REPORT ON SOIL ANALYSES, UNKAR DELTA
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SCHOOL OF AMERICAN RESEARCH

Report to: Dr. Douglas Schwartz
From: Peter S. Bennett, K.V.L. Laboratory
Subject: Analysis of samples from Unkar Delta, Grand Canyon, Arizona.

In accordance with your instructions, we have completed work on the thirty-three samples submitted to the laboratory for testing. The following constitutes our final report.

Introduction

The samples from Unkar have been subjected to a variety of tests in order to determine 1) the past environment, 2) the relationship of the past environment to the present, 3) the relative and absolute chronology of some of the Unkar sites, and 4) the feasibility and extent of agriculture in this portion of Grand Canyon.

An understanding of the inherent problems of pollen analysis is necessary for proper interpretation of pollen results. Pollen analysis is still a young and very much developing science. The potential for error existing in our present subjective method for quantitative vegetational interpretation becomes obvious when pollen analysis theory is considered. The assumption basic to the pollen analysis method is that under normal circumstances, the amount of a given type of pollen deposited per unit time at a given point is directly related to the (RELATIVE ?) abundance of the corresponding species in the surrounding vegetation. If this assumption is acceptable, it should be possible to make a statement about the abundances of the plant species in a locality from the pollen deposited in sediments subjected to analysis. Unfortunately, no one has yet been able to define 'normal circumstances' or exactly what is meant by 'directly related'. The pollen rain at any given point is subject to a bewildering number of variables. These include, in part: 1) the efficiency of the particular species under consideration as a pollen producer, 2) the efficiency of the dispersal of this pollen, 3) the direction and velocity of the prevailing winds, and even 4) the relative elevations between the pollen producers and the sampling point. These factors introduce various degrees of error between the observed pollen frequencies and the observed vegetation in a given locality. A great deal of research will be required in the future to transform these uncertainties into mathematical relationships. At the present time, the pollen analyst must rely heavily on his background to reduce these variables to a workable body of knowledge.

Some of these difficulties may be partially circumvented by comparing the present and past pollen spectra against the present and the presumed past vegetation. The basic assumption here is that the physical factors in the environment controlling pollen dispersal have remained unchanged, often over a period of hundreds of years. This has been proven to be basically untenable in many cases.

If the analyst wishes to go a step further and reconstruct the environment, even more uncertainties are introduced. Since the presumed past vegetation is used to reconstruct this environment, an understanding of vegetational change in relation to environmental change is also assumed. These relationships, at the present, are only poorly understood.

"Much work remains to be done to refine the method. For example, Chenopodiaceae pollen is frequently used by workers in analysis for indications of ecological flux or site deterioration. These counts are used either alone or involved in various ratios. However, there has as yet been no extensive or thorough investigation over long periods of time to verify the presumed indicator value of these plants. Salsola pestifer (Russian thistle) is an indicator of disturbed conditions, true; Chenopodium incisum, C. capitatum and C. fremontii are not indicators of such conditions... Obviously we must start somewhere, but an attitude of 'wait and see' should prevail until considerable research supports some of the long proposed hypotheses and elevates them to theories." (Bennett, 1967)

Environment, Past and Present

Pollen analysis has been the principal tool used for environmental reconstruction. All of the pollen material submitted was processed by the heavy liquid flotation method in general use at this laboratory. The adjusted pollen sum was employed in the analysis, as this has proved to be most useful in the interpretation of Southwestern vegetation patterns by many workers in the field.

Because of the rigors of the present environment in the Unkar area, coupled with a lack of habitat diversity, the number of plant species is severely limited, following well established ecological principles. Plants are basically of two types: phreatophytes and xerophytes. Both respond to the same climatic conditions; the former by developing deep root systems to reach the water below, even in the driest weather, and the latter by conservation of water. Water becomes a critical factor because of the very high evapo-transpiration rates dictated by a very hot, dry climate.

The dominant plants encountered on the Unkar Delta are cacti (Opuntia sp.), Mesquite (Prosopis juliflora), grasses, and a small assortment of annual flowering plants.

Except for importation from the nearby canyon walls and rim, the pollen spectra are quite simple. However, this simplicity is complicated by the importation of pollen, both by wind and to a lesser extent by water, from nearby complex vegetation zones. This imported pollen does not cause difficulty in environmental reconstruction since all communities in the area presumably have responded to past changes in environment. But it must be made clear that the occurrence of pollen of the Fagaceae, Betulaceae, or Juglandaceae does not imply that these plants ever grew or ever will grow in this area at the bottom of the canyon. The relative abundance or paucity of this pollen does indicate fluctuations in the climate in the places where they grow and presumably also in the canyon bottom.

