U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Palynological Data from the Imperial and Palm Spring Formations, Anza-Borrego Desert State Park, California

by

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U.S. Geological Survey

Open-File Report 93-678

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1993

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INTRODUCTION

The primary goal of PRISM (Pliocene Research, Interpretation, and Synoptic Mapping) is to produce a paleoclimatic map for the world at the time of a warm interval that has been identified in the mid-Gauss part of the Pliocene (Dowsett and Poore, 1991). As part of this effort, the Pliocene Continental Climates Project within PRISM is attempting to reconstruct paleoclimatic conditions in western North America during the Pliocene.

In order to construct paleoclimatic map of the world for this specific point in geologic time, data must be gathered from Pliocene sections that have high-quality temporal control. Anza-Borrego Desert State Park in southern California is one such site, as it has excellent exposures of a Pliocene section and a well-controlled temporal framework (Opdyke and others, 1977; Johnson and others, 1983). The objective of this study was to document the Pliocene palynology of the Anza-Borrego section and thus provide a basis for making paleoclimatic inferences for the Pliocene of southern California.

This report contains geological and palynological data from the Anza-Borrego section; raw data generated from this study are included in the appendices. Samples from Anza-Borrego are inadequate for making paleoclimatic inferences based on Pliocene palynomorphs. However, reworked Cretaceous pollen in some assemblages allows reconstruction of erosional history and paleoclimate of the Colorado Plateau and suggests that conditions in the southwestern U.S. were wetter in the Pliocene than today.

ACKNOWLEDGMENTS

This research would not have been possible without the cooperation of the staff at Anza-Borrego Desert State Park and I would especially like to thank Paul Remeika and David Van Cleeve for their assistance and cooperation. I thank David Schaub and Syd Brown of the California State Department of Parks and Recreation for granting permission to collect within Anza-Borrego Desert State Park. Everett Lindsay provided invaluable stratigraphic and geographic data related to his paleomagnetic research in the Anza-Borrego section. Several colleagues kindly discussed various aspects of the model of reworking developed herein—for sharing their knowledge and providing encouragement I would particularly like to thank Tom Ager, Bob Cushman, Karen Franczyk, Doug Nichols, Pete Peterson, and Bob Thompson. I would also like to thank Bernadine Tschudy for her warm hospitality during my sojourns in the Anza-Borrego Desert.

REGIONAL GEOLOGY AND STRATIGRAPHY

The Salton Trough is the northern extension of the Gulf of California. Both features lie along the transform boundary between the North American and Pacific Plates and are an expression of this tectonic boundary, which continues northwestward into California as the San Andreas fault system (Larson and others, 1968; Atwater, 1970; Larson, 1972). The Gulf of California opened around 5-4 Ma and resulted in over 6 km of sediment accumulation within the Salton Trough (Larson and others, 1968; Atwater, 1970; Larson, 1972; Sharp, 1982; Ward, 1991; Kerr and Kidwell, 1991).

These late Cenozoic sediments comprise locally derived detritus as well as sediment transported by the Colorado River (Merriam and Bandy, 1965; Muffler and Doe, 1968; Sharp, 1982; Kerr and Kidwell, 1991). The locally derived material is generally coarse-grained and consists of debris shed from adjacent mountain ranges, which are composed of Paleozoic metasedimentary and Cretaceous batholithic rocks (Norris and Webb, 1990; Kerr and Kidwell, 1991). In the Fish Creek-Vallecito area, located along the western margin of the Salton Trough in Anza-Borrego Desert State Park, approximately 6.5 km of exposed upper Cenozoic rocks represent this sedimentary infilling (Kerr and Kidwell, 1991).

Woodard (1974) described the lithostratigraphy and revised the stratigraphic nomenclature of Neogene rocks in the western part of the Salton Trough. In the Fish Creek-Vallecito area, Pliocene rocks include the Imperial Valley Formation and the Palm Spring Formation. Woodard subdivided the Imperial Formation into 3 informal members totaling 1200 m in thickness. The lower member (60 m) consists of gray feldspathic arenite. The middle member (750 m) is characterized by rhythmically interbedded gray silty-mudstone and fine quartz arenite. The upper member (390 m) comprises siltstone and sandstone with interbedded massive limestone and calcareous arenite. The Imperial Formation is underlain by the Split Mountain Formation and grades into the overlying Palm Spring Formation.

