNT
6282	513795	0	1
6283	525501	0	1
6284	525501	610	1
6285	525543	0	1
6286	525543	610	1
6287	526142	0	1
6288	526142	0	1
6289	526142	0	1
6290	526142	0	1

------- LOC=2 FM=45 SLOC=193 ------

OBS	HOST	GUEST	CNT
6291	526142	0	1
6292	526142	0	1
6293	526142	0	1
6294	526142	0	1
6295	526142	0	1
6296	526142	0	1
6297	526142	0	1
6298	526142	0	1
6299	526142	0	1
6300	526142	0	1
6301	526142	0	1
6302	526142	0	1
6303	526142	0	1
6304	526142	0	1
6305	526142	0	1
6306	526142	0	1
6307	526142	0	1
6308	526142	0	1
6309	526142	0	1
6310	526142	0	1
6311	526142	0	1
6312	526142	0	1
6313	526142	0	1
6314	526142	0	1
6315	526142	0	1
6316	526142	0	1
6317	526142	0	1
6318	526142	0	1
6319	526142	0	1
6320	526142	0	1
6321	526142	0	1
6322	526142	0	1
6323	526142	0	1
6324	526142	0	1
6325	526142	0	1
6326	526142	0	1
6327	526142	0	1
6328	526142	0	1
6329	526142	0	1
6330	526142	0	1
6331	526142	0	1
6332	526142	0	1
6333	526142	0	1
6334	526142	0	1
6335	526142	0	1
6336	526142	0	1
6337	526142	0	1
6338	526142	0	1
6339	526142	0	1
6340	526142	0	1
6341	526142	0	1
6342	526142	514	1
6343	526142	514	1
6344	526502	0	1

------ LOC=2 FM=45 SLOC=193 ------

OBS	HOST	GUEST	CNT
6345	526613	0	1
6346	526632	0	1
6347	526632	0	1
6348	526635	0	1
6349	712001	0	1
6350	712001	0	1
6351	712122	0	1
6352	712122	0	1
6353	712122	0	1

------ LOC=2 FM=55 SLOC=146 ------

OBS	HOST	GUEST	CNT
6354	526126	0	1

------ LOC=2 FM=60 SLOC=200 ------

OBS	HOST	GUEST	CNT
6355	520001	0	1
6356	520001	0	1
6357	525541	0	1
6358	525541	0	1
6359	525541	913	1
6360	525543	0	1
6361	525543	0	1
6362	525543	0	1
6363	525543	0	1
6364	525543	0	1
6365	525543	0	1
6366	525543	0	1
6367	525543	0	1
6368	525543	0	1
6369	525543	0	1
6370	525543	0	1

------ LOC=2 FM=60 SLOC=201 ------

OBS	HOST	GUEST	CNT
6371	520001	0	1
6372	526635	0	1
6373	712122	0	1

------ LOC=2 FM=60 SLOC=202 ------

OBS	HOST	GUEST	CNT
6374	520001	0	1
6375	525543	0	1
6376	525543	0	1
6377	525543	0	1
6378	525543	0	1
6379	525543	0	1
6380	525543	0	1
6381	525543	0	1
6382	525543	0	1
6383	525543	0	1
6384	525543	0	1
6385	525543	912	1
6386	525543	912	1
6387	526611	0	1

------ LOC=2 FM=60 SLOC=203 -------

OBS	HOST	GUEST	CNT
6388	512612	0	1
6389	520001	0	1
6390	525543	0	1
6391	525543	0	1
6392	525543	0	1
6393	525543	0	1
6394	525543	0	1
6395	525543	0	1
6396	526612	0	1

------ LOC=2 FM=60 SLOC=204 -------

OBS	HOST	GUEST	CNT
6397	512612	0	1
6398	512612	0	1
6399	512612	0	1
6400	512612	0	1
6401	512612	514	0
6402	512612	515	1
6403	512612	912	1
6404	512612	912	1
6405	513121	0	1
6406	513811	912	1
6407	513816	912	1
6408	525541	0	1
6409	712001	0	1
6410	712122	0	1

------ LOC=2 FM=60 SLOC=205 ------

OBS	HOST	GUEST	CNT
6411	525541	0	1
6412	712001	0	1

------ LOC=2 FM=60 SLOC=207 ------

OBS	HOST	GUEST	CNT
6413	526231	514	1
6414	526611	0	1
6415	526611	0	1
6416	527312	0	1

------ LOC=2 FM=60 SLOC=220 ------

OBS	HOST	GUEST	CNT
6417	525543	0	1
6418	525543	0	1
6419	525543	0	1
6420	525543	0	1
6421	525543	0	1
6422	525543	0	1
6423	525543	0	1
6424	525543	0	1
6425	525543	0	1
6426	525543	0	1
6427	525543	0	1
6428	525543	0	1
6429	525543	0	1
6430	525543	0	1
6431	525543	0	1
6432	525543	0	1
6433	525543	912	1

------- LOC=3 FM=10 SLOC=5 --------

OBS	HOST	GUEST	CNT
6434	521123	0	1
6435	521123	0	1
6436	521123	0	1
6437	521123	0	1
6438	521123	0	1

------- LOC=3 FM=20 SLOC=22 -------

OBS	HOST	GUEST	CNT
6439	512111	0	1
6440	512612	0	1
6441	521123	0	1
6442	526231	0	1
6443	526231	0	1
6444	526231	0	1
6445	526231	0	1
6446	526231	0	1
6447	526231	0	1
6448	526231	0	1

------- LOC=3 FM=20 SLOC=25 --------

OBS	HOST	GUEST	CNT
6449	10001	0	1
6450	20001	0	1
6451	20001	0	1
6452	20001	0	1
6453	20003	0	1
6454	510001	0	1
6455	510005	0	1
6456	510005	0	1
6457	511111	0	1
6458	512001	0	1
6459	512111	0	1
6460	512601	912	1
6461	512611	0	1
6462	514111	0	1
6463	520001	0	1
6464	520001	0	1
6465	520010	0	1
6466	521121	0	1
6467	521211	0	1
6468	531001	0	1
6469	531001	0	1
6470	700001	0	1
6471	700001	0	1
6472	700001	0	1
6473	821002	0	1
6474	821002	0	1
6475	830001	0	1

------- LOC=3 FM=20 SLOC=26 -------

OBS	HOST	GUEST	CNT
6476	512103	0	1
6477	512612	0	1
6478	513711	0	1
6479	526231	0	1
6480	528311	0	1

------- LOC=3 FM=20 SLOC=27 -------

OBS	HOST	GUEST	CNT
6481	512111	0	1
6482	513711	0	1
6483	711111	0	1

------- LOC=3 FM=20 SLOC=28 -------

OBS	HOST	GUEST	CNT
6484	10001	0	1
6485	510005	0	1
6486	512614	0	1
6487	513811	0	1
6488	513821	0	1
6489	513831	0	1
6490	520001	0	1
6491	525501	0	1
6492	526231	0	1
6493	526231	0	1
6494	531002	0	1