Studies conducted here at the laboratory and by Martin (1962) and Schoenwetter (1964) show that the development of major structural vegetational units can be differentiated in the Southwest by the use of arboreal pollen (AP) percentages when adjusted pollen sums are used. Since all arboreal pollen is imported into the area around Unkar Delta, suitable correction factors must be applied. This wind-borne pollen comes from a strip between Grandview Point and the old Hance Ranch and from points to the southwest and northeast along the axis of the prevailing wind. Near the canyon rim the vegetation is predominantly mixed coniferous woodland, yielding AP values of 90% or more. Western yellow pine (Pinus ponderosa) accounts for 50%, Two-needle pinyon pine (Pinus edulis) about 20%, Utah juniper (Juniperus utahensis) 10%, and Oaks (Quercus gambelii and Q. turbinella) 10%. Further to the southwest, this stately forest type is gradually replaced by pinyon pine and juniper with increasing amounts of understory species such as artemisia. This same replacement is observed to the northeast. Near Three Castles and Coronado Butte, pinyon-juniper woodland is the dominant vegetation and accounts for much of the pollen of these types found at Unkar. Because the AP is carried a minimum distance of four miles before being deposited at Unkar, the percentages are much reduced and undergo some differentiation. Juniper pollen, a heavy wingless type, drops out of the wind currents much faster than the winged pine pollen and is probably under represented, as are the oaks. However, the pinyon-juniper stands within the canyon are closer to Unkar and are over represented in proportion to their abundance in the modern pollen rain. Ponderosa pollen is found to have dropped from 50% to 1.2 - 14.5%. Pinyon-juniper frequencies have dropped from about 70% near Three Castles to 8.9 - 17.4% at sampling points on Unkar Delta. Therefore, AP frequencies in relation to themselves and to the non-arboreal pollen (NAP) represent climatic conditions at places considerably removed from the Unkar Delta. We must assume that the vegetation in the bottom of the canyon has responded to changing climatic conditions in direct proportion to that on the rim and walls, although this direct relationship has by no means been demonstrated. This is a basic theorem widely used in pollen analysis and is generally true in places of less dramatic topography; it may not apply literally to Grand Canyon however.

When the AP of the ancient pollen rain is compared to the modern, through the AP/NAP ratio, we find that in modern times the AP has increased considerably (by more than 0.100). In the past, such shifts have been thought to indicate cooler and probably moister climate. Probably a more reliable factor would be the ratio between the pollen from the cool-wet species, such as ponderosa pine, and the adjacent drier communities like the pinyon-juniper woodland. The Unkar pollen rain shows such a shift between the time of occupation and the present: in other words, the cool-wet species have expanded their coverage and/or density on the canyon's rim and probably in its interior also. Therefore less total precipitation during occupation is a distinct possibility. Even more important than total precipitation in the Southwest is the distribution of precipitation. Rainfall in the Grand Canyon area may occur as light but steady showers, falling as the result of the movement of storm fronts, or from violent convection storms. The former is typically a winter phenomenon while the latter is most prevalent in the summer. These summer thunderstorms may locally drop great quantities of rain in a very short period. It usually runs off quickly and little is absorbed. The winter rains tend to soak the earth to a much greater depth and are more useful to plants. The growth of shallow-rooted species is favored by summer rainfall more than that of the deeper rooted arboreal and other perennial plants. The pollen spectra of the Gramineae (comprising usually shallow-rooted species) shows such a rise in frequency just before Unkar occupation, at the expense of the arboreal and woody perennial species. Such conditions are known to have existed throughout the Southwest from about 1100 to 1300 A.D. Recently there has been some speculation that our climate is returning to this summer rainfall regimen (Antevs, 1955; Bryan and Albritton, 1943). The recent pollen record from the Desert View and Unkar areas fails to support this as yet.

Although the record from the Unkar area shows that during occupation a cycle of vegetational change was taking place, the casual observer would have seen the canyon bottom much as it appears today. The plants growing there are well adapted to the climate and would not be greatly affected even by long periods when rainfall was as much as 50% below normal. The shift from a summer to winter rainfall could, however, have profound effects on primitive agriculture.

A few words about the ecological responses of the principal taxa in the Unkar area would not be out of place here and should make interpretation of the pollen diagrams easier for the reader. Ponderosa or western yellow pine (Pinus ponderosa) is found on moist and dry slopes above 6,500 feet. It grows well in all soils from glacial debris and volcanic ash to stiff clay, but dry and sandy soils are preferred. Growth in the Grand Canyon area is somewhat inhibited by low moisture and very shallow soil. After maturity, the trees demand plenty of light and usually grow in well spaced stands. The ponderosa pine, in common with all pines, is a prolific pollen producer. The pollen can be carried great distances and pine pollen is commonly encountered in the ice at the South Pole. Such pollen would have had to be carried a minimum of 6,000 miles. The species is moderately long lived, mature trees being 300 to 500 years in age. Once well established, a stand of this species will 'hang on' tenaciously in spite of adverse climatic conditions.