The Palm Spring Formation (3000 m) includes interbedded siltstone, claystone, arkosic sandstone, pebble conglomerate, and limestone. The Palm Spring is overlain by the Canebrake Conglomerate in the Fish Creek-Vallecito area (Woodard, 1974). In addition, the Canebrake Conglomerate intertongues with the Imperial and Palm Spring Formations along the margins of the Salton Trough (Woodard, 1974; Dibblee, 1954).

Based on mineralogical and paleontological evidence, Merriam and Bandy (1965) and Muffler and Doe (1968) concluded that most of the fine-grained sediment in the Salton Trough primarily originated from the Colorado River drainage and was deposited by the Colorado River. The depositional environments associated with Colorado River deposition in the Fish Creek-Vallecito area include: turbidites; prodeltaic mudstone; delta front mudstones, siltstones, and sandstones; and intertidal and delta plain deposits (Kerr and Kidwell, 1991).

MATERIALS AND METHODS

The Anza-Borrego section is located in the Fish Creek-Vallecito area, where the Carrizo Badlands provide excellent exposures of the Imperial and Palm Spring Formations. I collected 86 samples from 33 localities through this section, with the sample positions tied to the stratigraphic framework of Downs and White (1968) and Opdyke and others (1977). E. Lindsay (written communication, 1991) provided the unpublished map and measured section data that served as the basis for these publications. I used these data to sample in the field and to develop the age model used in this study. In addition to samples collected specifically for palynological analysis, T. Cronin supplied an additional 25 samples originally collected for foraminifera and ostracodes from the Anza-Borrego section (Quinn and Cronin, 1984).

Samples were processed using standard palynological processing procedures (Doher, 1980). Initially samples with promising lithologies from the interval of interest (i.e., from the Gauss Normal-Polarity Chron) were processed. These samples produced sparse palynological assemblages or were barren—some of these were reprocessed using larger sample sizes and alternative processing techniques but results were not significantly improved. Out of the 86 samples collected for palynology, the 25 most promising samples were processed with generally poor results.

AGE CONTROL

Downs and White (1968) published the first comprehensive list of fossil mammals from Anza-Borrego Desert State Park and established a biostratigraphic zonation for the upper part of the Imperial Formation and the Palm Spring Formation. They divided the stratigraphic section into three faunas. From oldest to youngest these are the Layer Cake fauna, the Arroyo Seco fauna, and the Vallecito Creek fauna. Downs and White estimated the land mammal age of the Layer Creek fauna to be early Blancan, the Arroyo Seco fauna to be late Blancan, and the Vallecito fauna to be Irvingtonian. Based on the chronology of

Kurten and Anderson (1980) these land mammal ages indicate that this part of the Anza-Borrego section is Pliocene to middle Pleistocene in age.

Using the work of Downs and White (1968) for biostratigraphic and geographic control, Opdyke and others (1977) published the first paleomagnetic stratigraphy for Pliocene and Pleistocene rocks in Anza-Borrego Desert State Park. They collected samples from 150 sites through approximately 3800 m of a stratigraphically continuous interval in the Imperial and Palm Spring Formations. Using the pattern of declination values for the statistically valid sites, Opdyke and others (1977) derived a magnetic stratigraphy for the Anza-Borrego section. By calibrating the magnetic stratigraphy with the vertebrate zonation of Downs and White (1968), they identified the Gilbert Reversed-Polarity, Gauss Normal-Polarity, and Matuyama Reversed-Polarity Chrons. Within the Gilbert they detected a single event that they interpreted to be the Cochiti Normal-Polarity Subchron. Within the Gauss they identified the Mammoth and Kaena Reversed-Polarity Subchrons. They detected one event within the Matuyama and the base of another event at the top of the sequence. They suggested that the lower event could be either the Reunion or Olduvai Normal-Polarity Subchrons and that the upper event could be the base of either the Olduvai or the Jaramillo Normal-Polarity Subchron.