------ LOC=3 FM=30 SLOC=40 -------

OBS	HOST	GUEST	CNT
6495	526227	0	1
6496	526227	0	1
6497	526231	0	1

------ LOC=3 FM=30 SLOC=41 -------

OBS	HOST	GUEST	CNT
6498	513713	0	1
6499	521111	0	1
6500	521221	0	1
6501	526231	0	1

------ LOC=3 FM=30 SLOC=42 -------

OBS	HOST	GUEST	CNT
6502	512601	0	1
6503	526231	0	1
6504	526231	517	1

------- LOC=3 FM=30 SLOC=45 -------

OBS	HOST	GUEST	CNT
6505	521226	0	1
6506	521226	23	1
6507	526231	0	1
6508	526231	0	1

------ LOC=3 FM=30 SLOC=46 -------

OBS	HOST	GUEST	CNT
6509	526231	0	1

------ LOC=3 FM=35 SLOC=92 -------

OBS	HOST	GUEST	CNT
6510	524214	0	1

------ LOC=3 FM=40 SLOC=61 -------

OBS	HOST	GUEST	CNT
6511	520001	0	1

------ LOC=3 FM=40 SLOC=62 --------

OBS	HOST	GUEST	CNT
6512	513795	0	1
6513	513818	0	1
6514	513818	23	1
6515	513818	912	1
6516	521221	0	1
6517	524221	0	1
6518	524222	0	1

------ LOC=3 FM=40 SLOC=63 --------

OBS	HOST	GUEST	CNT
6519	521212	0	1

------ LOC=3 FM=50 SLOC=83 -------

OBS	HOST	GUEST	CNT
6520	510005	0	1
6521	513711	0	1
6522	513711	0	1
6523	513841	514	0
6524	513841	912	1
6525	520001	0	1
6526	520001	0	1

------ LOC=3 FM=50 SLOC=85 -------

OBS	HOST	GUEST	CNT
6527	510005	0	1
6528	510005	0	1
6529	510005	912	1
6530	513819	912	1
6531	513819	913	1

------ LOC=3 FM=50 SLOC=86 -------

OBS	HOST	GUEST	CNT
6532	510005	0	1
6533	512111	0	1
6534	512612	912	1
6535	512612	912	1
6536	513801	0	1
6537	711111	0	1

------ LOC=3 FM=50 SLOC=87 -------

OBS	HOST	GUEST	CNT
6538	510007	0	1
6539	512602	0	1
6540	512611	0	1
6541	512611	24	1
6542	513841	0	1
6543	520001	0	1
6544	520001	0	1
6545	521111	912	1
6546	524201	0	1
6547	524201	0	1
6548	524201	0	1
6549	524201	610	1
6550	524201	911	1
6551	524201	912	0
6552	524201	912	1
6553	524214	0	1
6554	524214	0	1
6555	524214	0	1

------ LOC=3 FM=50 SLOC=87 -------

OBS	HOST	GUEST	CNT
6556	524214	610	1
6557	524214	912	1
6558	524214	912	1
6559	524214	913	0
6560	524214	913	0
6561	525112	0	1
6562	525114	912	1
6563	525501	0	1
6564	525501	912	1
6565	526101	0	1
6566	526142	0	1
6567	526142	0	1
6568	526142	0	1
6569	526142	514	1
6570	526221	0	1
6571	526231	0	1
6572	528111	0	1
6573	528111	0	1
6574	528111	0	1
6575	528111	0	1
6576	528111	912	1
6577	528111	913	0
6578	611111	0	1

------ LOC=3 FM=50 SLOC=88 -------

OBS	HOST	GUEST	CNT
6579	512111	0	1
6580	512111	0	1
6581	512111	514	0
6582	512111	912	1
6583	512612	0	1
6584	512612	0	1
6585	512612	912	1
6586	512612	912	1
6587	512612	913	1
6588	513211	912	1
6589	513212	912	1
6590	513711	514	1
6591	513841	0	1
6592	513841	912	1

------ LOC=3 FM=50 SLOC=89 --------

OBS	HOST	GUEST	CNT
6593	513841	0	1
6594	513841	912	1

------ LOC=3 FM=50 SLOC=90 -------

OBS	HOST	GUEST	CNT
6595	513801	0	1
6596	513841	912	1
6597	524214	0	1
6598	524214	913	1
6599	525112	0	1
6600	525112	0	1
6601	525114	0	1
6602	525114	912	1
6603	525114	912	1
6604	525114	913	1
6605	525114	913	1
6606	525114	913	1
6607	525114	913	1
6608	525114	914	0
6609	526231	0	1
6610	527311	0	1

------ LOC=3 FM=50 SLOC=91 -------

OBS	HOST	GUEST	CNT
6611	513211	0	1
6612	525114	0	0
6613	525114	0	1
6614	525114	0	1
6615	525114	0	1
6616	525114	0	1
6617	525114	912	1
6618	525114	912	1
6619	525114	913	0

------ LOC=3 FM=50 SLOC=92 --------

OBS	HOST	GUEST	CNT
6620	513841	610	0
6621	513841	610	0
6622	513841	912	1
6623	513841	912	1
6624	513841	913	0
6625	524214	0	1
6626	524214	0	1
6627	524214	0	1
6628	524214	912	1
6629	524214	912	1
6630	524214	912	1
6631	528111	0	1
6632	528111	0	1
6633	528111	0	1
6634	528111	0	1
6635	528111	0	1
6636	528111	0	1

------ LOC=3 FM=50 SLOC=92 -------

OBS	HOST	GUEST	CNT
6637	528111	912	1
6638	528111	912	1
6639	611211	0	1
6640	611211	610	1

------ LOC=3 FM=50 SLOC=93 -------

OBS	HOST	GUEST	CNT
6641	513122	0	1
6642	526142	0	1
6643	526142	0	1
6644	526231	0	1
6645	526231	0	1
6646	821002	0	1

------ LOC=3 FM=50 SLOC=94 -------

OBS	HOST	GUEST	CNT
6647	512111	0	1
6648	512111	0	1
6649	512111	610	1
6650	512111	913	1
6651	512614	0	1
6652	512614	0	1
6653	512614	0	1
6654	512614	0	1
6655	513711	0	1
6656	513711	0	1
6657	513711	601	1
6658	513795	0	1
6659	513841	0	1
6660	513841	601	0
6661	513841	912	1
6662	525114	0	1
6663	525114	0	1
6664	525544	0	1
6665	527311	912	1
6666	528111	0	1
6667	621121	0	1

------ LOC=3 FM=50 SLOC=95 --------

OBS	HOST	GUEST	CNT
6668	524214	0	1
6669	524214	912	1
6670	524214	913	0
6671	525114	0	1
6672	525114	0	1

------ LOC=3 FM=50 SLOC=96 -------

OBS	HOST	GUEST	CNT
6673	512612	0	1
6674	512612	0	1
6675	512612	912	1
6676	512612	912	1
6677	513121	0	1
6678	513121	0	1
6679	513121	0	1
6680	513122	0	1
6681	513122	610	1
6682	513311	0	1
6683	513312	0	1
6684	513715	601	1
6685	513715	912	0
6686	513796	516	1
6687	513851	0	1
6688	524214	0	1
6689	525544	0	1
6690	525544	0	1
6691	526132	0	1
6692	526132	3	1
6693	526132	610	1
6694	526142	0	1
6695	527311	0	1
6696	528111	0	1
6697	528111	913	1
6698	611111	0	1
6699	611311	0	1