Two-needle pinyon pine (Pinus edulis) is best developed on dry soils where it becomes a dominant species. It is found throughout the region at altitudes of 6,000 to 8,000 feet. In the Unkar area, pinyon rarely occurs in pure stands. It is mixed with juniper at its lower altitudinal range, and at the upper with ponderosa pine. Large 'parks' of Artemisia, Cowania, and similar plants are encountered. This species thrives in dry, hot climates where high evapo-transpiration takes place. Although typically slow growing, it thrives with as little as five inches of precipitation in the upper portions of the altitudinal range. The pinyon pine is intolerant of shade and normally grows in very open stands. This species does not typically reach great age, adults being generally between 100 and 200 years old. For this reason, the two-needle pinyon pine is a better climatic indicator than many other trees of the area.

Utah juniper (Juniperus utahensis) grows throughout the Colorado Plateau area at elevations of 5,000 to 8,000 feet. It is the most drought resistant arboreal species in the Grand Canyon region. Although J.utahensis grows well in deep moist soil, it is best able to compete in much drier conditions where other trees are unable to survive. Pure stands of this species are found where rainfall is about five inches and where summer temperatures are in excess of 115^{o} F. The Utah juniper commonly reaches ages in excess of 800 years and is therefore not a very sensitive climatic indicator.

Grasses are probably the most abundant species of desert plant. They are common, however, at all elevations within the canyon. Two types of grasses may be distinguished for the purpose of pollen analysis: those with oval and those with spherical pollen grains. Most of the cereal crops of the world belong to the group with spherical grains. The species found naturally at Grand Canyon belonging to this group are not edible, however. The oval-grained grasses are the most abundant type. Since Columbian times, many new species of grasses have been introduced into this area and their pollen is common in modern spectra. The distinction between the two types is ecologically artificial and is used as a tool only for relative dating.

The most common member of the rose family (Rosaceae) is black-brush (Coleogyne ramosissima). Although it is a perennial species, it is very irregular in its flowering: sparingly in dry years, prolifically in wet years. It occurs at elevations between 3,000 and 6,000 feet. Black-brush grows best in well-drained soils with about 11 to 15 inches of rainfall a year. There is a large black-brush community upwind of Unkar Delta below Zuni point and northeast of the Tabernacle. This community has, no doubt, contributed most of the Rosaceae pollen found in the samples.

The ecological role of the goosefoots and amaranths (Chenopodiaceae-Amaranthaceae, 'Cheno-Am')remains an enigma. Martin (1963) states that 'The ecology of cheno-ams is distinctive. They prefer fine alkaline soils of flood plains and disturbed ground.' Also, 'The cheno-ams increase and the compositae decline at a time when prehistoric farming was on the wane in the Southwest.' This latter statement fails to agree with the former, and the former is not universally true. These statements are representative of those made by many different workers in the field. In our opinion, the Cheno-Ams are more likely to respond to edaphic conditions rather than to ecological disturbance in the mechanical sense (e.g. farming, erosion, etc.). We believe that their indicator value should be limited to this in addition to the normal responses of a typical flowering plant.

Mormon tea (Ephedra sp.) is the most useful indicator for summer versus winter precipitation. In areas of summer rainfall, the torreyana type is predominate while in areas of winter rainfall the nevadensis type is most common. Ratios that compare these types show a significant rise in summer rainfall in the Grand Canyon region during the time period between 1100 and 1300 A.D.

The Compositae or sunflower family is the largest (154 genera in Arizona!), most advanced, and most complex family of flowering plants yet evolved. Because of their tremendous diversity, it is difficult to assign any ecological role to the group as a whole. Schoenwetter (1962 and 1964) and Martin (1963) feel that the Compositae probably indicate summer precipitation. Our opinion is that they may very well respond to these conditions in specified localities, but that this must be demonstrated for each locality and that generalities are likely to be misleading. In the Grand Canyon area, Artemisia tridentata, Erigeron, and Helianthus sp. are known to respond to this specific condition. Since these are far and away the most common pollen species in the Unkar sediments, we feel that this generalization will hold true in this case. The correlation with Gramineae and Ephedra bears out this conclusion.

