The SR133 Realignment Project (Laguna Canyon, Southern California): Pollen and Other Macrobotanical Analyses

Peter E. Wigand[1] & Manuel Palacios-Fest[2]

[1]Great Basin and Mojave Paleoenvironmental Consulting, Reno, NV 89506-9128
[2]Terra Nostra Earth Sciences Research, Tucson, AZ,

Introduction

The presence of discontinuous cultural features within the area prompted a quaternary geologic/paleobotanical study of the lake-bed environment. In response to these findings District 12, Department of Transportation, Division of Engineering Services, State of California, authorized a series of paleobotanical studies within the area impacted by the SR133 realignment just east of Laguna Beach. In late November 2006, Drilling Services personnel and geologists from the Office of Geotechnical Design South-1, drilled and logged six punch-core borings in the area adjacent to the cluster of three lakes in Laguna Canyon above Laguna Beach. The results of the paleobotanical investigations on samples taken from these sediment cores is contained in this report.

Setting

Location:

The cores were taken near the south end of Lake 3, the southeastern most lake in the system. The site is located at 33° 36' 32.09" N, 117° 45' 31.19" W, USGS, Laguna Beach 7.5-minute quadrangle, Orange County, California.

Topography, Hydrology, Ecoregion and Local Geology and Topography:

Topography

The topography in the local area around Laguna Lakes ranges from very gently sloping hills and ridges in or near the valley bottom to steep rugged scrub covered uplands to the west and east. Laguna Canyon drains toward the Pacific Ocean from an up valley elevation of ~ 122 m down to 104 m near SR73 at the south end of the valley. Laguna Canyon is confined on the by north-south running ridges that range up to 293 m elevation on the west and just above 183 m elevation on the east.

Regional Geology

The area lies within the geographical section of California known as section 261B (*Southern California Coast*) (Miles and Goudey 1997). This geographical region includes the mountains, hills, valleys, and plains of the Transverse Ranges and of the Peninsular Ranges. It is comprised of the narrow ranges and broad fault blocks; alluviated lowlands, and coastal terraces that makeup the Transverse and Peninsular Ranges geomorphic province. Lithologically the region is characterized by Cenozoic marine and nonmarine sedimentary rocks and alluvial deposits. The section is close enough to the Pacific Ocean for the climate to be greatly modified by marine influence.

Subsection 261Bi (Coastal Hills) is the geographic subsection within the Southern California Coast geographical section that encompasses the Laguna Lakes (Miles and Goudey 1997). This subsection includes the foothills along the west side of the Peninsular Ranges from the Santa

Ana River southeast to the Mexican border. This subsection contains mostly Mesozoic granitic and mafic Oligocene marine and nonmarine, and Miocene marine sedimentary rocks. The many canyons and valleys that typify this area are filled with Quaternary fluvial deposits.

Geomorphology

This region is characterized by moderately steep to steep hills which lie between the mountains of the Santa Ana and Laguna Mountains of the northwest trending Peninsular Ranges and coastal terraces that run along the southwest edge of this subsection.

Hydrology

Many of the streams which cross the region from the mountains to the coast have alluvial plains hundreds of meters wide, and there is a particularly broad valley at El Cajon (Miles and Goudey 1997). The subsection elevation range is ~ 152 m to 610 m. Mass wasting and fluvial erosion are the main geomorphic processes. Fluvial deposition is an important process on floodplain and alluvial fans in the valleys. Three small lakes occur within Laguna Canyon and are known as the Laguna Lakes (Harris 2007). These are numbered as Lake 1 in the north, Lake 2 in the southwest, and Lake 3 in the southeast. Lakes 2 and 3 are currently bisected by roadway, but were actually connected below the old roadway by a box culvert. More than likely they were physically connected during periods of high water before the establishment of a permanent roadway. The Laguna Canyon Watershed covers ~27 square km and includes portions of the cities of Aliso Viejo, Laguna Beach, and Laguna Woods. The main tributary is the Laguna Canyon Channel.

Presently, surface water flow in Laguna Canyon creek is non-existent (characteristic of many of the streams in the subsection), and there is little evidence of active incision, or deposition (Harris 2007). Apparently surface drainage in the valley is mostly by rapid sheet flow, and that the porous nature of soils cause rapid percolation of surface water.

Soils

The soils are mostly Lithic Xerorthents; Lithic, Pachic, and Calcic Haploxerolls; Typic Argixerolls; Typic Natrixeralfs; Natric Palexeralfs; and Chromoxererts and Pelloxererts (Miles and Goudey 1997). On granitic rocks, soils are usually shallow Typic Xerorthents and Typic Haploxeralfs. On mafic plutonic rocks, they are primarily Mollic and Typic Haploxeralfs and Typic Rhodoxeralfs. Common soils on floodplains, terraces, and alluvial fans are Typic Xeropsamments, Cumulic Haploxerolls, and Typic Haploxeralfs. The soils are usually well drained. Calcium carbonates accumulate in many of the soils (usually a good indication that pollen preservation will be poor). The soil temperature regimes are thermic (warm). Soil moisture regimes are xeric (dry).

Climate:

The Laguna Canyon watershed experiences a Mediterranean climate with cool dry summers, and mild wet winters. Since rainfall occurs almost exclusively in the winter, streams are typically dry in the summer months. The climate details in the canyon can be inferred from the nearby 80-year record at Laguna Beach (Table 1). Yearly precipitation (mostly as rain) in the Laguna Canyon averages from ~.51 mm to 71 mm per year with the peak precipitation occurring in February, and the lowest in July. Temperatures are mild ranging from 18 to 25 ° C with January being the coldest month and August the warmest. The mean frost-free period ranges from ~ 275 to 350 days (Bailey 1975). Late spring through early fall drought characterizes the region (Table 1), with snow only occurring very rarely.

The number of days between the last spring freeze and the first autumn freeze provides a good measure of the length of the growing season. However, in order to measure the efficiency of the growing season degree-days are calculated. Degree-days are the number of degrees by which daily mean temperature is above or below a selected base temperature. To better characterize the actual impact of temperature on plant growth upper and lower temperature limits are applied. Usually, Temperate region plants don't really respond with significant growth to temperature increases until about 10°C (50°F). Above 30°C (86°F) growth is also inhibited. As a result growing degree-days is usually looked at as the temperature amount between 10°C (50°F) and 30°C (86°F) that contributes to plant growth. This is calculated with the formula:

Growing Degree-Days =

½ [(30°C - Temperature^{maximuum})+ (Temperature^{minimum} - 10°C)] – Base Temperature (10°C in this case)

or in English system measurements

½ [(86°F - Temperature^{maximum})+ (Temperature^{minimum} - 55°F)] – Base Temperature (55°F in this case) *

(note: the figures will be in the English system) (Houghton *et al.* 1975)

The peak growing degree days coincide with the driest part of the year. *i.e.*, May through September. It is clear that greatest degree-day amounts are skewed toward late spring and summer so that temperatures favoring most plant growth is greatest after May, but drop off sharply by November. This is in juxtaposition to the supply of precipitation in the region, indicating that winter storage of precipitation is crucial for adequate plant growth during the following summer. Biotic production in the region is maximized during the spring when conditions of increasing growing degree days coincides with the highest levels of accumulated ground water derived from winter rainfall. Under this kind of climatic pattern winter droughts, can be regionally catastrophic for plant growth. During periods of drier conditions plant maturity occurs earlier in the year. That is, plant foods will mature up to a month or more earlier then during wetter years. Under normal conditions plants growing in the drier areas of the region will mature earlier than in wetter area. Therefore, with the diversity of microclimates found in the area the harvest of specific plant species can be extended by collecting first in warmer, drier areas and then later at cooler, wetter locations.

The climatic pattern found in southern California is exactly the opposite of that occurring in the Southwest were summer monsoons (highest annual input of precipitation) coincide with the highest degree growing days. Therefore, in the Southwest plants are adapted to take advantage of dramatic inputs of surface water during the summer, whereas in southern California they depend upon the water stored in the soils during the winter rainy season.

The accumulation of some growing degree days in winter indicates that some plant growth occurs in winter in southern California (in northern California or in the Great Basin there is no accumulation of degree growing days during the winter months). This means that plant species adapted to take advantage of this can be available for collection by native populations throughout the year.

Corn degree growing days is different than degree growing days only in that it uses a lower base temperature:

Corn Growing Degree-Days =

½ [(30°C - $Temperature^{maximuum}$)+ ($Temperature^{minimum}$ - 10°C)] – Base Temperature (10°C in this case)

or in English system measurements

½ [(86°F - $Temperature^{maximum}$)+ ($Temperature^{minimum}$ - 50°F)] – Base Temperature (50°F in this case) *

(note: the figures will be in the English system) (Based upon U.S. Weather Service usage)

Therefore, higher degree day values are accumulated. This index reflects the potential for plants that are able to start growing at lower temperatures to start growing earlier in the year. Such plants extend the season during which growing plants are available to native populations. In the coastal region of southern California this season is significantly longer than that available for peoples from east of the Sierra Nevada Mountains.

In comparison to the Laguna Beach weather record that of the Laguna Lakes area is probably a bit cooler (due to its higher elevation and distance from the moderating influence of the ocean), and perhaps a bit wetter because the orographic rainfall effect may be a bit stronger. In general, the area is drier than sites further north in the Los Angeles Basin in the winter, and moister than other inland sites in the summer. It has a relatively long growing season similar to that found at inland sites.

In summary, the Laguna Canyon Lakes lie in an area where marine air masses moderate the effects of hotter and drier interior locations in southern California, and they lie high enough to avoid more extreme winter cooling caused by cool air drainage from the eastern mountains. Higher evaporation rates result in relatively drier conditions than in the lowlands to the north and northeast.

Vegetation

The predominant native plant community series are the California sagebrush - California buckwheat, the California sagebrush - black sage series, and the Coast live oak series (Miles and Goudey 1997; Hickman 1993). There are scattered occurrences of the Chamise, White sage, and Scrub oak series, as well. California sycamore occurs in riparian areas. Characteristic series by lifeform include:
1) Grasslands: California annual grassland series.
2) Shrublands: Black sage series, California buckwheat series, California buckwheat - white sage series, California sagebrush series, California sagebrush - black sage series, California sagebrush series - California buckwheat series, Chamise series, Chamise - black sage series, Chamise-mission-manzanita - woollyleaf ceanothus series, Coast prickly - pear series, Mixed sage series, Mixed scrub oak series, Scrub oak series, Scrub oak - chamise series, Sumac series, White sage series.
3) Forests and woodlands: California sycamore series, Coast live oak series, Engelmann oak series.