------ LOC=3 FM=50 SLOC=97 --------

OBS	HOST	GUEST	CNT
6700	512312	912	1
6701	525114	0	1
6702	525114	0	1
6703	525541	0	1
6704	528111	0	1

------ LOC=3 FM=50 SLOC=98 --------

OBS	HOST	GUEST	CNT
6705	10001	0	1
6706	512111	0	1
6707	512622	0	1
6708	512622	0	1
6709	512622	0	1
6710	512622	0	1
6711	513121	0	1
6712	513121	0	1
6713	513121	0	1
6714	513121	0	1

------ LOC=3 FM=50 SLOC=98 -------

OBS	HOST	GUEST	CNT
6715	513121	512	1
6716	513122	0	1
6717	513122	601	1
6718	513122	603	1
6719	513311	0	1
6720	513311	0	1
6721	513311	0	1
6722	513311	514	1
6723	513311	912	1
6724	513311	912	1
6725	513311	912	1
6726	513711	0	1
6727	513711	514	1
6728	513713	912	1
6729	513731	0	1
6730	513795	912	1
6731	520001	101	1
6732	524214	913	1
6733	525114	0	1
6734	525114	0	1
6735	525114	0	1
6736	525114	516	0
6737	525114	912	1
6738	526141	0	1
6739	526142	0	1
6740	526142	0	1
6741	526142	0	1
6742	526142	0	1
6743	526142	0	1
6744	526142	0	1
6745	526142	0	1
6746	526142	0	1
6747	526142	0	1
6748	526142	0	1
6749	526142	0	1
6750	526142	0	1
6751	526142	0	1
6752	526142	0	1
6753	526142	0	1
6754	526142	0	1
6755	526142	0	1
6756	526142	0	1
6757	526142	0	1
6758	526142	0	1
6759	526142	0	1
6760	526142	0	1
6761	526142	0	1
6762	526142	0	1
6763	526142	0	1
6764	526142	0	1
6765	526142	0	1
6766	526142	0	1
6767	526142	0	1
6768	526142	0	1

------ LOC=3 FM=50 SLOC=98 -------

OBS	HOST	GUEST	CNT
6769	526142	0	1
6770	526142	0	1
6771	526142	0	1
6772	526142	0	1
6773	526142	0	1
6774	526142	0	1
6775	526142	0	1
6776	526142	0	1
6777	526142	0	1
6778	526142	0	1
6779	526142	912	1
6780	526231	0	1
6781	526525	0	1
6782	526525	0	1
6783	526611	0	1
6784	528110	0	1
6785	611111	0	1
6786	611113	0	1
6787	611211	0	1

------ LOC=3 FM=50 SLOC=99 -------

OBS	HOST	GUEST	CNT
6788	513711	0	1
6789	513841	0	1
6790	513841	0	1
6791	524214	912	1
6792	525112	514	1
6793	525112	516	1
6794	525114	0	1

------ LOC=3 FM=50 SLOC=100 -------

OBS	HOST	GUEST	CNT
6795	512614	0	1
6796	512614	0	1
6797	512614	912	1
6798	513711	0	1
6799	513711	601	1
6800	513711	912	1
6801	513841	0	1
6802	513841	912	1
6803	513841	912	1
6804	513841	913	0
6805	520001	0	1
6806	526234	516	1
6807	526525	0	1
6808	528111	0	1
6809	528111	0	1
6810	528111	913	1

------- LOC=3 FM=50 SLOC=101 ------

OBS	HOST	GUEST	CNT
6811	513841	0	1

------- LOC=3 FM=50 SLOC=102 ------

OBS	HOST	GUEST	CNT
6812	521225	0	1

------- LOC=3 FM=50 SLOC=103 ------

OBS	HOST	GUEST	CNT
6813	513815	912	1
6814	521226	0	1
6815	525114	0	1
6816	525114	0	1
6817	525114	913	1
6818	611221	0	1

------ LOC=3 FM=50 SLOC=104 ------

OBS	HOST	GUEST	CNT
6819	512413	514	1
6820	512413	514	1
6821	513122	514	1
6822	513711	0	1
6823	513711	514	1
6824	513711	514	1
6825	513795	0	1
6826	513795	0	1
6827	513797	0	1
6828	513797	0	1
6829	513818	0	1
6830	513841	0	1
6831	513841	0	1
6832	513841	0	1
6833	513841	0	1
6834	513841	515	0
6835	513841	601	1
6836	513841	912	0
6837	513841	912	1
6838	513841	912	1
6839	513841	912	1
6840	513841	912	1
6841	513841	912	1
6842	513841	912	1
6843	525114	0	1
6844	525114	0	1
6845	526132	0	1
6846	526132	0	1

------ LOC=3 FM=50 SLOC=104 ------

OBS	HOST	GUEST	CNT
6847	611221	0	1

------ LOC=3 FM=50 SLOC=105 ------

OBS	HOST	GUEST	CNT
6848	510005	610	1
6849	512413	0	1
6850	512611	912	1
6851	512611	913	0
6852	512612	0	1
6853	512612	514	1
6854	512612	514	1
6855	513121	0	1
6856	513121	0	1
6857	513121	0	1
6858	513121	0	1
6859	513121	0	1
6860	513121	0	1
6861	513121	514	1
6862	513122	0	1
6863	513122	0	1
6864	513711	0	1
6865	513711	0	1
6866	513711	0	1
6867	513711	0	1
6868	513711	0	1
6869	513711	0	1
6870	513711	0	1
6871	513711	0	1
6872	513711	0	1
6873	513711	514	0
6874	513711	514	1
6875	513711	912	1
6876	513711	912	1
6877	513711	912	1
6878	513711	912	1
6879	513711	913	0
6880	513714	0	1
6881	513795	0	1
6882	513795	0	1
6883	513795	514	1
6884	513795	913	1
6885	513796	0	1
6886	513796	0	1
6887	513796	0	1
6888	513796	0	1
6889	513796	0	1
6890	513796	912	1
6891	513841	0	1
6892	513841	0	1
6893	513841	0	1
6894	513841	0	1

------- LOC=3 FM=50 SLOC=105 ------

OBS	HOST	GUEST	CNT
6895	513841	0	1
6896	513841	514	1
6897	513841	514	1
6898	513841	514	1
6899	513841	514	1
6900	513841	514	1
6901	513841	912	1
6902	513841	912	1
6903	524201	0	1
6904	524201	0	1
6905	524201	0	1
6906	524201	610	1
6907	524201	610	1
6908	524201	912	1
6909	524201	913	0
6910	525111	913	1
6911	525114	0	1
6912	525114	0	1
6913	525114	0	1
6914	525114	0	1
6915	525114	514	0
6916	525114	514	1
6917	525114	514	1
6918	525114	912	1
6919	525114	912	1
6920	525114	913	0
6921	525114	913	0
6922	525114	913	1
6923	525114	913	1
6924	525114	914	0
6925	611111	0	1