Reconstruction of rainfall and temperature, even on a relative basis, is difficult to do with any degree of certainty. The only period represented in the Unkar samples about which an intelligent guess can be made is the period between 1100 and 1300 A.D. when summer rainfall was dominant. The only defensible method for such an estimation is in terms of the present climatic conditions. Since there is no way to estimate the effect of a different regimen on the existing vegetation, we can speak with authority only about times in the past that were not very different from the present. This is particularly true during times (800 to 1000 A.D. and 1300 to 1500 A.D.) when the Southwest generally had a winter rainfall pattern, and the present ecological forces were not in action. From 1100 to 1200 A.D., the weather cycle reversed itself to a pattern of summer rainfall. During this time period the total precipitation was about the same as it had been since before 1000 A.D. but the change in distribution during the year brought about several major changes in the vegetation and possibly in the erosional picture also. The plants that are better able to compete during a summer rainfall pattern (Gramineae, Chenopodium, the torrayana type Ephedra, and to a lesser degree the Compositae) show a marked increase in pollen frequency. Our guess is that the prehistoric peoples who lived in Grand Canyon found the summer rainfall advantageous, if they farmed in the manner of the present day Hopis. The moisture conditions would certainly be more favorable for summer crops and the increased humidity following rain would decrease evapo-transpiration, if only for a short period of time.

Pollen cannot be used to reconstruct the temperature picture here in the Southwest. Temperature does not directly influence plant growth except in extreme cases. It does effect the evapo-transpiration rate and the effective moisture values. Wind and solar radiation value changes can cause similar effects. In addition, the plants growing at Grand Canyon are presumably well adapted to this climate. Temperatures vary greatly during the growing season in the Southwest. The plants living here developed mechanisms long ago to deal with such variations. Therefore temperature may exert influence on the pollen spectra, but only in an indirect manner.

Dating: Chronometric and Relative Dates

Chronometric dates for Unkar Delta are based on two events that have been fixed in time at Grand Canyon. Unpublished results of palynological analyses of samples from Tusayan Ruin (Grand Canyon National Park) indicate that from about 1100 to 1300 A.D. the area experienced a reversal from a winter to a summer precipitation pattern. This effect is shown by the *Ephedra torrayana* type : *E. nevadensis* type ratios. (See Appendix) While *Ephedra* counts were not as high as we might wish, the results obtained by the use of this ratio correlate well with tree-ring dates obtained for the site by Haury and Gladwin and with dates published by Schoenwetter (MS, 1965) for the Flagstaff area.

Construction on Unkar Delta falls within the time period from 1100 ± 50 to 1250 ± 50 A.D. This period falls within the time of a summer rainfall pattern (1100 to 1300 A.D.) and near the end of the relatively treeless period that lasted from 1100 to about 1200 A.D.

Dating based solely on pollen analysis cannot be much more accurate than ±50 years. Precise dating requires sudden and sharp fluctuations in the pollen spectrum. Arboreal species generally used as site indices rarely produce pollen when they are less than 30 years of age. Thus, there is a minimum lag in the pollen record of 30 years following a sudden increase in indicator species density.

A sudden decrease is theoretically demonstrable. However, even this effect is probably often negated by the transport of pollen from adjacent sites unless the change is very widespread. Widespread vegetational effects are usually due to climatic fluctuations. Such fluctuations are most likely to effect germination and survival of seedlings rather than the mature plants. Most arboreal indicator species have a life expectancy well in excess of 100 years. Even fairly drastic climatic changes will for this reason be expressed only slowly by arboreal species. Because of the lag of, say, 30 years in the expression of increasing arboreal density and the lag of 100 years in decreasing density, sudden fluctuations are not common. Fluctuations in the arboreal counts are most likely due to major climatic trends.

Relative dates (see K.V.L. report submitted 6/16/67) are determined by comparing ratios of the frequencies of the pollen from various taxa against the same ratios from a standard chart. The best fit is determined for each pair. The relative position of each pair of taxa is treated to arrive at an average time value. Please see Appendix for results.

We want to emphasize again that the validity of this method of relative dating is predicated upon several factors: The first is that the samples of the standard column must cover short periods of time in relation to the total length of time under consideration. The second is that the material to be dated falls within the time period covered by the standard samples against which it is to be compared. We feel that the first requirement has been reasonably well met. The second is much more difficult to evaluate. Several samples will not date. Trouble is indicated when standard deviations are greater than 0.30. This may be due to problems with the time span of the standard samples.