Johnson and others (1983) remeasured the data set of Opdyke and others (1977) after thermal demagnetization of the original samples. In addition, they obtained a fission-track date of 2.3 Ma $\pm$ 0.4 m.y. on an air-fall tuff that occurs in the Palm Spring Formation. With these new data, they refined the magnetic stratigraphy of the Anza-Borrego section, identifying the lower event in the Matuyama as the Olduvai and the event at the top of the section as the base of the Jaramillo. Repenning (1992) disagreed with the conclusion of Johnson and others (1983) that the event at the top is the base of the Jaramillo; he maintains that the upper event is the base of the Brunhes. Repenning based his conclusion on the presence of *Terricola meadensis* below the youngest normal polarity zone in the Anza-Borrego section. This species is not know before 850,000 years ago (Repenning, 1992). For the purposes of this study, modifying the age model according to Repenning would make little difference. Most of the samples collected are below the tuff (dated at 2.3 Ma) and the magnetostratigraphy proposed by Johnson and others (1983) is valid below the stratigraphic level of the tuff.

In constructing the age model for this study, I first developed a stratigraphic framework for the 86 samples that I collected during two field excursions in 1992 and for the 25 samples provided by T. Cronin from the lower part of the section. Stratigraphic positions for Cronin's samples were derived from Quinn and Cronin (1984). As discussed above, the sample positions were integrated with both the stratigraphic section of Opdyke and others (1977) and the unpublished stratigraphic and geographic data used for Opdyke and others (1977). Using the Imperial-Palm Spring formation contact of Opdyke and others (1977) as the datum, all of the sample positions for this study were integrated within a single stratigraphic section. Appendix 1 contains a data matrix with sample numbers and stratigraphic position with respect to the Imperial-Palm Spring contact.

The age model for the Anza-Borrego section was derived from the paleomagnetic stratigraphy as developed in Johnson and others (1983) and the currently revised geomagnetic polarity time scale of Cande and Kent (1992). Johnson and others (1983; their figure 4) published a figure showing sediment accumulation versus age. I revised this curve with the new age values from Cande and Kent and fit a third-order polynomial to the resulting plot. Appendix 2 contains the sediment accumulation values obtained from Johnson and others and the age values from Cande and Kent used to generate the new plot. The polynomial has an R^2=0.995 and the curve (Figure 1) closely matches that published by Johnson and others. I used this equation to calculate the sample ages, which are listed in Appendix 1.