------- LOC=3 FM=50 SLOC=106 -------

OBS	HOST	GUEST	CNT
6926	512601	514	1
6927	512612	514	1
6928	513711	0	1
6929	513711	513	0
6930	513711	514	1
6931	513711	601	1
6932	513713	0	1
6933	513713	513	1
6934	513713	514	1
6935	513713	912	1
6936	513713	912	1
6937	513715	514	0
6938	513715	912	1
6939	513715	912	1
6940	513841	0	1
6941	513841	913	1
6942	525114	515	1

------ LOC=3 FM=50 SLOC=106 ------

OBS	HOST	GUEST	CNT
6943	526132	0	1

------ LOC=3 FM=50 SLOC=107 ------

OBS	HOST	GUEST	CNT
6944	513122	0	1
6945	513122	514	1
6946	513711	513	0
6947	513711	514	0
6948	513711	912	1
6949	513711	914	1
6950	525114	0	1
6951	526231	0	1

------ LOC=3 FM=50 SLOC=108 ------

OBS	HOST	GUEST	CNT
6952	20004	0	1
6953	513841	0	1
6954	513841	514	1
6955	513841	514	1
6956	513841	514	1
6957	520001	0	1
6958	520001	0	1
6959	524201	0	1
6960	524201	0	1
6961	524214	0	1
6962	524214	0	1
6963	524214	912	1
6964	524214	912	1
6965	525114	0	1
6966	525114	0	1
6967	525114	912	1
6968	525114	913	0

------ LOC=3 FM=50 SLOC=109 ------

OBS	HOST	GUEST	CNT
6969	512601	0	1
6970	512611	603	1
6971	512612	0	1
6972	524214	0	1
6973	524214	0	1
6974	524214	912	1
6975	524214	913	1
6976	525114	514	1

VITA

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DATE OF BIRTH: October 26, 1958.

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PROFESSIONAL EXPERIENCE: Teaching and research assistanships at Texas A&M University

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Project geologist, Sun Gas Company, Oklahoma City, OK and Corpus Christi, TX

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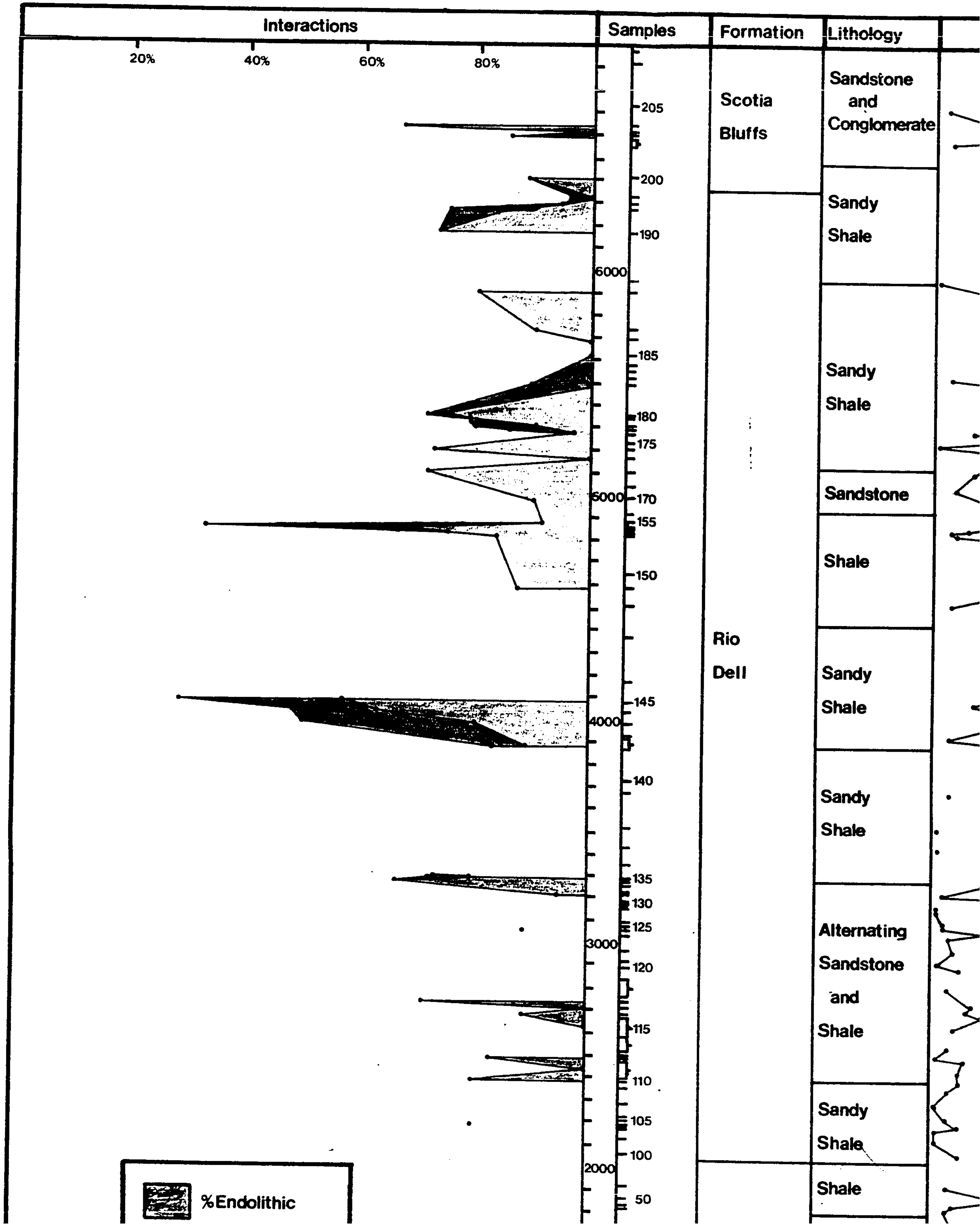
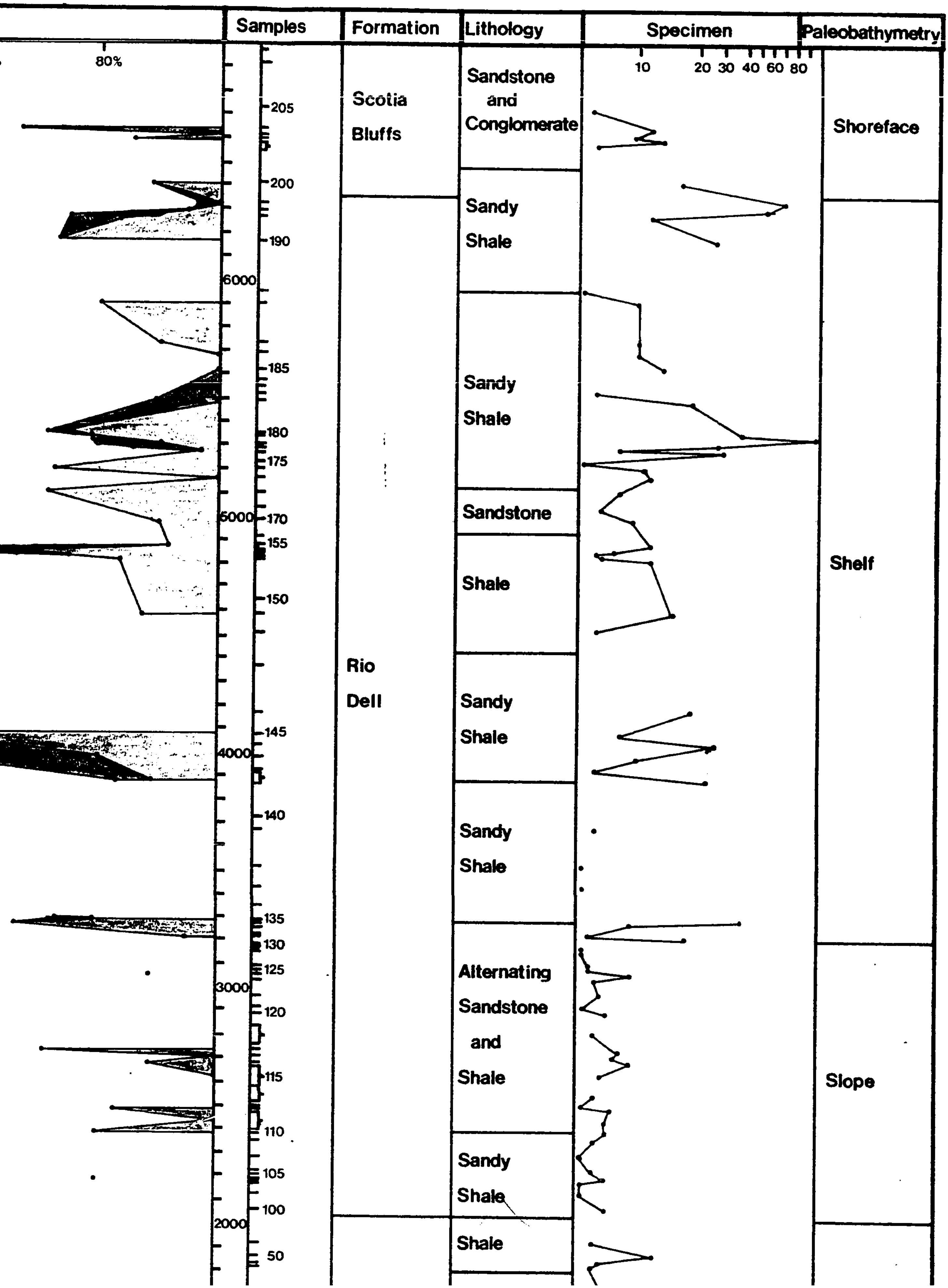