Soils

In accordance with your instructions, six samples were subjected to soil analysis. The objective of these analyses was to evaluate several possible agricultural sites on the Delta. Some of the tests may be meaningless to the reader whose training is largely in the field of archaeology, hence a brief explanation follows:

Soil texture: The three inorganic components of soil (sand, silt, and clay) are expressed in percentages. The results are compared with a tri-coordinate chart and broad soil classifications are determined. Soils with high silt and sand content are capable of holding much less water than soils with high clay content. However, heavy clayey soils bind water much more tightly than the former and do not yield it readily to plants.

pH: The pH of a soil is a measure of its alkalinity or acidity. pH values below 7 are increasingly acid, those above are increasingly basic, viz.:

Extremely acid	below 4.5
Very strongly acid	4.5 - 5.0
Strongly acid	5.1 - 5.5
Medium acid	5.6 - 6.0
Slightly acid	6.1 - 6.5
Neutral	6.6 - 7.3
Mildly alkaline	7.4 - 7.8
Moderately alkaline	7.9 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	9.1 and higher

Improper pH values effect the growth of many plants.

Total dissolved solids (TDS): the amount of water soluble material in the soil expressed in parts per million (ppm). High TDS is harmful to some crops.

Potassium: The amount of potassium contained in the soil expressed in ppm's. Satisfactory levels of potassium are required for the proper formation of sugars and starches and their transfer from one portion of the plant to the other. They are also necessary for the formation of proteins and normal cell division. As a rule of thumb, about 50 ppm of potassium (expressed as K_2O)is needed for proper plant growth.

Phosphorous: The amount of phosphorous (expressed as P_2O_5) in soil. All of the phosphorous in the soil is not available for plant use at any given time. Considerable portions may be tied up in unusable compounds. Plants use phosphorous in metabolic enzyme formation and for energy transfer within the plant. Young plants or at least rapidly growing parts of plants need large amounts of phosphorous. For light farming, about 10 ppm phosphorous is adequate.

Nitrate: Nitrates form the principal source of nitrogen for plants. They are necessary for protein and enzyme formation. Nitrate levels ($NO_3^{=}$) of 50 ppm are satisfactory.

Organic carbon: Organic carbon is finely divided pieces of plant and animal matter as well the submicroscopic humic material in the soil. This is in contrast with carbonate carbon which may be of animal or plant origin but is considered to be inorganic. The amount of organic carbon in the soil influences the availability of various nutrients, pH, 'stiffness' of a soil, the amount of water that it will store, the availability of the water, and the rate of percolation of water through the soil. Fairly high organic levels (20% or so) are desirable. Low organic carbon, while typical of soils from arid climates, adversely affects most soils.

Cation exchange capacity (CEC): A measure of the degree to which a soil will store readily available ions for plant use. It is expressed in milli-equivalents of hydrogen ion per 100 gm. of soil. CEC is enhanced by high clay and organic carbon levels. However, a high CEC does not mean a fertile soil unless the nutrients, as available ions, are present to be exchanged. Soils with high levels of available nutrients but low CEC are quickly exhausted, becoming effectively infertile. CEC's of 100+ are considered desirable for modern farming and high yields.

Plants differ widely in their nutrient requirements. They also differ greatly in the latitudes of undesirable soil properties that they can withstand. Some native plants such as rabbitbrush (Chrysothamnus) can withstand TDS levels that would quickly kill Zea. The requirements for the two most common Southwestern cultigens follow:

Zea: Grows well in porous sandy to light clay soils. It is rather tolerant to pH, growing in soils from pH 5.0 to 8.0. For best yields, fairly high nitrogen levels are required owing to its rapid growth. Soils high in calcium are likely to contain insufficient levels of potassium and phosphorous. Corn is fairly tolerant of moderately high TDS levels and is not readily poisoned by excessive boron (the latter is not a problem at Grand Canyon). Corn planted in soils of low clay content matures earlier than ~~those~~ that planted in soils with high clay (40% or more).

Cucurbita: Squash is much less tolerant of less than optimum pH values than corn. This plant does best at pH 5.5 to 7.5. At higher pH values, yield and growth decrease. It is rather sensitive to high TDS values (250 or more) and high boron content. Squash grows well in shallow soil but it must be sandy, warm, and well drained.

The soils at Unkar Delta are not generally very well suited for agriculture. This is not to say that agriculture was not feasible. Considerable amounts of Zea pollen were found in several samples, including behind the checkdam. This suggests that farming was carried out in the immediate vicinity. (See Appendix for results of soil tests) Some sites seem much more promising than others for primitive agriculture.

The material from behind the checkdam at Un-10 (FS-14, K.V.L. #1746) yielded information suggesting this as the best agricultural site in the area. The soil has the highest fertility and generally the lowest content of undesirable substances (TDS and calcium). Although calcium levels were not tested, they were high in all samples. This material was merely lower in the checkdam sample, but still above what would be considered the maximum desired level by modern standards.