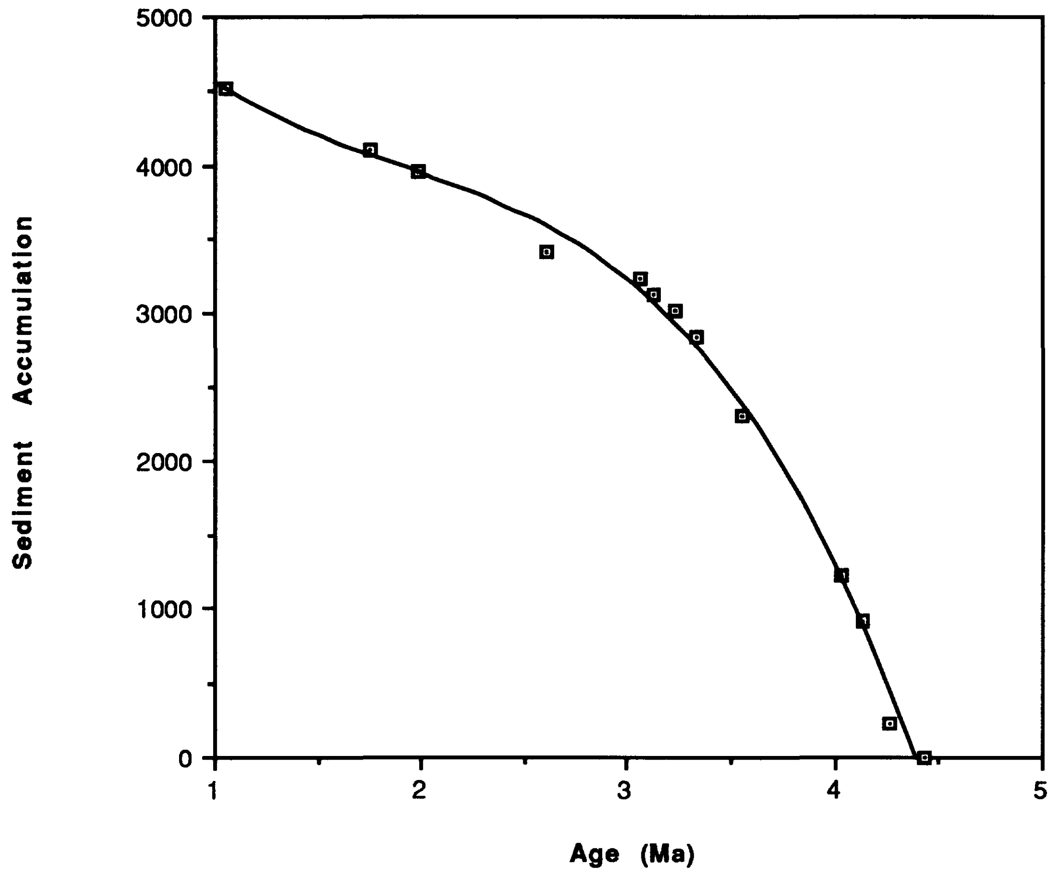

Figure 1. Age model for the Anza-Borrego section. Age (Ma) is plotted versus sediment accumulation (in meters). Sediment accumulation values derived from Johnson and others (1983). Age values from Cande and Kent (1992). Values used to generate this plot are listed in Appendix 2. Equation for curve is:

$$y = 6162.7 - 2468.9\ x + 1043.7\ x^2 - 182.44\ x^3$$

where x = age (Ma) and y = sediment accumulation (in meters).

PLIOCENE PALYNOLOGY

Palynological assemblages from the Imperial and Palm Spring Formations are sparse, with most samples barren of palynomorphs. Marginally adequate assemblages were recovered from the lower part of the section (i.e., the upper part of the Imperial Formation and the lower part of the Palm Spring Formation). Preliminary counts were attempted on these samples but the samples were too sparse and several slides with numerous transects were necessary to generate a minimally adequate number of specimens. Because these samples are so sparse, I do not regard the counts as statistically reliable and the raw and relative abundance data are not presented. Occurrence data from analysis of these samples are presented in Appendix 3.

All samples from the upper part of the section are barren, including eighteen samples from the Gauss Normal-Polarity Chron. Because this interval was the focus of this study, I did not process additional samples from the Anza-Borrego section. These results indicate that the lithologies through the upper part of this section are unsuitable for paleoclimatic analysis using Pliocene palynomorphs.

Some samples produced assemblages containing three palynomorph categories that are potentially useful for making paleoclimatic interpretations. The first category is algal. Two samples (D7697-83TC38 and D7697-83TC39) from the lower part of the Palm Spring Formation produced assemblages that are overwhelmingly dominated by coenobia of *Pediastrum*; the assemblages also contain coenobia of *Scenedesmus*. In modern environments *Pediastrum* and *Scenedesmus* occur as associated phytoplankton in freshwater lakes and ponds. Fossil coenobia of these genera have been used as paleoenvironmental indicators (Fleming, 1989) and their presence in sediments of the lower Palm Spring Formation indicates that conditions were wet enough for ponds or lakes to develop. This suggests that conditions in the Anza-Borrego area at about 4 Ma were wetter than today.

The second category is represented by *Picea*. Pollen of *Picea* occurs in Imperial Formation samples (D7697-83TC19 and D7697-83TC20), which have age estimates of 4.42 Ma. Adam (1973) reported *Picea* from Pleistocene sediments near Lake Tahoe and discussed its climatic significance. He concluded that its presence is partly dependent on adequate summer rainfall. Its presence in the Anza-Borrego section provides additional evidence for wetter conditions than today in Anza-Borrego.

The third category is reworked Cretaceous palynomorphs. Reworked fossils were recovered from the upper part of the Imperial Formation and the lower part of the Palm Spring Formation. The significance of these fossils in terms of paleoclimate will be discussed in the following section.

REWORKED CRETACEOUS POLLEN

A suite of reworked palynomorphs occurs in eleven samples from the upper part of the Imperial Formation and the lower part of the Palm Spring Formation. Reworked taxa recognized are: *Proteacidites* spp., *Aquilapollenites* spp., *Mancicorpus* sp., *Tricolpites interangulus*, *Pistillipollenites* sp. cf. *P. mcgregorii*, *Corollina* sp., *Appendicisporites* sp., *Cicatricosisporites* sp., *Camarazonosporites* sp., *Dinogymnium* sp., and *Palaeohystrichophora infusorioides*. In some samples, reworked fossils compose a significant part of the assemblage.