Interactions
20%
40%
60%
80%
Samples
Formation
Lithology
205
200
190
6000
185
180
175
5000
170
155
150
145
4000
140
135
130
125
3000
120
115
110
105
100
2000
50
Scotia
Bluffs
Rio
Dell
Sandstone and Conglomerate
Sandy Shale
Sandy Shale
Sandstone
Shale
Sandy Shale
Sandy Shale
Alternating Sandstone and Shale
Sandy Shale
Shale
%Endolithic


Samples
Formation
Lithology
Specimen
Paleobathymetry
80%
10
20
30
40
60
80
205
200
190
6000
185
180
175
5000
170
155
150
145
4000
140
135
130
125
3000
120
115
110
105
100
2000
50
Scotia
Bluffs
Rio
Dell
Sandstone
and
Conglomerate
Sandy
Shale
Sandy
Shale
Sandstone
Shale
Sandy
Shale
Sandy
Shale
Alternating
Sandstone
and
Shale
Sandy
Shale
Shale
Shoreface
Shelf
Slope

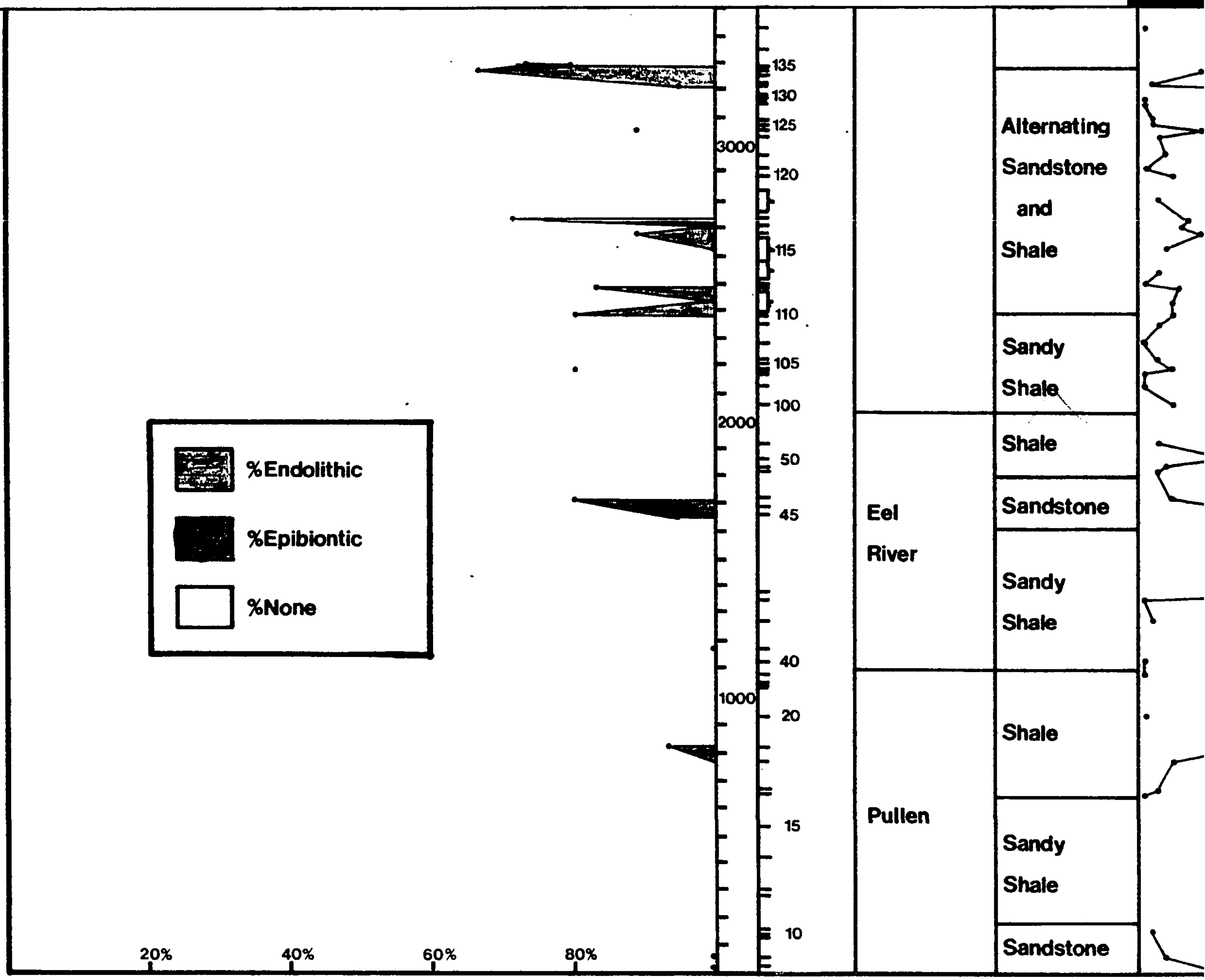
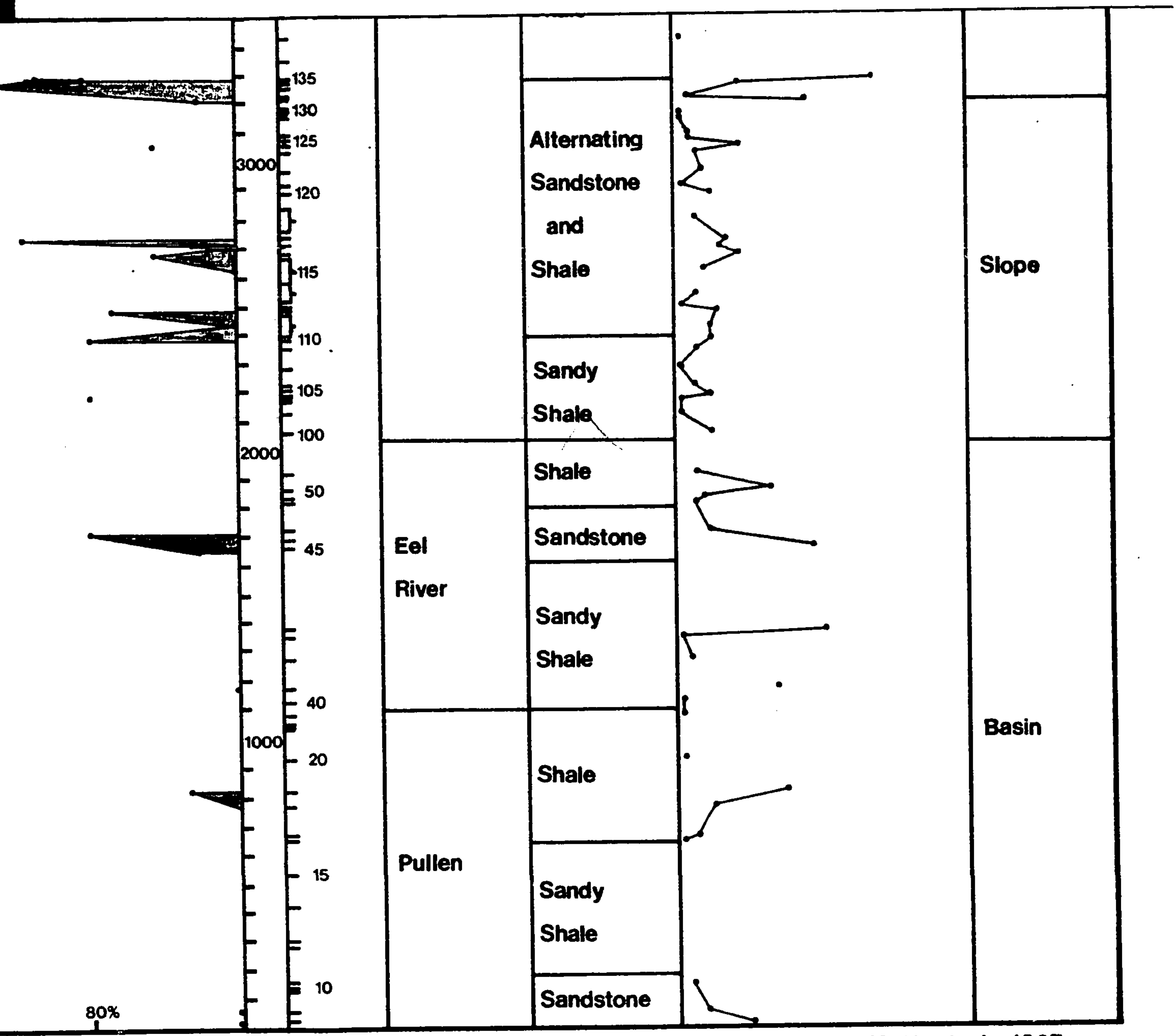
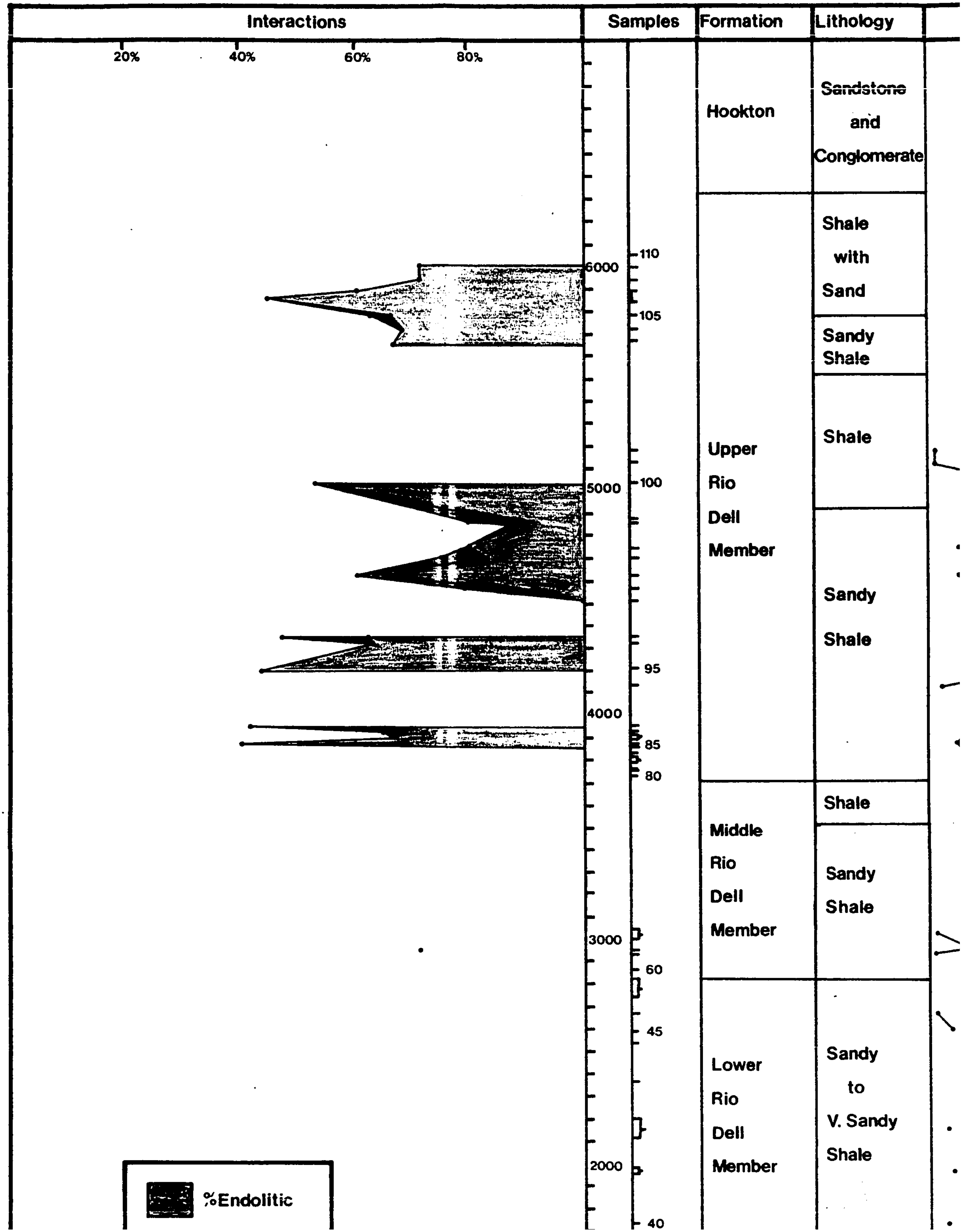