Only very slightly inferior to the above soil is that from Un-10, terrace 2 (FS-13, K.V.L. #1751). Clay content here is much higher (and better), potassium content is higher, phosphorous is much higher, CEC is better (probably because of the higher clay content) while the pH, TDS, $NO_3^=$, and organic carbon levels are less desirable. This and the preceding soil are the most likely and best candidates for agriculture.

The sample from the east portion of the south terrace 1 (FS-701, K.V.L. #1728) and the sample from the surface in Unkar Wash (FS-703, K.V.L. # 1729) probably represent the bare minimum suitable for sustained agriculture. CEC's are quite low. If this ground were farmed on a continuous basis, barring the importation of new soil by creek or river flooding, it would become exhausted rather quickly. Low phosphorous and organic carbon probably would not allow proper growth of *Zea* or *Cucurbita*.

The soil of the semi-consolidated dune area east of south terrace 1 (FS-700, K.V.L. #1726) would be objectionable because of the high pH, high TDS, and calcium content. Growth of the two food plants would be inhibited.

Undoubtedly the worst soil of all is that of south terrace 2 (FS-702, K.V.L. #1727). The pH of this soil is the highest that we have ever seen. The TDS value is very high, everything else is quite low. There is no question that this area would be unsuitable for agriculture.

APPENDIX

1. Pollen Counts, All Samples
2. Pollen Spectrum for Relative and Chromometric Dating
3. Table of Relative and Chronometric Dates
4. Table of Results of Soil Analysis

		ARBOREAL POLLEN						
KVL #	Your #	Juniperus	Pinus edulis	P. ponderosa	Quercus	Fagaceae	Betulaceae	Juglandaceae
1716	Un-1,F13	12.1	5.2	1.7				
1717	Un-1,F7	13.2	5.5	0.1				
1718	Un-1,F13	15.1	9.9	4.6				
1719	Un-1,F7	7.3	13.3					
1720	Un-15,F3	5.0	2.6	1.2	3.3	2.2	0.2	0.7
1721	Un-15,F3	5.3	3.1	1.4	3.5	2.0	0.8	0.6
1722	1 (Un-2)	11.0		0.8	2.3			0.4
1723	2 (Un-2)	1.6	5.2	0.5				
1724	3 (Un-2)	3.2	6.7	5.5				
1725	4 (Un-2)	3.4	5.2	4.3				
1726	FS 700	6.3	2.6	1.2	0.7	0.2	0.7	
1727	FS 702	7.6	10.4	14.5	0.9			
1728	FS 701	5.5	4.3	2.0	1.3	0.1	0.6	0.1
1729	FS 703	3.2	14.6	20.4	0.6			
1730	FS 227	6.9	5.8	5.1	1.8			
1731	FS 197	6.9	4.6	7.7	0.8	-----0.8------		
1732	FS 230	2.7	12.0	27.7	0.9			
1733	FS 228	5.2	4.1	1.4	1.3			
1734	FS 229	1.9	5.1	0.7	2.5			
1735	FS 232	9.2	1.9	1.7	2.0			
1736	FS 231	8.8	4.6	0.8	0.3			
1737	FS 233	3.1	6.3	6.5				
1738	FS 234	3.2	6.2	5.5				
1742	FS 134	3.7	4.1	0.7	0.4			
1743	FS 133	2.9	3.9	0.7	0.4			
1744	FS 129	8.9	1.9	1.9	2.3	0.1	0.2	0.4
1745	FS 127	7.6	11.2	15.6	0.7	0.1	0.2	
1746	FS 14 – Un-10							
1747	FS 132	3.0	5,4	1.1	2.1	0.1		
1748	FS 135	3.7	5.0	4.6	4.0	0.2	0.1	
1749	FS 136	5.1	5.5	3.1	3.5			
1750	FS 130	8.1	4.6	4.0	4.3	1.8		
1751	FS 13 - Un 10							