A vegetation transect from just south of the site area was recorded by the Vegetation Type Map (VTM) survey of California conducted by the U.S. Forest Service between 1927 and the early 1940s. Transect 179A records the vegetation from the coast just east of San Juan Capistrano, through Capistrano into the mountains to the east (Figure 1). It indicates shrubland in the hills near the coast dominated by California sagebrush, buckwheat, true sages, and *Baccharis*. Further inland grasslands predominate. However, by the time that transect was recorded the area had already been subjected to heavy grazing.

Methods

Coring:

Six 4.25-inch diameter rotary wash borings were obtained utilizing a truck mounted CME-85 drill rig. Continuous sampling of the soil column was taken with a 2.5-inch internal diameter wire-line punch-core barrel. Samples were logged and placed in core boxes with depth below ground surface measurements labeled between sample intervals. Although overall core recovery was adequate, only one of the cores (core #1) was selected paleobotanical investigation. Core one was selected because it was relatively continuous, it had fine sediment size (similar to the size of the paleobotanical materials to be analyzed), it had a dark color promising the presence of organic material, and it had a high moisture content which often promises excellent preservation of paleobotanical fossils.

Although the cores had been logged in the field, they were again described by Dr. Manuel Palacios-Fest at SRI just prior to sampling. He used the USCS system for soil classification and a Munsell color chart for soil color. Although Dr. Palacios-Fest described six cores only two (cores 1 an 2) were sampled for pollen, ostracodes and radiocarbon dates. Of these, only core 1 was processed for pollen.

Radiocarbon Dating:

Twelve radiocarbon samples were taken from cores 1 and 2. Of these eight were submitted to Beta Analytic in Miami, Florida. One of these samples included a piece of wood also recovered from the core.

Pollen Analysis:

Extraction

The forty-five sediment samples taken from Core 1 (RW06-1) were extracted for pollen in the Department of Geography Paleoecology Laboratory (Table 4). These were extracted using the following procedure.

Processing of samples for pollen, and selected spores began with placement of one teaspoon (see Table 4 for exceptions) of sample into a 400 ml plastic beaker with triple distilled water (Table 2). For statistical purposes two *Lycopodium* tracer spore tablets (batch #124961 with 12,542 ±3.3% spores per tablet) were added to each of the ten samples. This equaled 25,084± 828 tracer spores per sample.

Because of the high probability that the pollen in these samples may have been degraded (usually to be expected with samples from open sites) the extraction procedure was modified to remove those steps that might be more damaging to the pollen during processing. The modified procedure was as follows. Samples were treated with concentrated hydrochloric acid (HCl) to remove carbonates and rinsed through 150-mesh screen using distilled water.

Omitted at this point were a series of steps that are meant to remove in organic and organic material from the sample, but which can be highly corrosive. These steps included: 1) a treatment with hydrofluoric acid (HF) to remove inorganic materials (primarily silicates) after which it would be left to stand overnight; 2) an additional treatment with HF while in a 30 minute hot water bath; 3) another HCl treatment followed by a distilled water wash removed silica gels generated during the HF treatment; 4) a treatment of the samples with 10% HNO3 to remove organic carbon; 5) a water wash; 6) a third treatment with HCl in a two minute boiling water bath to remove dissolved organic material; 7) a distilled water wash to remove soluble

organic carbon; 8) a treatment with glacial acetic acid to dry the samples; 9) then a treatment with an acetolysis mixture (9 parts acetic anhydride plus 1 part H2SO4) in a one minute boiling water bath; 10) another glacial acetic treatment to halt the reaction; 11) a distilled water wash to remove the small particulate organic carbon; 12) a treatment with 10% KOH to remove soluble organic carbon samples; 13) finally, four distilled water washes to change the pH and remove the remaining soluble and fine particulate carbon.

Instead, these samples were treated with a solution of sodium polytungstate with a specific gravity of 2.1. This floated all pollen, diatoms, algae, insect parts, etc. that could have been destroyed by the standard procedure. The float was decanted into a new test tube, and concentrated using a centrifuge. The residue (material which did not float) has been saved. There followed numerous hot distilled water washes to remove suspended clays, charcoal and colloidal materials that were also floated during the sodium polytungstate procedure. After the water washe the samples were dried with two treatments of ETOH alcohol (the first 95% concentration and the second 100% concentration). The pollen was stained with safranin O during the first alcohol treatment, and the samples were transferred to vials with Tertiary Butyl alcohol, and completed with the addition of a mounting medium (2000 cs silicone oil). Finally, the Tertiary Butyl alcohol was evaporated from the samples in a low temperature oven for a couple of hours. Pollen samples were mounted on glass slides and at least 10 contiguous rows were counted for each sample. Identification of certain unknown pollen types was assisted by the use of a reference slide collection, several online pollen floras (linked to from a website at the University of Arizona: http://www.geo.arizona.edu/palynology/pol_pix.html), and several pollen photomicrograph publications of Southwestern pollen types that were helpful for types that seem to be intrusive from the Southwest (Martin and Drew 1969 and 1970; Solomon *et al* 1973).

Results

Raw terrestrial and aquatic pollen counts were converted to percentages (Table 5; Figure 2) of total terrestrial pollen. Raw counts of spores were converted to percentages of total pollen (Table 5). Using L. Maher's (1972) formulas for calculating pollen population estimates the raw counts and *Lycopodium* tracer spores were used to generate estimates of: 1) Aster-type pollen percentage per sample (Figure 3), 2) total Aster-type pollen per sample (Figure 4), 3) total pollen per sample (Figure 5), and 4) total pollen per cubic centimeter (Figure 6) all with their 95% confidence intervals. Because pollen counts are low in many of the samples the relative percentages of less abundant pollen types vary erratically. "Unknown" pollen types were included in the "Undeterminable" category as were "Deteriorated" pollen grains.

Radiocarbon Dates:

The radiocarbon results (Table 6) indicate that the sediment of the lower portion of core 1 (the secton analyzed by these investigators) date from between 10580 and 12820 cal BP. Therefore, roughly 2300 years is represented in this record. These dates were used to generate a deposition rate curve for the cores so that a approximate calendar age before the present was assigned to each pollen sample. This was used in plots of the pollen samples.

Discussion

Pollen:

It is clear from the pollen counts that all pollen recovered appears to be free of modern contamination. However, there preservation varies considerably. In general the appearance of the pollen varied considerably. They can be divided into several groups.

Group 1: This group includes poorly preserved pollen grains with pitted surfaces, and/or indistinct features, or that have been torn into fragments. The pollen grains in this group appear to characterize the samples from the lower portion of the core. These could date to the time of deposition, and simply evidence severe degradation after burial. Conversely some of this pollen could predate the age of deposition, and reflect pollen that was eroded from older sediments on the surrounding slopes and washed in along with the sediments that were filling the lake. If this were the case, however, there should be some pollen in fairly good shape that reflects direct airfall of pollen into the lake. Because all the pollen appears to be in poor condition in the lower portion of the core, post-depositional degradation seems to be cause.

The poorly preserved state of the pollen could be the result of age (long exposure to degradation), or the result of soil conditions that favor pollen degradation (high soil ph (basic) and/or high eH - oxidation potential). It could also be the result of bacterial activity which is favored by wetting and drying during cycles of warm, moist conditions. In most cases it was impossible to identify the grains in this group because their preservation is too poor. They are included in the “undeterminable” category.

Group 2: This group is comprised of pollen grains that appear to be well preserved (Aster-type pollen), but whose abundance is much greater than would be expected in any “natural” plant community. As with the pollen grains of group one these pollen grains could date to the time of primary deposition. Conversely some of these could also predate the age of deposition, and have been present in older sediments that had been eroded from the surrounding slopes and were filling the lake. Of the more common pollen types included in this group are: most of the “*Aster*-type” pollen, Poaceae (grass), and trilete spores (ferns) appear to be part of this group as well.

The inclusion of often abundant, well preserved sedge pollen in this group suggests a local origin for this pollen that is contemporaneous with the time of deposition. Sedge is a pollen grain that does not preserve well. It is thin-walled, and easily destroyed though mechanical (abrasion), chemical (high soil ph (basic) and/or high eH - oxidation potential), or bacterial action.

Group 3: These pollen grains of this group are native species. They are background pollen, *i.e.*, deriving from the local plant community, but they appear to be much better preserved than most of the other pollen grains in the samples. Because they are much better preserved than most of the pollen grains in the samples they may represent pollen that was introduced during collection of the cores or of the pollen samples. These pollen types include: *Proboscidea* (devil's claw), among others.

Group 4: In addition, there are at least some pollen grains, e.g., some of the grass (Poaceae) pollen grains, which although a modern/native plant appear much darker and more flattened than most other pollen grains in the samples. These characteristics are typical of pollen eroded from much older deposits and re-deposited into younger sediments. The much darker color could also be the result of burning of the pollen grains before deposition.

<u>Pollen Preservation and Interpretation of the Record</u> - There are several factors the suggest that the pollen preservation in these samples is poor. Primary is the eroded appearance of many of the grains. Secondly is the over representation of one or two pollen types especially if they are pollen types that studies have shown are resistant to erosion (they usually have a much thicker pollen wall). Along with this factor is the lack of diversity in the pollen types in the samples. Finally, there are usually very low numbers of pollen grains per cubic centimeter of sediment in each sample (this could be caused by rapid deposition rates as well, but in combination with the other factors it indicates poor preservation. All of these factors seem to be reflected in the pollen from the Laguna Canyon core.

Many pollen grains appeared highly eroded. This could have been as a result of bacterial action, oxidation or mechanical damage during aeolian transport. Thin-walled pollen grains were effected the greatest. However, even some of the thick-walled pollen grains such as the Chenopodiineae and Aster-type pollen were also highly eroded in these samples.

Low numbers of pollen per cm per year sample and especially per cubic centimeter indicate that pollen preservation was fair to poor in all samples (see pollen per cubic centimeter values in Figure 6). In a semi-arid to sub-humid environment the amount of pollen deposited per square centimeter per year will range from 6,000 to 8,000 (occasionally up to 10,000 in wet years) pollen grains. Each of the pollen samples submitted for analysis (given their initial volumes) should contain the sediment accumulated from several years with a pollen abundance on the order of 18,000 to 30,000 grains per cubic centimeter. The pollen per cubic centimeter estimates of these samples does not even approach such values. This suggests either poor pollen preservation or rapid sediment deposition. Although rapid deposition does not effect pollen preservation it exacerbates the problem of pollen abundance. That is, if sediment deposition rates are rapid, pollen will be more thinly distributed through the sediment. Add to this the issue of poor preservation and the pollen will be even more thinly dispersed through the sediment. A pollen sample taken from such soil will yield very little pollen.