The occurrences of reworked palynomorphs in the samples are listed in Appendix 4. The suite of reworked fossils includes the distinctive Cretaceous genera *Proteacidites*, *Aquilapollenites*, and *Mancicorpus*. *Proteacidites* spp. occurs in most of the Imperial and Palm Spring samples that yield palynomorphs; triprojectate pollen (*Aquilapollenites* spp. and *Mancicorpus* sp.) first appears in the upper part of the section, in the lower part of the Palm Spring Formation. The first appearance of triprojectate pollen is in a sample with abundant reworked Cretaceous fossils. Two lines of evidence suggest that this first appearance is not related to the abundance of reworked palynomorphs. First, several samples from the lower part of the section also contain abundant reworked Cretaceous palynomorphs but lack triprojectate pollen (e.g., D7697-83TC30). Second, samples above the first appearance horizon that contain meager amounts of Cretaceous pollen also contain triprojectate pollen. This distribution suggests that *Proteacidites* was reworked into the Anza-Borrego section before *Aquilapollenites* and *Mancicorpus*.

Merriam and Bandy (1965) documented the reworking of foraminifera from the Cretaceous Mancos Shale into the Imperial and Palm Spring Formations. This evidence, in conjunction with sedimentological data, led them to conclude that the bulk of sediment composing the Imperial and Palm Spring Formations was derived from the Colorado River drainage. I conclude that the available sedimentological and paleontological evidence indicates that the reworked palynomorphs in the Anza-Borrego section were derived from the same source—the Colorado River drainage including the Colorado Plateau part of the Western Interior of North America.

In the Western Interior of North America, *Proteacidites* ranges from the Coniacian to the Maastrichtian; triprojectate pollen ranges from the Campanian to the Maastrichtian (Nichols and others, 1982). In addition to being restricted to Campanian and Maastrichtian rocks, triprojectate pollen has a restricted paleobiogeographic distribution. *Aquilapollenites* and *Mancicorpus* have been documented from southwestern Colorado and southeastern Utah (Lohrengel, 1969; May, 1972; Fouch and others, 1983; Franczyk and others, 1990; Cushman and Nichols, 1992). However, they become less abundant further south and are absent or extremely rare in northern Arizona and northern New Mexico (Anderson, 1960; Thompson, 1972; Tschudy, 1973; Jameossanaie, 1987). Their southernmost extent forms a line that approximately parallels the Arizona-Utah and Colorado-New Mexico boundaries. In contrast, *Proteacidites* is present in sedimentary rocks throughout the Western Interior, including Arizona and New Mexico (Anderson, 1960; Orlansky, 1971; Tschudy, 1973; Jameossanaie, 1987; Nichols and others, 1982).

IMPLICATIONS OF REWORKED POLLEN FOR PLIOCENE CLIMATE

These data on reworked pollen constrain the erosional history of the Colorado River drainage, which includes the Grand Canyon and the Colorado Plateau. In turn, the constraints on the erosional history of the Colorado Plateau bear on paleoclimatic conditions during the Pliocene. This section presents the rationale for this scenario and its implications.

The stratigraphic distribution of reworked fossils in Pliocene sediments of the Anza-Borrego section suggests that erosion of Cretaceous rocks containing *Proteacidites*, but lacking *Aquilapollenites* and *Mancicorpus*, began at least by 4.5 Ma. This is reflected in the lower part of the Pliocene sequence where *Proteacidites* first appears without triprojectate pollen. At this time, erosion on the Colorado Plateau had exposed the Mancos Shale in Arizona and New Mexico. In the northern part of the plateau, Mancos Shale containing triprojectate pollen would not have been exposed at this time. Erosion into rocks containing triprojectate pollen began around 3.9 Ma, as reflected in the first appearance of these forms in the Palm Spring Formation. This suggests that the Mancos Shale was not exposed in southern Utah and southern Colorado until about 3.9 Ma. The timing of this erosional event indicates that a considerable amount of erosion on the Colorado Plateau occurred after 3.9 Ma. This is consistent with Lucchitta's conclusions (Lucchitta, 1972; 1979; 1987) that the cutting of the Grand Canyon occurred during the Pliocene.