	Pseudotsuga %
1720	0.2
1721	0.2

NON-ARBOREAL POLLEN

KVL #	Your #	Spherical Gramineae	Oval Gramineae	Rosaceae	Cheno-Am	Malvaceae	Ephedra torr. type	Ephedra Nev. type
1716	Un-1,F13	-----32.4-----		24.1	6.9	1.7		
1717	Un-1,F7	-----38.6-----		22.9	7.1			
1718	Un-1,F13	-----25.6-----		25.7	15.9			
1719	Un-1,F7	----- 4.5-----		0.2				
1720	Un-15,F3	6.1	11.2	21.5	8.9	0.2	1.6	0.5
1721	Un-15,F3	6.5	13.2	24.0	11.6	0.3	1.8	0.3
1722	1 (Un-2)	4.2	12.2	11.4	16.0	2.7	2.1	1.0
1723	2 (UN-2)	5.8	14.9	5.0	11.6	3.3		
1724	3 (Un-2)	7.9	6.3	2.4	17.4	3.2	1.0	
1725	4 (Un-2)	1.1	4.8	8.0	4.6	1.1	2.3	1.3
1726	FS 700	7.0	7.7	8.9	7.7	5.1	-----2.6------	
1727	FS 702	3.9	6.1	4.0	11.5	2.4	12.7	1.7
1728	FS 701	5.7	7.8	7.5	9.2	5.2	-----3.2------	
1729	FS 703	----- 7.1-----		0.3	26.7	1.9	1.3	1.3
1730	FS 227	-----17.5-----		1.1	17.9	5.1	3.6	2.2
1731	FS 197	-----19.2-----		1.5	23.8	4.6	0.8	2.3
1732	FS 230	----- 9.3-----		14.8	14.8	2.8		0.9
1733	FS 228	9.0	13.7	6.9	10.3	2.5	-----0.8------	
1734	FS 229	-----28.4-----		5.0	2.8	2.6	----- + ------	
1735	FS 232	-----21.6-----			6.1	2.0	1.0	0.5
1736	FS 231	-----28.1-----		5.0	4.6	2.9	0.2	
1737	FS 233	8.5	8.2	1.1	20.5	3.4	0.4	0.6
1738	FS 234	11.1	8.0	3.1	16.2	2.8		
1742	FS 134	12.5	14.2	3.0	4.4	2.1	0.1	0.2
1743	FS 133	-----29.3------		2.4	4.7	2.3	-----0.5------	
1744	FS 129	-----22.6------			12.2	2.7	1.7	2.2
1745	FS 127	-----11.9------		3.7	2.7	2.4	10.2	2.6
1746	FS 14							
1747	FS 132	-----20.3------			16.7		1.7	0.2
1748	FS 135	-----15.8------		3.1	5.6	3.4	1.3	0.9
1749	FS 136	-----13.0------		7.5	4.4	5.1	0.6	1.2
1750	FS 130	-----18.8------			24.7	1.9	1.7	2.1
1751	FS 13							

KVL #	Your #	Compositae	Leguminosae	Prosopis	Cactaceae	Ericaceae	ΣA.P.	ΣN.A.P.	A.P.:N.A.P.
		NON-ARBOREAL POLLEN							
1716	Un-1,F13	12.1					19.0	77.2	0.246
1717	Un-1,F7	18.8					18.8	80.4	0.234
1718	Un-1,F13	12.2					29.5	79.6	0.371
1719	Un-1,F7						20.6	4.7	----
1720	Un-15,F3	22.5				1.4	15.4	73.9	0.208
1721	Un-15,F3	24.9	0.3				16.9	82.9	0.407
1722	1 (Un-2)	31.6	1.9	1.7	1.1		14.5	85.7	0.169
1723	2 (Un-2)	49.8	0.5	0.5	3.3	0.5	7.3	93.2	0.078
1724	3 (Un-2)	39.5	1.6		1.6		15.4	79.9	0.193
1725	4 (Un-2)	61.6		0.9	2.7		13.0	87.0	0.149
1726	FS 700	37.4			5.1	0.7	11.8	87.9	0.134
1727	FS 702	18.2	0.7	4.7	3.0	0.1	33.4	67.3	0.497
1728	FS 701	35.3			5.2	0.8	13.7	79.9	0.171
1729	FS 703	5.2		2.3	2.6		38.9	48.8	0.795
1730	FS 227	6.9		10.9	9.8		19.7	75.1	0.262
1731	FS 197	10.8		6.9	2.3		20.0	72.3	0.276
1732	FS 230	5.5		4.6	3.7		43.5	56.6	0.770
1733	FS 228	34.6					12.0	77.8	0.188
1734	FS 229	36.0	0.6	0.8	3.1		10.2	79.3	0.128
1735	FS 232	39.9		10.0	1.8		14.8	83.9	0.176
1736	FS 231	38.6	0.9	1.0	2.9		14.5	84.2	0.172
1737	FS 233	32.7	1.6	4.2	2.9		15.9	84.1	0.190
1738	FS 234	40.6		0.2	2.0	0.1	14.9	84.1	0.177
1742	FS 134	45.3	0.8	0.6	2.9		8.9	86.1	0.103
1743	FS 133	42.4	0.9	1.7	2.1		7.9	86.3	0.183
1744	FS 129	23.6	1.9	2.4	5.2	0.7	15.7	75.2	0.208
1745	FS 127	18.3		3.6	5.7		35.3	61.1	0.577
1746	FS 14								
1747	FS 132	47.1	0.3	0.6	1.0		11.7	87.8	0.133
1748	FS 135	42.9	0.9	1.7	2.9		18.2	78.5	0.233
1749	FS 136	40.6	4.8	1.0	3.3	0.8	17.2	82.3	0.210
1750	FS 130	28.1					22.8	77.3	0.294
1751	FS 13								