Another clue to the state of preservation of the pollen samples is how well the pollen assemblage reflects the current (or assumed past vegetation community). In this case the dominant type recovered from the pollen samples was *Aster*-type (sunflower family plants. Although a variety of plants producing *aster*-type pollen occur in nearby modern vegetation communities, they are not the major pollen types that one would expect in the modern pollen rain. The scan of these pollen samples undertaken for this study clearly indicates that the pollen samples from these features do not seem to reflect the relative abundance of the pollen types to be expected in the current or past local/regional pollen accumulation. They lack species which should be relatively abundant, including sagebrush *(Artemisia)*, buckwheat *(Eriogonum)*, and true sage *(Salvia)*. The lack of diversity, especially the extremely low abundance of grass, and sagebrush pollen strongly suggests that these types were destroyed after deposition of these sediments.

Finally the lack of pine pollen in most of these samples may be another indication that preservation is poor. Although there is no upwind, i.e., coastal source for pine pollen, the winds vary significantly enough in the region to bring pine into the record. It is, however, extremely rare.

Poor pollen preservation reflects any number of factors. It may not only reflect the basic ph of the soil (acid soils favor pollen preservation, but basic soils are inimical to pollen preservation), but may reflect the coarseness of the soil matrix within which it is found. The coarse texture of some of the sediments (though many were clay rich as well) was noted during extraction of the pollen in the laboratory. This already hinted at poor pollen preservation. Coarse soils allow for rapid flow of water through the soils. Frequent wetting and drying of the soils indicates a well-drained condition with plenty of air movement into the soil. These conditions are ideal for a high oxidation potential, + eh, to occur. High oxidation potential is very destructive for pollen, especially because it creates an environment favorable to bacterial growth. Bacteria that thrive under such conditions literally eat pollen.

Soils in the Laguna Lakes area are probably primarily of fluvial origin. Originally they derived from the alluvium that was swept out of the mountains to the east. Subsequently these sediments were reworked by local streams, and the ocean to accumulated in the lakes through either fluvial or colluvial processes. During these processes they would have been subjected to mechanical abrasion. This could explain some of the damage that we see on the pollen grains.

Any one of the factors above could result in poor pollen preservation, but together they assure that pollen survival will be extremely poor or, at best, rare. Unfortunately, these conditions are similar to those encountered by many palynologists conducting archaeological palynology investigations Throughout southern California and the American Southwest.

Having covered the cons with regard to the pollen record from the Laguna Lakes core pollen we now turn to what other information can be gleaned from the record. Of the samples that were processed only the upper samples from the sequence seem to provide reliable information regarding the environment. However, the lower samples used in conjunction with the information gleaned from the samples in the upper part of the sequence can also provide some information.

The abundant *Aster*-type pollen in these samples derives from the many plants of the composite family that grow in the area. Perhaps one of the major sources of this pollen type is the genus *Baccharis*. However, the diversity reflected in the *Aster*-type pollen recovered from the core indicates that there are many plants from the aster family contributing to the pollen record.

Several species of the genus *Baccharis* could be responsible for the pollen that we see in the record. Most are typical of riparian areas and in the coastal chaparral on the bluffs around Laguna Canyon area. *B. glutinosa* is found in the freshwater marshes and in riparian areas. *B.*

pilularis ssp. *consanguinea* is found in disturbed areas and in coastal shrub communities on bluffs. Another species *B. emoryi* is found in the dry bottoms of vernal pools or around dry springs and on the sandy edges of rivers, washes and salt marshes (Mattoni and Longcore 1997; Hickman 1993). As with all composite species they produce copious amounts of pollen. It is to be expected that they would be well represented in the pollen record, but not to the extent that occurs in the samples from the Laguna Lakes record. An indication that much of the *Aster*-type pollen is from *Baccharis* is that the pollen is relatively small and has a morphology consistent to that expected for *Baccharis*.

The rare Chenopodiaceae pollen is primarily from non-*Salicornia* (pickleweed) species. Much of it has a morphology consistent with the genus *Atriplex* though other genera cannot be ruled out. Various species of *Atriplex* occur in the area on dry, well-drained slopes and bluffs. In particular, *A. lentiformis* (big saltbush) grows on bluffs near the seashore. The fact that these produce copious amounts of pollen, but are rare in the record indicates that they were rare on the landscape as well..

The abundant occurrence of sedge in the record clearly records the presence of a marsh at the point where the cores were taken. Its great abundance, relative to aster-type pollen in some samples, is clear evidence that extensive marsh was present at the time that these samples mark. Sedge pollen in these numbers probably were not washed in from areas above the Laguna Lakes, nor was it blown in from elsewhere. It is just too abundant. Therefore we can clearly see an episode of higher lake levels during which much of the area surrounding the lakes was inundated and into which marsh expanded. Relatively great fluctuations of the values sedge pollen suggests that the marsh itself fluctuated greatly as well (Figure 7). Although sedge pollen is easily weathered, its current abundance in the record suggests that it may have been much more abundant when initially deposited in the Laguna Canyon lakes.

Finally, devil's claw, *Probosidea* cf. *parviflora* pollen, though rare, also occurs in the samples processed from the Luguna Canyon Lake record. The seed pods of this annual were used by native populations in the manufacture of basketry. There is little or no possibility that pollen of devil's claw could have been collected along with the seed pod as the time when they flower and produce mature seed pods is many weeks apart. However, collection and use by native peoples of these plants might have lead to the establishment of some of these plants adjacent to or in the settlements, perhaps even near the work areas in the sites. Alternatively, there may have not been any use of devil's claw on the site, and the appearance of its pollen in the record may be purely co-incidental because it grew as a nearby weed.

Diatom Samples:

Eighteen samples were analyzed by Dr. Scott Starratt for the presence of diatoms (Table 7). Only one sample (629-630 cm) contained two unidentifiable fragments. He indicates that these results are typical for lacustrine sediments from southern California. He suggests that in many cases, groundwater conditions are such that diatoms and other biogenic silica remains (i.e., chrysophyte stomatocysts, phytoliths, etc.) are destroyed after burial or even before burial.

Additional evidence of the lack of diatoms in these samples was also confirmed by the scans of the pollen samples. The manner in which the pollen samples were extracted (without the use of HF acid) should have left any diatoms intact. None were observed in any of the 45 samples that were scanned during pollen analysis

Ostracode Samples:

Ostracode samples were taken as a paired sample for all pollen samples by Dr. Manuel Palacios-Fest. Unfortunately, Dr. Palacios-Fest recovered no ostracodes from any of the samples.

Preservation Issues vs Interpretation:

Preservation is clearly an issue with regards to the abundance and type of macrofossils recovered from the Laguna Canyon cores. Clearly, post-depositional destruction of ostracodes suggests that either at the time of depostion or at some time after burial the water moving through the sediments were acidic. This might also explain the destruction of diatoms as well. Acid conditions can also result in eventual dissolution of silicates in soils. In general, acid conditions should not affect pollen, and yet the pollen preservation in the lower portion of the profile is quite poor while at the top of the record it is better. If post-depostional wetting and drying were responsible for pollen degradation one would expect pollen throughout the record to be equally degraded, however it isn’t. This suggests that destruction of the pollen occurred at the time of deposition. This could happen if pollen were deposited in an environment were seasonal wetting and drying prevailed. Seasonally dry marshes during periods of reduced winter precipitation combined with summer drought would result in significant destruction of pollen. On the other hand, periods of increased winter precipitation would result in sustained marshes throughout the summer. In this case pollen would eventually be buried without significant destruction.

Environmental and Climate History:

As part of the discussion of the pollen record we have utilized a macrophysical climatic modeling (MCM) based upon the relationship between large-scale atmospheric dynamics and synoptic climatology (Bryson and Bryson 2000). This program uses the modern monthly averages of temperature, precipitation, evaporation, etc. from individual weather stations to generate climate trends at 100 year resolution for the last 16,000 years. The very close correspondence between the reconstructed precipitation trends for the Laguna Beach station and the record of sedge pollen from the Laguna Lakes is clear (Figures 8 and 9). The Laguna Beach climate reconstruction indicates a dramatic increase in winter (notice that summer precipitation does not increase accordingly) precipitation between 11,500 and 10,500 cal BP. This corresponds to the period of dramatic increases in sedge pollen as well. In addition, both the climatic reconstruction from the MCM model and the sedge pollen record reveal great fluctuation during this period. Prior to 11,500 cal BP the MCM climate model indicates relatively drier conditions. This corresponds to the period when, although there is some pollen in the samples from the core, it is poorly preserved in respect to that of the period between 11,500 and 10,500 cal BP. This event is also evident in the pollen record from the Playa Vista area (Wigand 2004). Further afield, this period corresponds to an episode of increased spring activity in the northern Mojave Desert that is characterized by increased spring discharge and changes in vegetation evidenced in ancient woodrat midden records (Quade et al 1998; Wigand

and Rhode 2002). The Tulare Lake record also indicates that water levels were higher between 11,500 and 10,500 cal BP (Negrini et al 2006). Figure 12 in Negrini et al 2006 indicates other correspondences of high water during this period including Lake Mojave, and Owens Lake. Interestingly enough, although Lake Elsinore indicates a sustained lake during this period, it does not indicate a deepening of the lake in concert with the Laguna Canyon lakes. In the Mojave Desert and further north this period has been associated with increased spring or summer precipitation. This interpretation was due to the kinds of plants that seemed to be responding. That is, plants that today respond to increased summer precipitation/and or increased spring discharge where becoming more abundant in the woodrat midden record (Wigand and Rhode 2002).

This data suggest that as a result of increased winter precipitation along the southern coast of California, lake levels rose in the Laguna Canyon Lakes resulting in extensive flooding of the surrounding valley floor. Sustained flooding resulted in the establishment of sedge-rich...though there was some tall coastal cat-tail as well...marsh. For brief, periods the water may have been slightly deeper allowing the establishment of emergent aquatic plants such as water smart weed (*Polygonum persicaria* - type pollen).

Citations and References Used

Bailey, H. P. 1975. Weather of Southern California. California Natural History Guides 17. University of California Press. 87 pp.

Bryson, R. A., and R. U. Bryson. 2000. Site-specific high-resolution models of the monsoon for Africa and Asia. *Global and Planetary Change* 26:77-84.

California Native Plant Society. 1997. A Manual of California Vegetation. On line publication at: http://davisherb.ucdavis.edu/cnpsActiveServer/index.html

Hickman, J. C. (ed). 1993. The Jepson Manual. University of California Press, Berkeley. 1400 pp.

Maher, L. J. Jr. 1972. Momograms for computing 0.95 confidence limits of pollen data. *Review of Paleobotany and Palynology* 13:85-93.