These data corroborate results from several other studies of the Pliocene climatic evolution of southwestern U.S. Thompson (1991) summarized paleoclimatic proxy data from throughout the Western Interior of the U.S. showing that levels of effective moisture were higher than modern conditions. Smith (1984) documented an interval from 3.2 Ma to 2.5 Ma in Searles Lake of southern California that indicates a very moist climate. Smith and others (1993) concluded that a middle Pliocene wet period occurred in western North America, based on stable-isotopic compositions of paleosol carbonates from Arizona. Winograd and others (1985) suggested that uplift of the Sierra Nevada and Transverse Ranges during the Pleistocene blocked inland-bound Pacific storm systems that in the Pliocene provided moisture to southwestern U.S. Finally, in the Anza-Borrego section Remeika and others (1988) documented the presence of forest taxa during the Pliocene that are indicative of a more temperate climate with more maritime influence and dominance of winter precipitation.

Using a General Circulation Model, Ruddiman and Kutzbach (Ruddiman and others, 1989; Ruddiman and Kutzbach, 1989) modeled climatic effects of plateau uplift based on the uplift of the Tibetan Plateau and the Colorado Plateau. Their results for the Pliocene suggest increased summer and winter precipitation in the southern Rockies, including the Colorado Plateau. To a certain extent, evidence from the Anza-Borrego section are consistent with their model results.

CONCLUSIONS

The data on reworked palynomorphs presented here support recent erosion of the Grand Canyon and suggest that erosion rates were very high on the Colorado Plateau during the Pliocene. Increased erosion rates over the present suggest that the climate in and around the plateau was wetter than today. Taken together, I conclude that the region of the Colorado Plateau was significantly wetter than present and was probably cooler as a consequence.

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APPENDIX 1

Appendix 1 contains a list of the samples collected by F. Fleming and T. Cronin. Stratigraphic positions of the samples are given in meters above (positive values) or below (negative values) the Imperial-Palm Spring formation contact as defined by Opdyke and others (1977). Age (Ma) shown for each sample is based on the age model developed herein using Johnson and others (1983) and Cande and Kent (1992). The "Recovery" column refers to results of palynological processing. Samples were either sparse, barren, or not processed.

APPENDIX 1	(PART 1)		
Sample	Position (meters)	Age (Ma)	Recovery
83TC16	-1281	4.485	Sparse
83TC17	-1036	4.425	Sparse
83TC18	-1025	4.420	Not Processed
83TC19	-1015	4.420	Sparse
83TC20	-999	4.415	Sparse
83TC21	-988	4.410	Not Processed
83TC22	-980	4.410	Not Processed
83TC23	-903	4.390	Sparse
83TC24	-759	4.350	Sparse
83TC25	-711	4.340	Not Processed
83TC26	-679	4.330	Sparse
83TC27	-567	4.300	Not Processed
83TC28	-551	4.295	Not Processed
83TC29A	-401	4.250	Barren
83TC29B	-321	4.230	Not Processed
83TC30	-279	4.215	Sparse
83TC31	-257	4.210	Not Processed
83TC33	-167	4.185	Sparse
83TC34	-135	4.175	Not Processed
83TC35	-113	4.170	Barren
83TC36	-108	4.165	Not Processed
92FF1	-88	4.160	Not Processed
92FF2	-85	4.160	Not Processed
92FF3	-84	4.160	Not Processed
92FF4	-82	4.160	Not Processed
92FF5	-78	4.155	Not Processed
83TC37	63	4.110	Not Processed
83TC38	95	4.105	Sparse
83TC39	111	4.100	Sparse
83TC40	143	4.085	Barren
92FF6	323	4.025	Not Processed
92FF7	629	3.920	Barren
92FF8	631	3.920	Not Processed
92FF9	632	3.915	Not Processed
92FF10	632	3.915	Not Processed
92FF11	633	3.915	Sparse
92FF12	683	3.895	Sparse
92FF13	683	3.895	Sparse
92FF14	713	3.885	Sparse
92FF15	718	3.885	Not Processed
92FF19	841	3.835	Not Processed
92FF20	862	3.830	Not Processed
92FF16	868	3.825	Not Processed
92FF17	873	3.825	Not Processed
92FF18	873	3.825	Barren
92FF22	1253	3.660	Not Processed
92FF21	1268	3.665	Barren
92FF47	1527	3.525	Barren
92FF46	1626	3.475	Not Processed
92FF48	1637	3.470	Not Processed
92FF41	1786	3.380	Not Processed
92FF42	1786	3.380	Not Processed
92FF43	1786	3.380	Barren
92FF44	1788	3.380	Not Processed
92FF45	1789	3.380	Not Processed
92FF40	1893	3.315	Not Processed