Plate I.
Eel River Section



William M. Harris Jr., 1987

Plate I.
Eel River Section


Interactions
Samples
Formation
Lithology
20%
40%
60%
80%
6000
5000
4000
3000
2000
110
105
100
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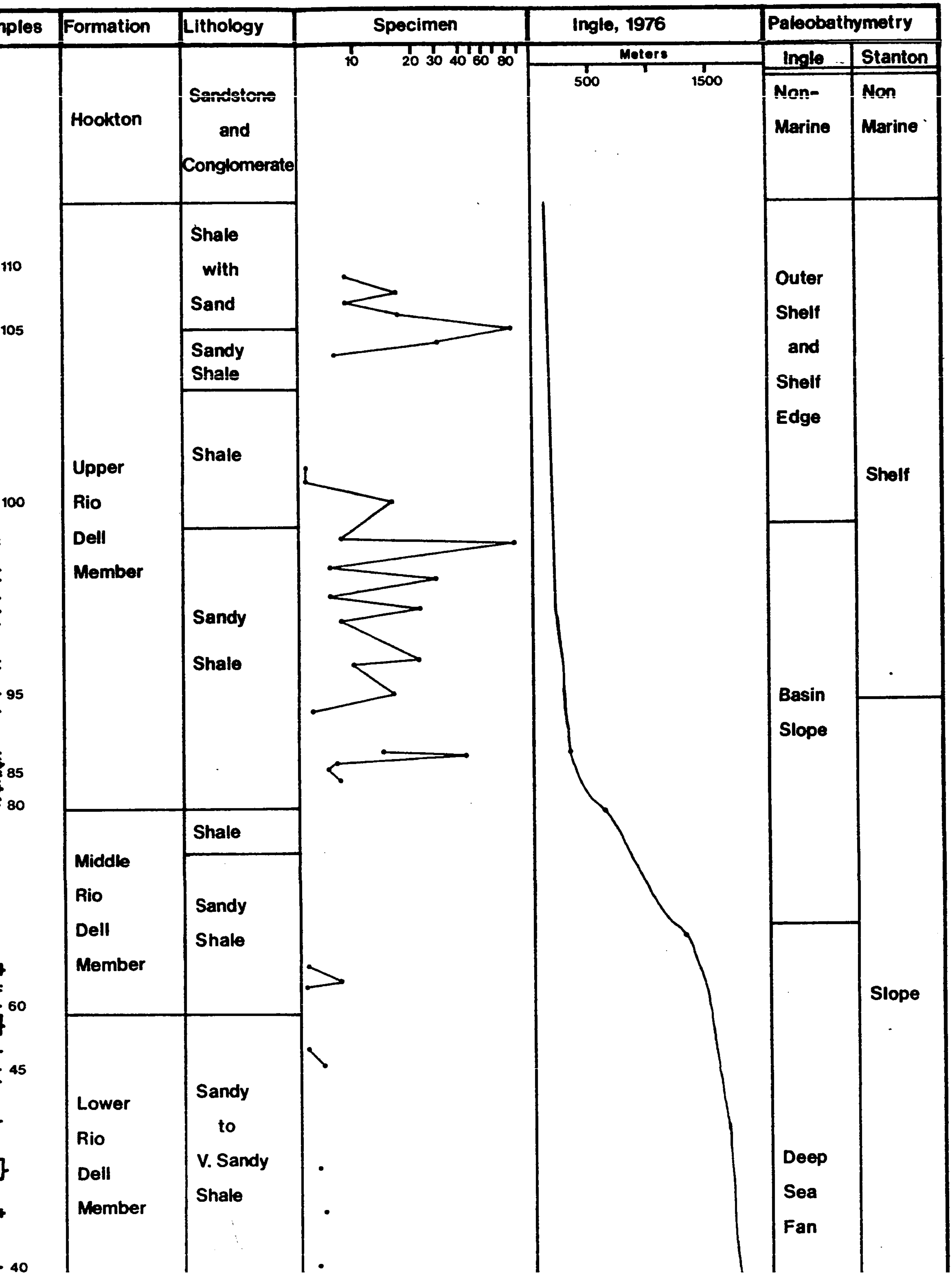
80
60
45
40
Hookton
Upper
Rio
Dell
Member
Middle
Rio
Dell
Member
Lower
Rio
Dell
Member
Sandstone
and
Conglomerate
Shale
with
Sand
Sandy
Shale
Shale
Sandy
Shale
Shale
Sandy
Shale
Sandy
to
V. Sandy
Shale
%Endolitic



nples
Formation
Lithology
Specimen
Ingle, 1976
Paleobathymetry
10
20 30 40 60 80
Meters
500
1500
Ingle
Stanton
Hookton
Sandstone and Conglomerate
Non-Marine
Non Marine
110
105
100
95
85
80
60
45
40
Upper Rio Dell Member
Shale with Sand
Sandy Shale
Shale
Sandy Shale
Outer Shelf and Shelf Edge
Shelf
Basin Slope
Middle Rio Dell Member
Shale
Sandy Shale
Slope
Lower Rio Dell Member
Sandy to V. Sandy Shale
Deep Sea Fan