Martin, P. S. and C. M Drew. 1969. Scanning Electron Photomicrographs of Southwestern Pollen Grains. *Journal of the Arizona Academy of Science 5 (3): 147-176.*

Martin, P. S. and C. M Drew. 1970. Additional Scanning Electron Photomicrographs of Southwestern Pollen Grains. *Journal of the Arizona Academy of Science 6: 140-161*.

Miles, S. R. and C. B Goudey (compilers). 1997. Ecological Subregions of California: Section and Subsection Descriptions. US Department of Agriculture, Forest Service, Pacific Southwest Region, San Francisco, CA. Publication Number R5-EM-TP-005.

Negrini, R.M., P.E. Wigand, S. Draucker, K. Gobalet, J.K. Gardner, M.Q. Sutton, R.M. Yohe, II., 2006. The Rambla highstand shoreline and the Holocene lake-level history of Tulare Lake, California, USA, Quaternary Science Reviews, v. 25, p. 1599-1618.

Quade, J., Forester, R.M., Pratt, W.L., Carter, C. 1998. Black mats, Spring-fed streams, and Late-Glacial-age recharge in the Southern Great Basin. Quaternary Research 49, 129–148.

Solomon, A. M., J. E. King, P. S. Martin, and J. Thomas. 1973. Further Scanning Electron Photomicrographs of Southwestern Pollen Grains. *Journal of the Arizona Academy of Science 8(3)135-157.*

Wigand, P. E. 2004. “Estuarine Evolution, Chaparral History, and Changing Plant Resource Availability.” Unpublished manuscript submitted to Statistical Research Inc. for the Playa Vista Project.

Wigand, P. E. and D. Rhode. 2002. Great Basin Vegetation History and Aquatic Systems: The Last 150,000 years. Pp. 309-367. In Hershler, R., D. B. Madsen and D. R. Currey (eds.), *Great Basin Aquatic Systems History*. *Smithsonian Contributions to Earth Sciences* 33. Smithsonian Institution Press, Washington, D.C.

Table 1. Monthly averages for the period of record (1928-1970) for Laguna Beach, CA. (Source: Western Regional Climate Center, Western U.S. Climate Historical Summaries)

	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**
Jan	64.01	18.39	6.11	12.33
Feb	71.12	18.94	6.72	12.83
Mar	52.07	19.50	7.67	13.55
Apr	24.89	20.55	9.11	14.83
May	6.35	21.61	11.67	16.61
Jun	2.79	22.78	13.39	18.11
Jul	0.51	24.72	15.17	19.94
Aug	1.78	25.55	15.33	20.50
Sep	6.60	25.28	14.55	19.89
Oct	12.45	23.61	12.05	17.83
Nov	31.50	21.33	8.61	15.00
Dec	49.02	19.00	6.33	12.72
Annual	322.83	21.78	10.55	16.11

Table 2. Monthly growing degree days for period of record for Laguna Beach, CA (Source: Western Regional Climate Center, Western U.S. Climate Historical Summaries)

Base	J	F	M	A	M	J	J	A	S	O	N	D	Ann
55 M	49	52	77	122	217	283	400	431	385	283	133	55	249
55 S	49	101	177	300	516	804	1204	1635	2020	2303	2436	2491	2491

M = monthly average S = summed values

Table 3. Monthly corn growing degree days for period of record for Laguna Beach, CA (Source: Western Regional Climate Center, Western U.S. Climate Historical Summaries)

Base	J	F	M	A	M	J	J	A	S	O	N	D	Ann
50 M	244	235	275	307	384	440	555	585	535	447	329	262	4594
50 S	244	479	755	1061	1445	1886	2441	3025	3557	4004	4333	4594	4594

M = monthly average S = summed values

Table 4: Pollen samples analyzed from Site 12ORA133, Orange County, CA, Core RW06-1

Sample #	Drive	Interval	Collector	Date Collected	Depth (cm)	Geological Unit	Description	Years/cm of depth
1	10	43-45.5'	MP/KB	1/29/2008	463.5	14c	Organic cobble clay	5.00
2	10	43-45.5'	MP/KB	1/29/2008	469.5	14c	Organic cobble clay	5.00
3	11	45.5-48'	MP/KB	1/29/2008	500.5	14c	Organic cobble clay	5.35
4	11	45.5-48'	MP/KB	1/29/2008	513.1	14c	Organic cobble clay	4.60
5	11	45.5-48'	MP/KB	1/29/2008	522.5	14c	Organic cobble clay	4.26
6	11	45.5-48'	MP/KB	1/29/2008	531.5	14c	Organic cobble clay	3.89
7	11	45.5-48'	MP/KB	1/29/2008	540.5	14c	Organic cobble clay	3.67
8	11	45.5-48'	MP/KB	1/29/2008	555.5	14c	Organic cobble clay	3.27
9	11	45.5-48'	MP/KB	1/29/2008	581.5	14c	Organic cobble clay	2.88
10	12	48-50.5'	MP/KB	1/29/2008	608.5	14a	Organic clay	2.30
11	12	48-50.5'	MP/KB	1/29/2008	617.5	14a	Organic clay	2.22
12	12	48-50.5'	MP/KB	1/29/2008	629.5	14a	Organic clay	1.67
13	12	48-50.5'	MP/KB	1/29/2008	640.5	14a	Organic clay	1.55
14	12	48-50.5'	MP/KB	1/29/2008	651.5	14a	Organic clay	1.64
15	12	48-50.5'	MP/KB	1/29/2008	661.5	14a	Organic clay	1.60
16	13	50.5-55.5'	MP/KB	1/29/2008	666.5	14a	Organic clay	1.20
17	13	50.5-55.5'	MP/KB	1/29/2008	676.5	14a	Organic clay	1.40
18	13	50.5-55.5'	MP/KB	1/29/2008	688.5	14a	Organic clay	1.25
19	13	50.5-55.5'	MP/KB	1/29/2008	696.5	14a	Organic clay	1.25
20	13	50.5-55.5'	MP/KB	1/29/2008	703.5	14a	Organic clay	1.71
21	13	50.5-55.5'	MP/KB	1/29/2008	712.5	13	f - m sand	1.00
22	13	50.5-55.5'	MP/KB	1/29/2008	722.5	12	Organic clay	1.30
23	13	50.5-55.5'	MP/KB	1/29/2008	731.5	12	Organic clay	1.22
24	13	50.5-55.5'	MP/KB	1/29/2008	737.5	11	fining up m to f sand	1.17
25	13	50.5-55.5'	MP/KB	1/29/2008	758.5	10c	fining up silty clay	1.48
26	13	50.5-55.5'	MP/KB	1/29/2008	770.5	10b	fining up silty clay	1.50
27	13	50.5-55.5'	MP/KB	1/29/2008	775.5	10a	course sand	1.20
28	14	55.5-60.5'	MP/KB	1/29/2008	792.5	8	Coarse up silty clay	1.71
29	14	55.5-60.5'	MP/KB	1/29/2008	803.5	7	c to f sand	2.18
30	14	55.5-60.5'	MP/KB	1/29/2008	814.5	7	c to f sand	2.09
31	14	55.5-60.5'	MP/KB	1/29/2008	835.5	6d	silty clay fining to clay	2.38
32	14	55.5-60.5'	MP/KB	1/29/2008	845.5	6d	silty clay fining to clay	2.50
33	14	55.5-60.5'	MP/KB	1/29/2008	857.5	6c	silty clay fining to clay	3.08
34	14	55.5-60.5'	MP/KB	1/29/2008	898.3	6c	silty clay fining to clay	3.58
35	14	55.5-60.5'	MP/KB	1/29/2008	879.5	6b	sandy silt fining to silt	3.88
36	14	55.5-60.5'	MP/KB	1/29/2008	899.5	6a	c to f sand fining up	3.90
37	14	55.5-60.5'	MP/KB	1/29/2008	909.5	5	clayey silt	5.10
38	15	60.5-65.5'	MP/KB	1/29/2008	920.5	5	clayey silt	4.64
39	15	60.5-65.5'	MP/KB	1/29/2008	944.5	3	sandy clay	5.42
40	16	65.5-70.5'	MP/KB	1/29/2008	960.5	2c	silty clay fining to clay	5.94
41	16	65.5-70.5'	MP/KB	1/29/2008	970.5	2c	silty clay fining to clay	7.10
42	16	65.5-70.5'	MP/KB	1/29/2008	980.5	2c	silty clay fining to clay	6.90
43	16	65.5-70.5'	MP/KB	1/29/2008	991.5	2c	silty clay fining to clay	7.64
44	16	65.5-70.5'	MP/KB	1/29/2008	1000.5	2c	silty clay fining to clay	8.33
45	16	65.5-70.5'	MP/KB	1/29/2008	1012.5	2c	silty clay fining to clay	8.67

Table 5a. Raw counts of pollen and spores from the Laguna Canyon Lakes record.

Sample #	Depth (cm)	Cal Age BP	*Pinus*	*Juglans*	cf *Sequoia*	*Juniperus*/ TCT	*Quercus*	*Salix*	*Acer*	*Alnus*	*Cercocarpus*	*Artemisia*	Asteraceae	*Ambrosia*-type	Liguliflorae	Chenopodiaceae	Poaceae
1	463.5	10660	2		1								55	1			2
2	469.5	10690	3			1				1			31	2		2	7
3	500.5	10856	0			1							6				
4	513.1	10914	0										16				1
5	522.5	10954	1										54	1			5
6	531.5	10989	2			4			1			1	35				2
7	540.5	11022	1									1	64			1	5
8	555.5	11071	0								1		61				2
9	581.5	11146	1			1						1	58			2	
10	608.5	11208	0								1	1	8				
11	617.5	11228	0								1		7				
12	629.5	11248	4			1					1	2	59	1	1	3	1
13	640.5	11265	1							1			41		1		2
14	651.5	11283	0										5				
15	661.5	11299	0				1						3				
16	666.5	11305	0			1							4				
17	676.5	11319	0										2			3	
18	688.5	11334	1	1									69			2	3
19	696.5	11344	0										5				1
20	703.5	11356	1														
21	712.5	11365	1			1		1					78				
22	722.5	11378	0									1	4			1	2
23	731.5	11389	0				1						12				
24	737.5	11396	0										11	1			
25	758.5	11427	0									1	10				
26	770.5	11445	0										8				1
27	775.5	11451	0										5				
28	792.5	11480	0										9				
29	803.5	11504	1										10				
30	814.5	11527	0										2				1
31	835.5	11577	0										3				3
32	845.5	11602	0										17				1
33	857.5	11639	0										9				1
34	898.3	11785	0										10				2
35	879.5	11712	0										4				
36	899.5	11790	0										3				1
37	909.5	11841	0										6				
38	920.5	11892	1										7				1
39	944.5	12022	0										10				3
40	960.5	12117	0										1				
41	970.5	12188	0										0				
42	980.5	12257	0										3				
43	991.5	12341	0										0				
44	1000.5	12416	0										8				
45	1012.5	12520	0										6	1			

Table 5a. Raw counts of pollen and spores from the Laguna Canyon Lakes record (continued).