APPENDIX 1	(PART 2)		
Sample	Position (meters)	Age (Ma)	Recovery
92FF29	1999	3.245	Barren
92FF30	2018	3.230	Barren
92FF31	2018	3.230	Not Processed
92FF32	2045	3.215	Barren
92FF33	2076	3.190	Barren
92FF34	2076	3.190	Barren
92FF81	2150	3.135	Not Processed
92FF80	2151	3.135	Not Processed
92FF49	2213	3.085	Not Processed
92FF69	2218	3.080	Barren
92FF70	2223	3.080	Not Processed
92FF23	2228	3.075	Barren
92FF24	2228	3.075	Not Processed
92FF25	2228	3.075	Not Processed
92FF26	2228	3.075	Not Processed
92FF59	2228	3.075	Not Processed
92FF57	2229	3.075	Not Processed
92FF27	2229	3.075	Barren
92FF58	2229	3.075	Not Processed
92FF56	2233	3.070	Not Processed
92FF54	2238	3.065	Not Processed
92FF55	2238	3.065	Not Processed
92FF60	2243	3.065	Not Processed
92FF61	2246	3.060	Not Processed
92FF62	2246	3.060	Not Processed
92FF72	2250	3.055	Barren
92FF28	2258	3.050	Barren
92FF73	2275	3.035	Barren
92FF75	2278	3.035	Not Processed
92FF76	2280	3.030	Not Processed
92FF39	2281	3.030	Not Processed
92FF68	2284	3.030	Not Processed
92FF63	2289	3.025	Not Processed
92FF74	2295	3.020	Not Processed
92FF77	2302	3.010	Not Processed
92FF78	2302	3.010	Not Processed
92FF79	2302	3.010	Not Processed
92FF50	2304	3.010	Barren
92FF71	2315	3.000	Not Processed
92FF66	2319	2.995	Barren
92FF64	2320	2.995	Not Processed
92FF65	2320	2.995	Not Processed
92FF67	2329	2.990	Not Processed
92FF38	2411	2.910	Not Processed
92FF82	2472	2.850	Barren
92FF83	2472	2.850	Not Processed
92FF84	2487	2.835	Not Processed
92FF85	2487	2.835	Barren
92FF86	2487	2.835	Barren
92FF35	2649	2.645	Not Processed
92FF36	2649	2.645	Not Processed
92FF37	2650	2.645	Not Processed
92FF51	3081	1.900	Not Processed
92FF52	3104	1.850	Not Processed
92FF53	3112	1.835	Not Processed

APPENDIX 2

Appendix 2 lists the paleomagnetic event boundaries, the age (Ma) for the boundaries from Cande and Kent (1992), the sediment accumulation values derived from Johnson and others (1983), and the stratigraphic positions of the boundaries with respect to the Imperial-Palm Spring formation contact.

APPENDIX 2			
Paleomagnetic Boundary	**Age (Ma)**	**Sediment Accumulation (meters)**	**Position (meters)**
Base of Nunivak	4.432	0	-908
Top of Nunivak	4.265	242	-666
Base of Cochiti	4.134	917	9
Top of Cochiti	4.033	1217	309
Base of Gauss	3.553	2300	1392
Base of Mammoth	3.325	2833	1925
Top of Mammoth	3.221	3025	2117
Base of Kaena	3.127	3133	2225
Top of Kaena	3.054	3233	2325
Top of Gauss	2.600	3417	2509
Base of Olduvai	1.983	3950	3042
Top of Olduvai	1.757	4092	3184
Base of Jaramillo	1.049	4508	3600

APPENDIX 3

Appendix 3 lists samples from which Pliocene palynomorphs were recovered and the species present in each sample. The appendix lists only presence/absence data because none of the samples were considered adequate for reliable statistical counts. Presence of a species is indicated by an "X."