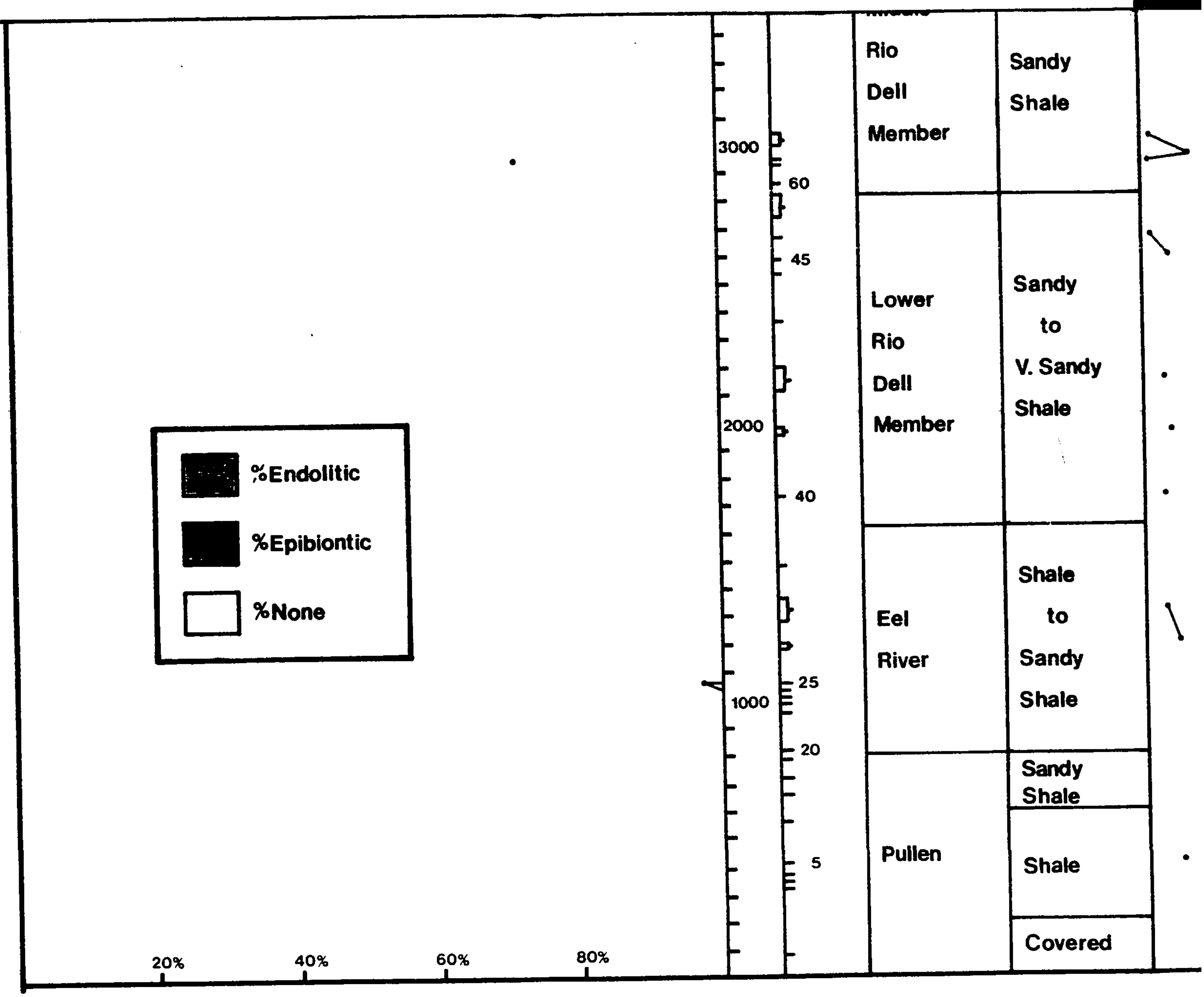
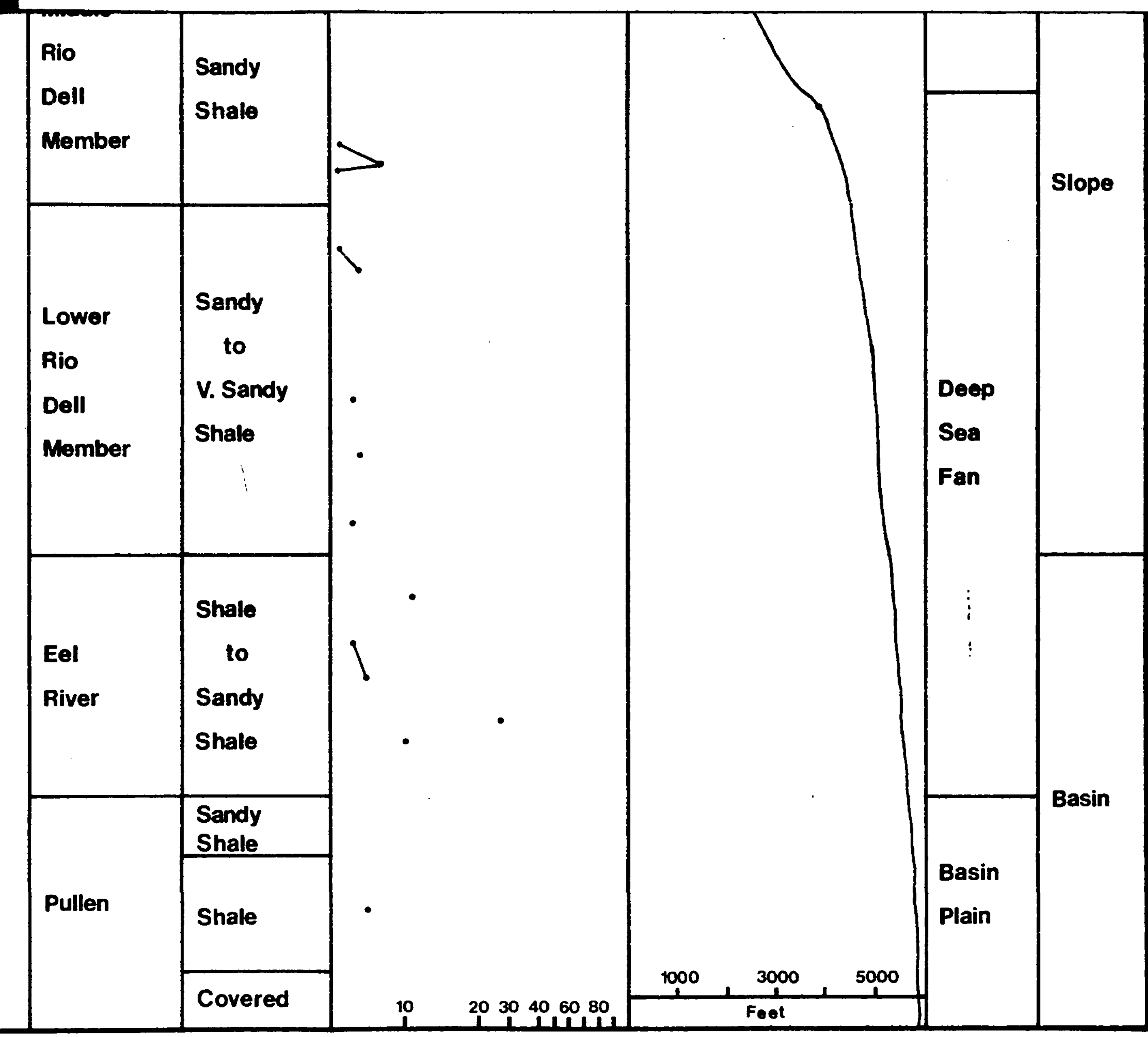


Plate II.
Centerville Beach Section



William M. Harris Jr., 1987

late II.
e Beach Section