Sample #	Eriogonum	Ribes	Ephedra viridis	Sphaeralcea	Proboscidea	Polemoniaceae	Caryophyllaceae	Symphoricarpos	Polygonaceae	cf Troanis	Saxifragaceae	Onagraceae	Undeterminable
1	2						1						9
2	1				1							1	27
3												1	7
4													6
5					2						1	1	18
6	1	1										1	23
7	2				1	1							16
8	1				1				1				13
9	4				1								25
10													1
11	1												9
12	1												27
13	2												11
14													2
15													0
16													2
17													2
18	1	1			1				1				14
19													0
20													3
21	2			1									15
22													1
23													4
24													3
25													3
26													1
27													7
28													0
29													4
30													1
31										1			1
32													3
33													9
34	1												2
35													0
36													1
37	1												1
38	1												1
39													0
40					2								2
41					2								0
42													0
43													0
44													0
45								1					2

Table 5a. Raw counts of pollen and spores from the Laguna Canyon Lakes record (continued).

Sample #	Cyperaceae	Potemogeton	Lemna	Typha monad	Polygonum persicaria	Ranunculus	Monolete Spore	Botrychium	Trilete Spore	Lycopodium Tracers
1	24			3			1		2	5
2	28								11	11
3	1								2	6
4	5									5
5	16	2		3		1	1		1	2
6	34	3	4	2			1		1	10
7	45				2		2		8	13
8	16		1					1	2	7
9	10			1	1					9
10	1			1						5
11	0									2
12	11		1						3	2
13	4								2	5
14	1									1
15	1									0
16	0									1
17	1									3
18	9			1					1	72
19	2									5
20	0									6
21	4						1		8	21
22	0								1	4
23	1									9
24	5									21
25	0									10
26	0									14
27	5									6
28	0									1
29	1								1	5
30	0								1	23
31	0									2
32	7								1	1
33	0									7
34	3									6
35	0									1
36	0									14
37	0									52
38	0									14
39	1		1						1	24
40	0								1	2
41	0									2
42	0									4
43	0									1
44	3									3
45	0								1	11

Table 5b. Relative Percentages of pollen and spores from the Laguna Canyon Lakes record.

Sample #	Depth (cm)	Estimated Radiocarbon Age	Total Pinus	Juglans	cf Sequoia	Juniperus/TCT	Quercus	Salix	Acer	Alnus	Cercocarpus	Artemisia	Asteraceae	Ambrosia-type
1	463.5	10660	1.84%	0.00%	1.38%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	76.04%	1.38%
2	469.5	10693	3.90%	0.00%	0.00%	1.30%	0.00%	0.00%	0.00%	1.30%	0.00%	0.00%	40.26%	2.60%
3	500.5	10844	0.00%	0.00%	0.00%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	0.00%
4	510.5	10901	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	69.57%	0.00%
5	522.5	10937	1.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	65.06%	1.20%
6	531.5	10972	1.90%	0.00%	0.00%	5.69%	0.00%	0.00%	1.42%	0.00%	0.00%	1.42%	49.76%	0.00%
7	540.5	11000	1.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.09%	69.57%	0.00%
8	555.5	11052	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.25%	0.00%	76.25%	0.00%
9	581.5	11127	1.08%	0.00%	0.00%	1.08%	0.00%	0.00%	0.00%	0.00%	0.00%	1.08%	62.37%	0.00%
10	608.5	11189	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.09%	9.09%	72.73%	0.00%
11	617.5	11205	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.56%	0.00%	38.89%	0.00%
12	629.5	11232	3.64%	0.00%	0.00%	0.99%	0.00%	0.00%	0.00%	0.00%	0.99%	1.99%	58.61%	0.99%
13	640.5	11253	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.69%	0.00%	0.00%	69.49%	0.00%
14	651.5	11272	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	71.43%	0.00%
15	661.5	11290	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%
16	666.5	11300	0.00%	0.00%	0.00%	14.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	57.14%	0.00%
17	676.5	11315	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.57%	0.00%
18	688.5	11334	1.06%	1.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	73.40%	0.00%
19	696.5	11344	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	83.33%	0.00%
20	703.5	11356	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	712.5	11369	1.01%	0.00%	0.00%	1.01%	0.00%	1.01%	0.00%	0.00%	0.00%	0.00%	78.79%	0.00%
22	722.5	11385	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%	44.44%	0.00%
23	731.5	11398	0.00%	0.00%	0.00%	0.00%	5.88%	0.00%	0.00%	0.00%	0.00%	0.00%	70.59%	0.00%
24	737.5	11408	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	73.33%	6.67%
25	758.5	11443	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.14%	71.43%	0.00%
26	770.5	11466	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	80.00%	0.00%
27	775.5	11473	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	41.67%	0.00%
28	792.5	11507	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
29	803.5	11532	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%
30	814.5	11555	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	0.00%
31	835.5	11613	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	37.50%	0.00%
32	845.5	11637	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	80.95%	0.00%
33	857.5	11677	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	47.37%	0.00%
34	868.5	11828	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%
35	879.5	11749	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
36	899.5	11828	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	60.00%	0.00%
37	909.5	11873	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%
38	920.5	11927	9.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	63.64%	0.00%
39	944.5	12051	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	76.92%	0.00%
40	960.5	12146	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%
41	970.5	12210	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
42	980.5	12276	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
43	991.5	12361	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
44	1000.5	12425	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
45	1012.5	12771	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	60.00%	10.00%

Table 5b. Relative Percentages of pollen and spores from the Laguna Canyon Lakes record (continued).

Sample #	Liguliflorae	Chenopod.	Poaceae	Eriogonum	Ribes	Sphaeralcea	Proboscidea	Polemoniaceae	Caryophyllaceae	Symphoricarpos	Polygonaceae	Troanis	Saxifragaceae	Onagraceae	Undeterminable
1	0.00%	0.00%	2.76%	2.76%	0.00%	0.00%	0.00%	0.00%	1.38%	0.00%	0.00%	0.00%	0.00%	0.00%	12.44%
2	0.00%	2.60%	9.09%	1.30%	0.00%	0.00%	1.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.30%	35.06%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.67%	46.67%
4	0.00%	0.00%	4.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.09%
5	0.00%	0.00%	6.02%	0.00%	0.00%	0.00%	2.41%	0.00%	0.00%	0.00%	0.00%	0.00%	1.20%	1.20%	21.69%
6	0.00%	0.00%	2.84%	1.42%	1.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.42%	32.70%
7	0.00%	1.09%	5.43%	2.17%	0.00%	0.00%	1.09%	1.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	17.39%
8	0.00%	0.00%	2.50%	1.25%	0.00%	0.00%	1.25%	0.00%	0.00%	0.00%	1.25%	0.00%	0.00%	0.00%	16.25%
9	0.00%	2.15%	0.00%	4.30%	0.00%	0.00%	1.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.88%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.09%
11	0.00%	0.00%	0.00%	5.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%
12	0.99%	2.98%	0.99%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.82%
13	1.69%	0.00%	3.39%	3.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.64%
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.57%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.57%
17	0.00%	42.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	28.57%
18	0.00%	2.13%	3.19%	1.06%	1.06%	0.00%	1.06%	0.00%	0.00%	0.00%	1.06%	0.00%	0.00%	0.00%	14.89%
19	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	90.00%
21	0.00%	0.00%	0.00%	2.02%	0.00%	1.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.15%
22	0.00%	11.11%	22.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	23.53%
24	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%
25	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	21.43%
26	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%
27	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	58.33%
28	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
29	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	26.67%
30	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%
31	0.00%	0.00%	37.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%	0.00%	0.00%	12.50%
32	0.00%	0.00%	4.76%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.29%
33	0.00%	0.00%	5.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	47.37%
34	0.00%	0.00%	13.33%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.33%
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
36	0.00%	0.00%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%
37	0.00%	0.00%	0.00%	12.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%
38	0.00%	0.00%	9.09%	9.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.09%
39	0.00%	0.00%	23.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%
41	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
42	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
43	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
44	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
45	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%	20.00%

Table 5b. Relative Percentages of pollen and spores from the Laguna Canyon Lakes record (continued).

Sample #	Cyperaceae	Potemogeton	Lemna	Typha monad	Polygonum persicaria/lapathifolium	Ranunculus	Monolete Spore	Botrychium	Trilete Spore
1	24.16%	0.00%	0.00%	3.02%	0.00%	0.00%	33.33%	0.00%	2.01%
2	26.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.48%
3	6.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%
4	17.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	15.24%	1.90%	0.00%	2.86%	0.00%	0.95%	50.00%	0.00%	0.95%
6	30.00%	2.65%	3.53%	1.76%	0.00%	0.00%	50.00%	0.00%	0.88%
7	32.37%	0.00%	0.00%	0.00%	1.44%	0.00%	20.00%	0.00%	5.76%
8	16.49%	0.00%	1.03%	0.00%	0.00%	0.00%	0.00%	33.33%	2.06%
9	9.52%	0.00%	0.00%	0.95%	0.95%	0.00%	0.00%	0.00%	0.00%
10	7.69%	0.00%	0.00%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%
11	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	9.76%	0.00%	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%	2.66%
13	6.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.17%
14	12.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17	12.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
18	8.65%	0.00%	0.00%	0.96%	0.00%	0.00%	0.00%	0.00%	0.96%
19	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	3.88%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	7.77%
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%
23	5.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
24	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
25	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
26	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
27	29.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
28	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
29	6.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.25%
30	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%
31	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
32	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.57%
33	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
34	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
36	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
37	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
38	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
39	6.67%	0.00%	6.67%	0.00%	0.00%	0.00%	0.00%	0.00%	6.67%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%
41	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
42	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
43	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
44	27.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
45	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%

Table 6. Radiocarbon dating results

Sample #	Beta #	Measured Radiocarbon Age	1 sigma	13C/12C Ratio	Conventional Radiocarbon Age	1 sigma	Material	Cal BP Range 1		Cal BP Range 2		Cal BP Range 3	
12-ORA-133-1	Beta - 242651	9480	50	-24.4	9470	50	Organic Sediment	11060	11020	11010	10960	10800	10580
12-ORA-133-2	Beta - 242652	9700	40	-25.9	9690	40	Organic Sediment	11210	11080	10930	10880		
12-ORA-133-3	Beta - 242653	9620	40	-26.9	9600	40	Organic Sediment	11160	10750				
12-ORA-133-4	Beta - 242654	126.1	0.3	-24.3	125.9	0.3	Wood						
12-ORA-133-5	Beta - 242655	9760	40	-26.1	9740	40	Organic Sediment	11230	11130				
12-ORA-133-6	Beta - 242656	10200	40	-25.5	10190	40	Organic Sediment	12070	11750				
12-ORA-133-7	Beta - 242657	10180	40	-26.3	10160	40	Organic Sediment	12040	11700	11670	11640		
12-ORA-133-8	Beta - 242658	10670	40	-25.9	10660	40	Organic Sediment	12820	12640				

Table 7. Depth of samples examined by Scott Starratt for diatoms.