APPENDIX 3	(PART 1)			
Sample Number	D7697-83TC16	D7697-83TC17	D7697-83TC19	D7697-83TC20
Position (meters)	-1261	-1036	-1015	-999
Age	4.49	4.43	4.42	4.42
Picea			X	X
Pinus	X		X	X
TCT undifferentiated			X	X
Ephedra	X		X	X
Alnus			X	
Artemisia	X	X		X
Betula			X	
Fremontodendron	X			
Quercus			X	
Salix	X		X	
Sarcobatus			X	X
Ulmus	X			
Asteraceae-Liguliflorae				
Asteraceae-Tubuliflorae	X		X	
Chenopodiineae	X		X	
Elaeagnaceae			X	
Poaceae	X		X	
Pediastrum				
Scenedesmus				
Dinoflagellates undifferentiated	X	X	X	X

APPENDIX 3	(PART 2)			
Sample	D7697-83TC23	D7697-83TC24	D7697-83TC26	D7697-83TC30
Position (meters)	-903	-759	-679	-279
Age	4.39	4.35	4.33	4.22
Picea		X		
Pinus	X	X	X	X
TCT undifferentiated		X	X	X
Ephedra	X	X	X	X
Alnus				
Artemisia			X	X
Betula				
Fremontodendron				
Quercus				
Salix	X			X
Sarcobatus			X	X
Ulmus				
Asteraceae-Liguliflorae			X	X
Asteraceae-Tubuliflorae	X		X	X
Chenopodiineae	X	X	X	X
Elaeagnaceae				
Poaceae			X	
Pediastrum				
Scenedesmus				
Dinoflagellates undifferentiated		X		

APPENDIX 3	(PART 3)			
Sample	D7697-83TC33	D7697-83TC38	D7697-83TC39	D7868-FF11
Position (meters)	-167	95	111	633
Age	4.19	4.11	4.10	3.92
Picea				
Pinus	X	X	X	X
TCT undifferentiated	X	X	X	X
Ephedra		X		X
Alnus				
Artemisia		X		
Betula				
Fremontodendron				
Quercus			X	
Salix		X		
Sarcobatus			X	
Ulmus				
Asteraceae-Liguliflorae				
Asteraceae-Tubuliflorae		X	X	
Chenopodiineae	X	X	X	X
Elaeagnaceae				
Poaceae				
Pediastrum		X	X	
Scenedesmus		X	X	
Dinoflagellates undifferentiated				

APPENDIX 3	(PART 4)	
Sample	D7868-FF12	D7868-FF14
Position (meters)	683	713
Age	3.90	3.89
Picea		
Pinus	X	X
TCT undifferentiated	X	
Ephedra		
Alnus		
Artemisia		
Betula		
Fremontodendron		
Quercus		
Salix		
Sarcobatus		
Ulmus		
Asteraceae-Liguliflorae		
Asteraceae-Tubuliflorae		
Chenopodiineae	X	X
Elaeagnaceae		
Poaceae		
Pediastrum		
Scenedesmus		
Dinoflagellates undifferentiated		

APPENDIX 4

Appendix 4 lists the samples that contained reworked palynomorphs. Presence of a species is indicated by an "X."

APPENDIX 4 (PART 1)				
Sample Number	D7697-83TC16	D7697-83TC19	D7697-83TC20	D7697-83TC23
Position (meters)	-1261	-1015	-999	-903
Age	4.49	4.42	4.42	4.39
Proteacidites	X	X	X	
Aquilapollenites				
Mancicorpus				
Tricolpites interangulus				
Pistillipollenites				
Corollina		X		
Appendicisporites		X		
Cicatricosisporites		X		X
Camarazonosporites				
Dinogymnium		X		
Palaeohystrichophora infusorioides				

APPENDIX 4 (PART 2)				
Sample Number	D7697-83TC26	D7697-83TC30	D7697-83TC33	D7697-83TC38
Position (meters)	-679	-279	-167	95
Age	4.33	4.22	4.19	4.11
Proteacidites	X	X	X	X
Aquilapollenites				
Mancicorpus				
Tricolpites interangulus				
Pistillipollenites				
Corollina		X		
Appendicisporites		X		
Cicatricosisporites			X	
Camarazonosporites				
Dinogymnium				
Palaeohystrichophora infusorioides				

APPENDIX 4 (PART 3)			
Sample Number	D7868-FF11	D7868-FF12	D7868-FF14
Position (meters)	633	683	713
Age	3.92	3.90	3.89
Proteacidites	X	X	X
Aquilapollenites	X	X	X
Mancicorpus	X		
Tricolpites interangulus			X
Pistillipollenites	X		
Corollina	X		
Appendicisporites			
Cicatricosisporites	X		
Camarazonosporites		X	
Dinogymnium		X	
Palaeohystrichophora infusorioides	X		