SOIL ANALYSIS

	Our #	Your #	Soil Texture % Sand	Silt	Clay	Soil Class	pH	ppm TDS	ppm K_2O	ppm P_2O_5	ppm NO_3	mil. eq. Cat. Exch Cap.	Fert. Val.*	
dunes	1726	FS 700	87	10	3	Sandy loam	8.9	810	11	16	77	9.5	29	dunes
ST2	1727	FS 702	83	9	8	Sandy loam	9.3	1100	13	9	30	6.1	-90	ST 2
ST 1	1728	FS 701	94	4	2	Sand	7.9	210	84	11	109	1.4	118	ST 1
ST 1	1729	FS 703	90	4	6	Loamy sand	7.9	380	65	5	123	3.3	109	
UNIO	1746	FS 14	89	9	2	Loamy sand	8.0	440	86	48	142	14.8	300	UNIO
UNIO	1751	FS 13	72	11	17	Sandy loam	8.1	460	91	76	98	15.5	293	

	Organic carbon
1726	3.7
1727	1.3
1728	0.2
1729	1.5
1746	7.3
1751	2.1

*The fertility value of a soil is a subjective measure of its potential for agricultural use. Actual suitability depends on the crop.

$$\text{Fert. Val.} = 10(CEC) + NO_3^{=} + P_2O_5 + K_2O - 1/10(TDS) - 10(pH_{\text{above } 7.0})$$

Our #	Your #	Unknown	N	Zea	Cucurbita	Typha Phragmites	Carex	Juncus	Salix
1716	Un-1,F13 B-1	3.8	215						
1717	Un-1,F7 B-1	0.8	198						
1718	Un-1,F13 B-1	0.0	227	+				0.2	
1719	Un-1,F7 B-1	74.7	205			2.0	1.5	1.0	7.2
1720	Un-15,F3	10.7	427	1.0					
1721	Un-15,F3	0.2	456						
1722	1 (Un-2)	5.7	270	1.5		0.7	0.4		
1723	2 (Un-2)	5.8	484						
1724	3 (Un-2)	4.0	253						
1725	4 (Un-2)	0.0	440						
1726	FS 700 [illegible]	6.0	417			0.6	0.3		
1727	FS 702 [illegible]	0.0	632			0.1			
1728	FS 701 [illegible]	6.4	559						
1729	FS 703 [illegible]	8.1	309			2.0			
1730	FS 227 B-2	5.1	274	0.1					
1731	FS 197 B-1	7.7	264	0.8					
1732	FS 230 B-1	2.8	216	2.9	4.2				
1733	FS 228 B-2	5.1	255						
1734	FS 229 B-2	10.1	263				----------0.4----------		
1735	FS 232 B-1	1.3	275						
1736	FS 231 B-1	1.3	260	0.2					
1737	FS 233 B-2		258	+					
1738	FS 234 B-1	10.0	841						
1742	FS 134-Un-2	5.1	525	5.3!!	1.2	2.0			
1743	FS 133-Un-2	5.8	307	10.4!!!!	2.6				
1744	FS 129-Un-2	9.1	229				0.6		4.7
1745	FS 127-Un-2	3.6	214						
1746	FS 14-Un-10	----	265	1.4	5.9				
1747	FS 132-Un-2	0.6	235						
1748	FS 135-Un-2	3.3	270						
1749	FS 136-Un-2	30.5	215			0.9			
1750	FS 130-Un-2	----	202						
1751	FS 13-Un-10	----	225	0.4	0.1		Also *Lycium* & Pigweed		

TABLE OF RELATIVE DATES

KVL #	Your #	A.P. / N.A.P.	Ephedra torr. / Ephedra nev.	Abs. Chron.	Relative
(1723	Un-2 #2	0.078	0.5	1100 A.D.	2.0*)
—(1742	FS 134	0.103	0.5	1100 A.D.	2.0*)
1736	FS 231	0.172			1.8 ±.16
1735	FS 232	0.176			1.8 ±.09
1738	FS 233	0.172			1.8 ±.24
—1743	FS 133	0.183	5.0		1.8 ±.22
1733	FS 228	0.188			1.7 ±.17
1747	FS (132)	0.133	8.0	1175 A.D.	1.6 ±.26
1734	FS 229	0.128			1.6 ±.09
1750	FS 130	0.294	0.4	1200 A.D.	1.2 ±.33
1722	Un-2 #1	0.169	2.0	1300 A.D.	1.0*

*These samples were used to define the relative time period between 1.0 and 2.0