Core RW06-1
469 - 470 cm
500 - 501 cm
531 - 532 cm
581 - 582 cm
608 - 609 cm
629 - 630 cm
661 - 662 cm
666 -667 cm
688 - 689 cm
703 - 704 cm
731 - 732 cm
770 - 771 cm
792 - 793 cm
803 - 804 cm
920 - 921 cm
970 - 971 cm
991 - 992 cm
1012 - 1013 cm

Figure 1. Vegetation transect from the coast in the west through San Juan Capistrano on the east. Vegetation transect was taken during the late 1930s.
2 GR = Grasslands dominated by mixed native grasses and associated low herbaceous plants.
3 Res = residential
3 Cu = cultivated
4 Ac = Artemisia californica
4 Ac Sa = Artemisia californica, Salvia apiana
4 Sm Ac Rl = Salvia mellifera, Artemisia californica, Rhus laurina
4 Sa Ac = Salvia apiana, Artemisia californica
12 A = Populus tremuloides

Figure 2. Relative Percentage Pollen Diagram of the pollen recovered from core RW06-1.

Figure 3. The statistically estimated percentage of Aster- type pollen grains in each sample with 95% confidence intervals based upon Maher's formula.

Figure 4. This is the statistically estimated number of Aster-type pollen in each sample with 95% confidence intervals based upon Maher's formula.

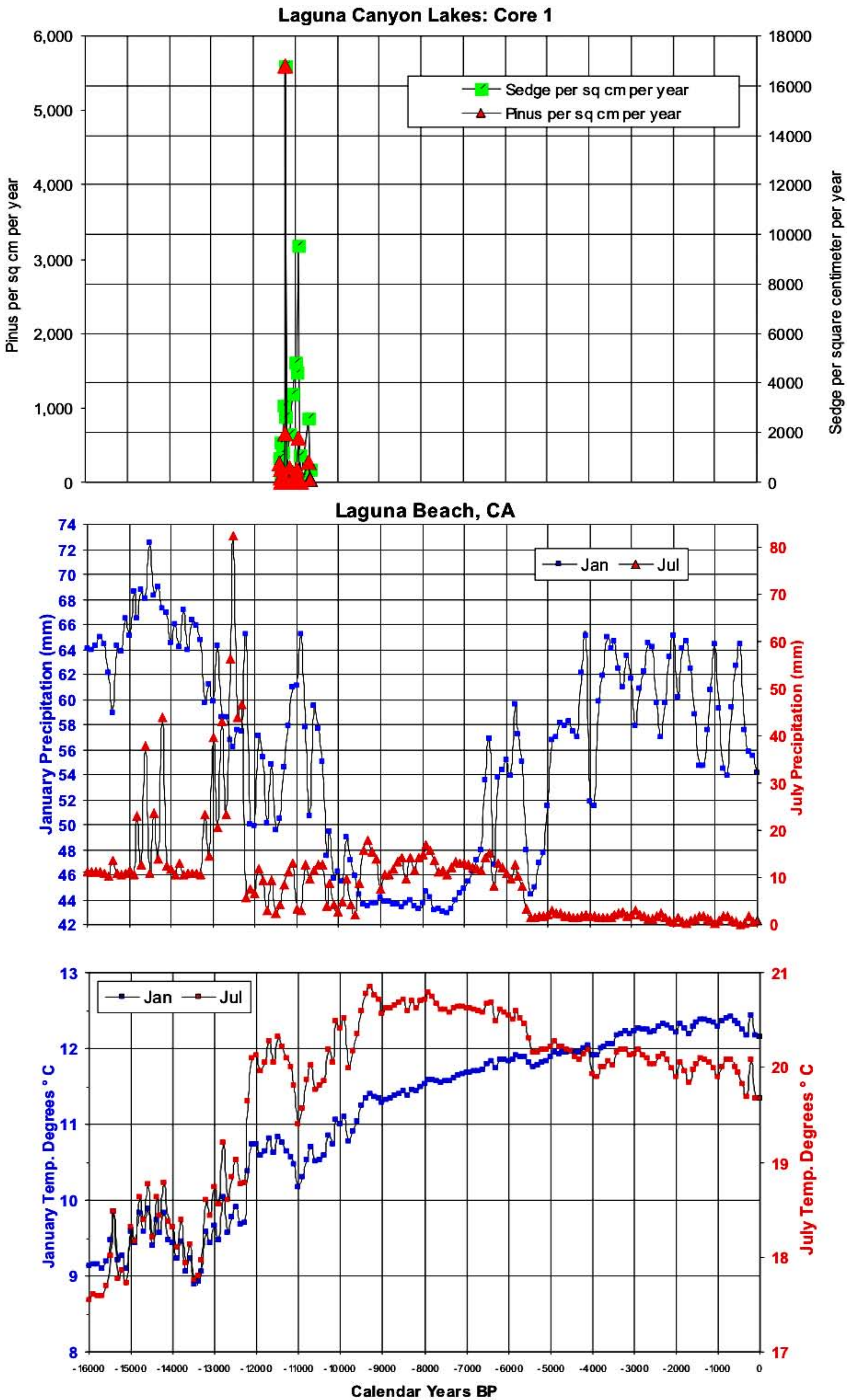
Figure 5. This is the statistically estimated pollen population of each sample with 95% confidence intervals based upon Maher's formula.

Figure 6. This is the statistically estimated pollen population per cc of each sample with 95% confidence intervals based upon Maher's formula.

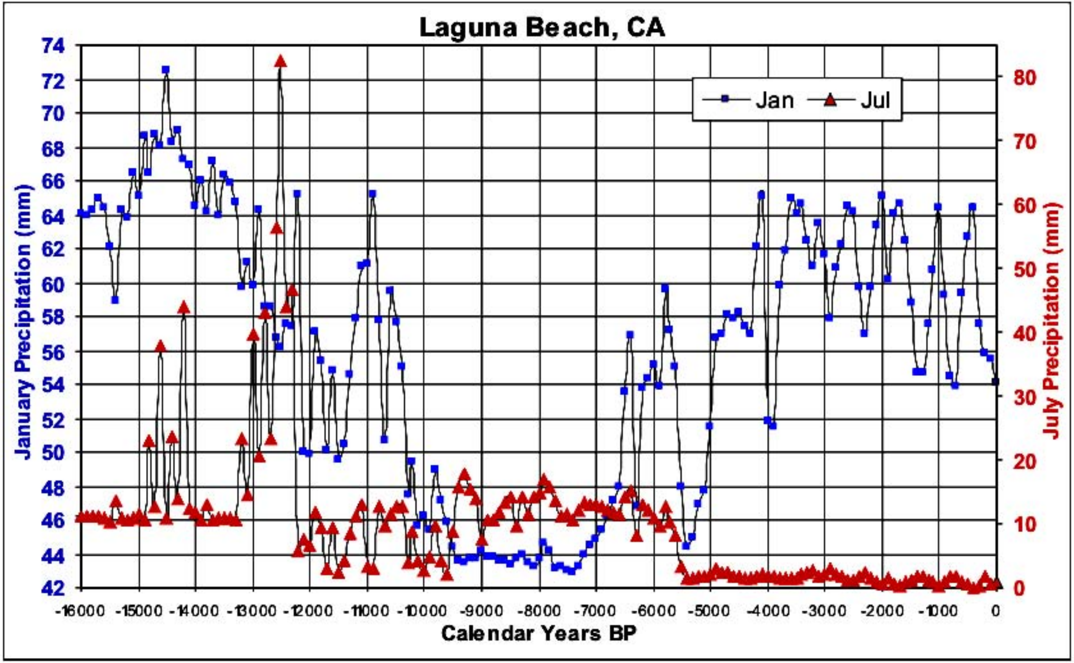
Figure 7. The statistically estimated percentage of sedge pollen grains in each sample with 95% confidence intervals based upon Maher's formula.

Figure 8. Reconstructed precipitation values for January and July for the last 16,000 years using the Bryson MCM physical climate model.

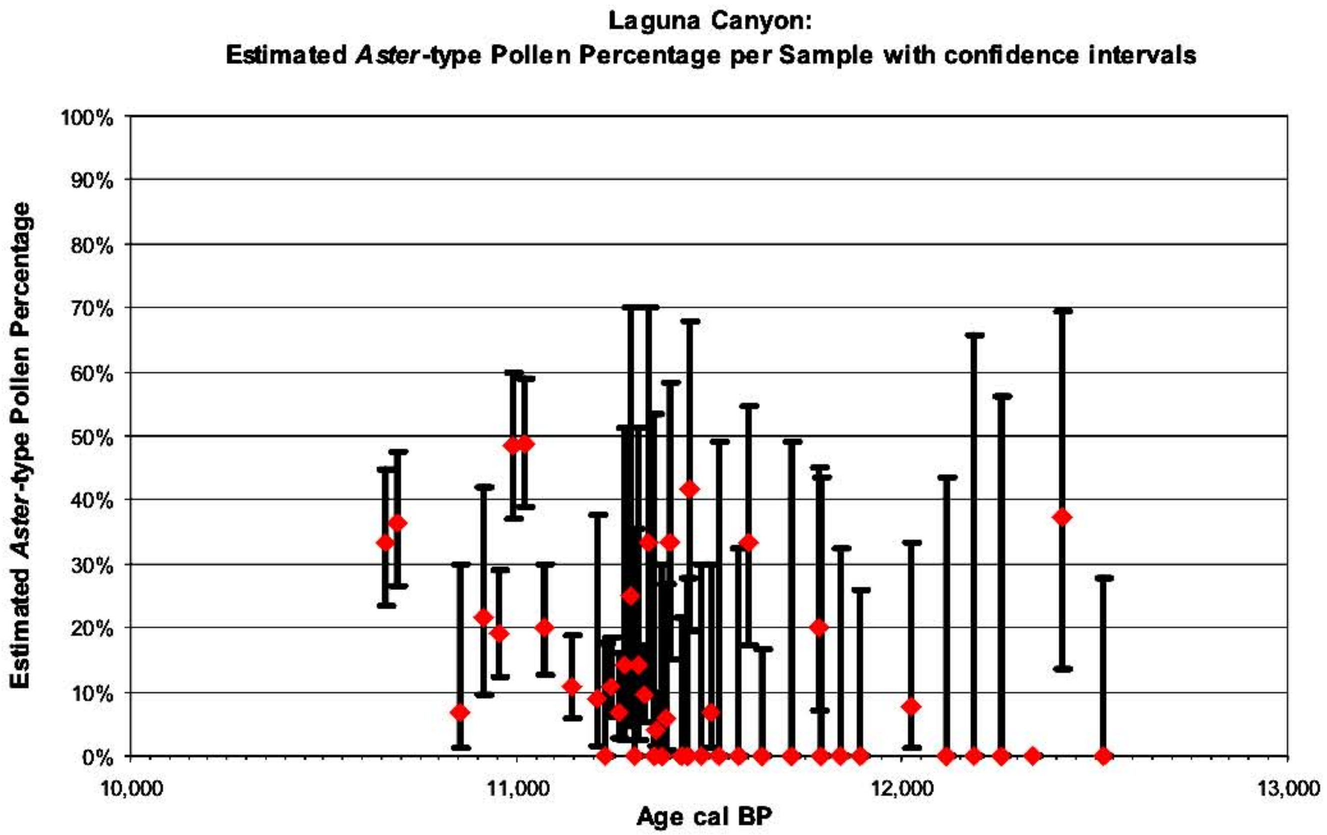
Figure 9. Comparison of the sedge pollen per square centimeter per year values and the pine per square centimeter per year values with the MCM model generated precipitation and temperature trends for the last 16,000 cal years. Sedge values are greatest in the upper portion of the record. The pine values are too small to be reliable, but they seem to follow the sedge values as well. The period of increased Sedge and pine values (and pollen preservation as well) occurs during the modeled period of both increased precipitation and decreased temperature. The lower portion of the pollen record when preservation is poor, corresponds to a period of lower winter precipitation and higher temperatures. These are conditions that could dramatically reduce pollen preservation.

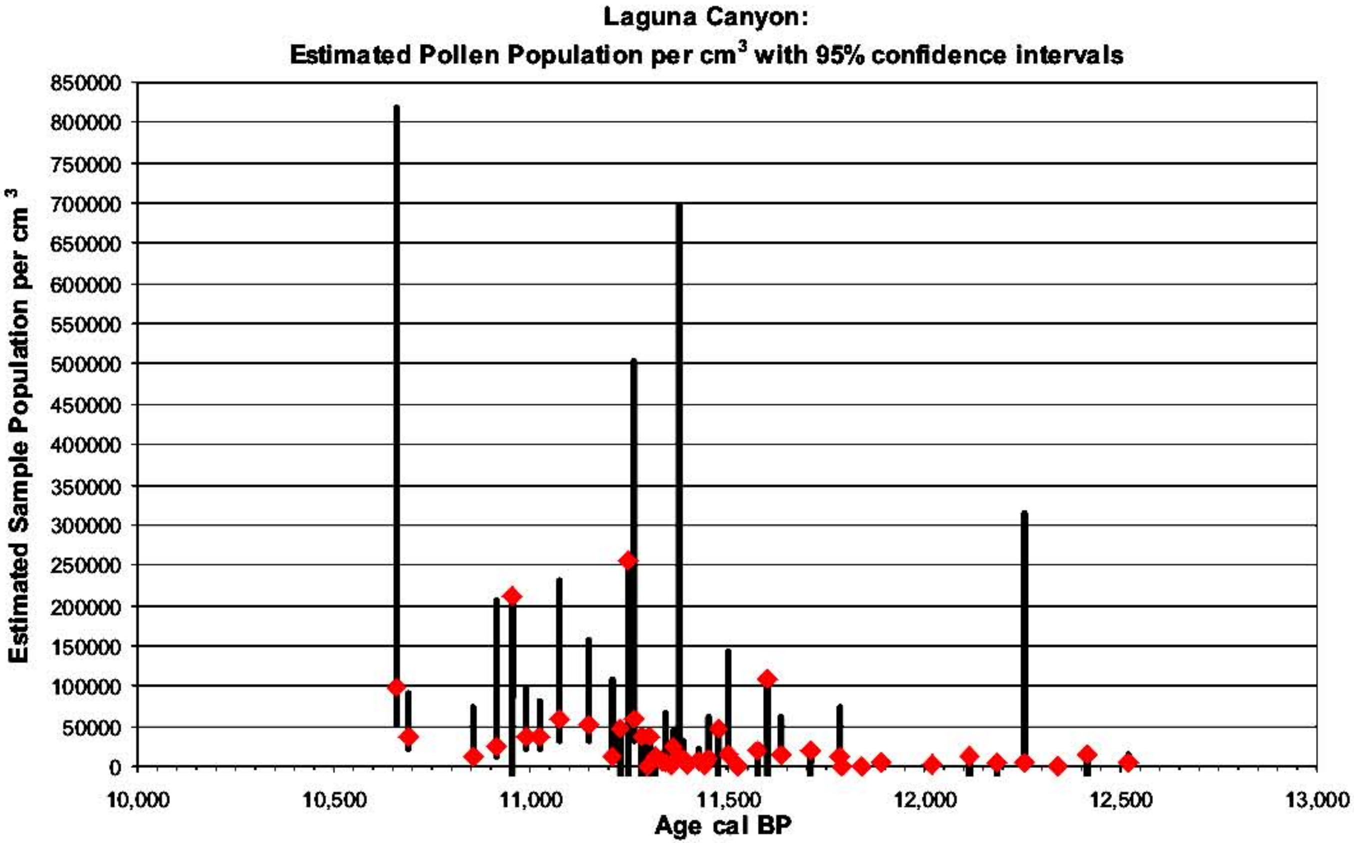


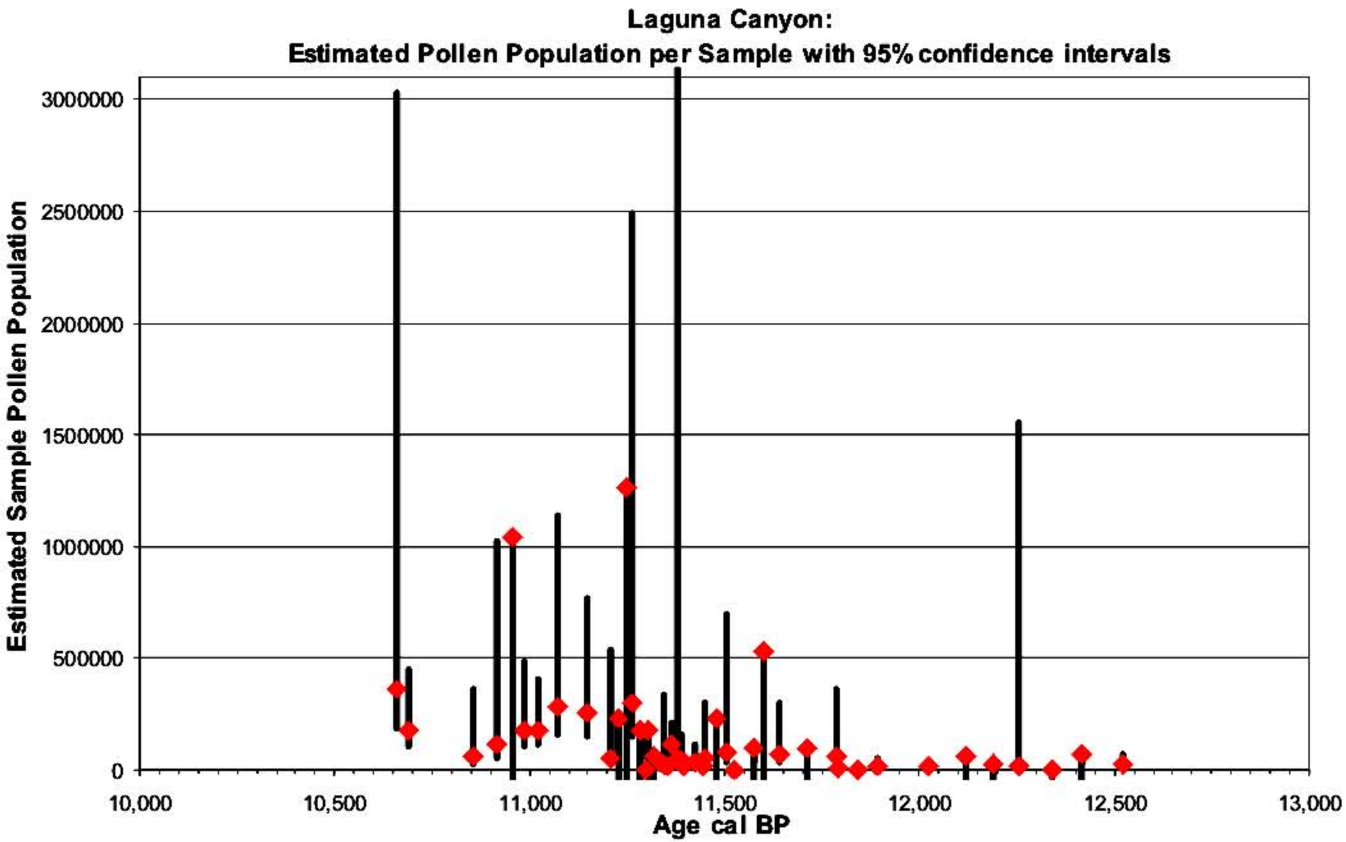
Laguna Canyon Lakes: Core 1
Sedge per sq cm per year
Pinus per sq cm per year
Pinus per sq cm per year
Sedge per square centimeter per year
Laguna Beach, CA
Jan
Jul
January Precipitation (mm)
July Precipitation (mm)
Jan
Jul
January Temp. Degrees ° C
July Temp. Degrees ° C
Calendar Years BP



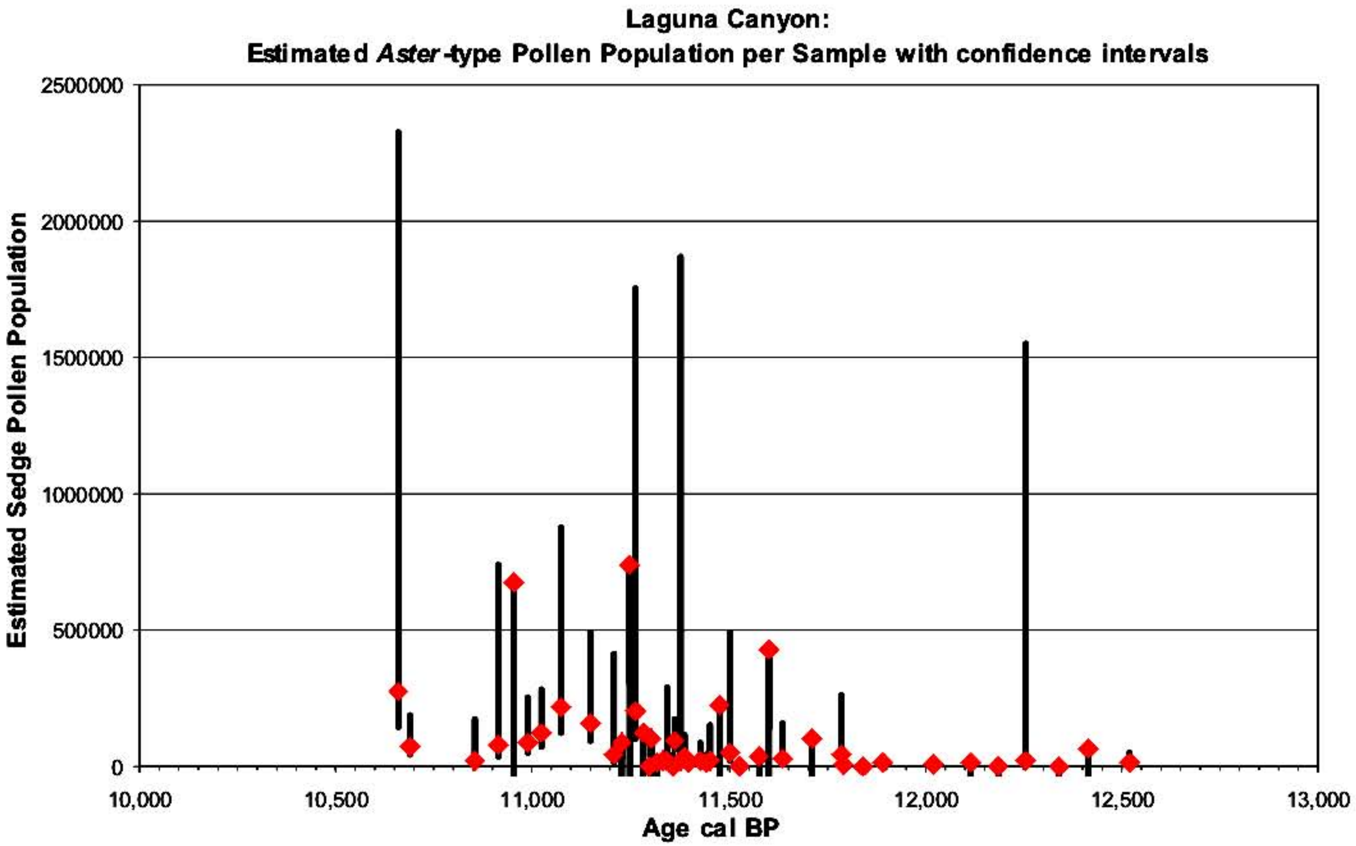
Laguna Beach, CA
Jan
Jul
January Precipitation (mm)
July Precipitation (mm)
Calendar Years BP
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
80
70
60
50
40
30
20
10
0
-16000
-15000
-14000
-13000
-12000
-11000
-10000
-9000
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0

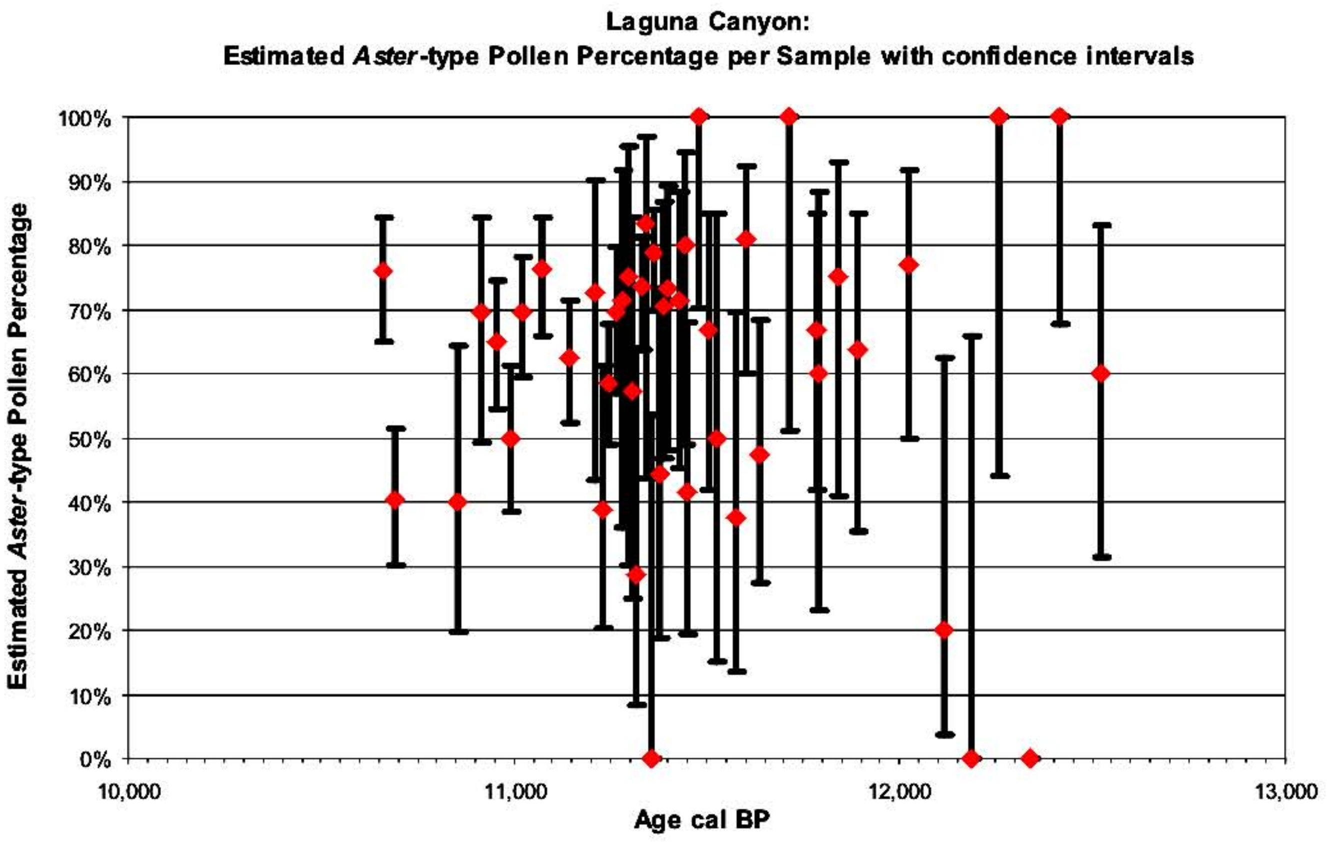

Laguna Canyon:
Estimated *Aster*-type Pollen Percentage per Sample with confidence intervals
Estimated *Aster*-type Pollen Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10,000
11,000
12,000
13,000
Age cal BP


Laguna Canyon:
Estimated Pollen Population per cm3 with 95% confidence intervals
Estimated Sample Population per cm 3
850000
800000
750000
700000
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
10,000
10,500
11,000
11,500
12,000
12,500
13,000
Age cal BP



Laguna Canyon:
Estimated Pollen Population per Sample with 95% confidence intervals
Estimated Sample Pollen Population
3000000
2500000
2000000
1500000
1000000
500000
0
10,000
10,500
11,000
11,500
12,000
12,500
13,000
Age cal BP

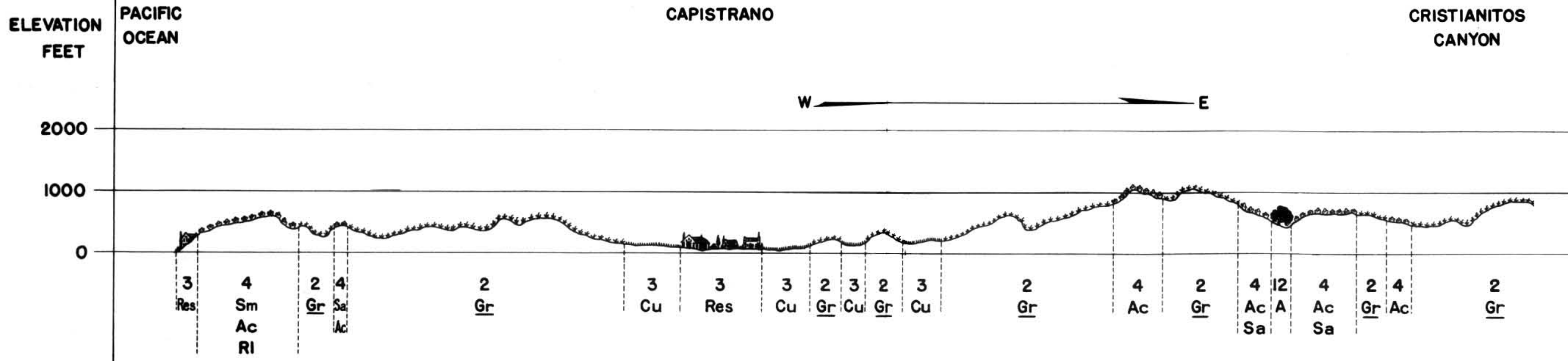

Laguna Canyon:
Estimated *Aster*-type Pollen Population per Sample with confidence intervals
2500000
2000000
1500000
1000000
500000
0
Estimated Sedge Pollen Population
10,000
10,500
11,000
11,500
12,000
12,500
13,000
Age cal BP


Laguna Canyon:
Estimated Aster-type Pollen Percentage per Sample with confidence intervals
Estimated Aster-type Pollen Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10,000
11,000
12,000
13,000
Age cal BP

LAGUNA CANYON, CALIFORNIA, CORE RW06-1

Relative Percentage Pollen Diagram of Major Pollen Types

Percentages based upon pollen sum


ELEVATION FEET
2000
1000
0
PACIFIC OCEAN
CAPISTRANO
CRISTIANITOS CANYON
W
E
3 Res
4 Sm Ac Rl
2 Gr
4 Sa Ac
2 Gr
3 Cu
3 Res
3 Cu
2 Gr
3 Cu
2 Gr
3 Cu
2 Gr
4 Ac
2 Gr
4 Ac Sa
12 A
4 Ac Sa
2 Gr
4 Ac
2 Gr