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1962, pp. 115-117. https://doi.org/10.56577/FFC-13.115

in:

Mogollon Rim Region (East-Central Arizona), Weber, R. H.; Peirce, H. W.; [eds.], New Mexico Geological Society 13 th Annual Fall Field Conference Guidebook, 175 p. https://doi.org/10.56577/FFC-13

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POLLEN ANALYSIS OF LAGUNA SALADA[1]

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The pollen record in northern Arizona has been based on archaeological sites or coprolite deposits, and, although this record extends into the Pleistocene, it is incomplete beyond 350 A.D. (Martin, Sabels, and Shutler, 1961; Schoenwetter, 1962). In order to obtain a more nearly continuous pollen record of archaeological and climatic significance, lake and spring sediments are currently being investigated between Flagstaff and Springerville.

Like many of the lakes north of the White Mountains, Laguna Salada is ephemeral, and when dry has a barren, salt-crusted surface. Prior to diversion of water for agricultural and stock-raising purposes, the lake did not dry out completely. Local residents fished in the lake in the late 1930's and early 1940's, about the time of the abandonment of the ghost town of Floy.

Pollen samples were taken during the summer of 1960 by J. Schoenwetter from West Arroyo (50 feet upstream of old bridge abutments), and by the author and M. E. Cooley during the summer of 1961 from various sites within the basin. Gastropod samples and sediment for C_{14} analysis were also collected during the summer of 1961. This summer (1962) additional samples from the dunes, as well as a core approximately 6 meters in length from the playa, were collected and are presently being processed. The results of the 1960-61 studies are summarized in Figure 1.

The pollen profile has been divided into four pollen zones on the basis of the relative abundance of the various pollen types rather than lithological units, inasmuch as the latter (at least those which yielded pollen) were for the most part fine-textured silts, clays, and muds. The coarser-textured sands and gravels were generally unproductive, and, when pollen was present, it was usually poorly preserved. Deposits on terraces, except for surface samples, were also sterile of pollen.

The pollen of zone I, obtained from a core of nearly 2 meters in length of the central lake sediments of modern Laguna Salada, shows little change. In general, the 2-meter core shows a greater abundance of arboreal pollen types such as pine (**Pinus**), juniper (**Juniperus**), and oak (**Quercus**) than is found in the modern record (excluding soil surface 2, which is believed to represent redeposited fossil pollen). The non-arboreal pollen (shrubby or herbaceous pollen types to the right of **Quercus** in Fig. 1) has several elements of interest, notably the occurrence of sagebrush or wormwood (**Artemisia**), **Myriophyllum**, and the halolimnetic **Ruppia**. Although relatively common in some areas of northern Arizona, **Artemisia** is rare in the basin of Laguna Salada, and for that reason its occurrence in these recent sediments is of interest, considering its absence in the modern pollen rain.

Ruppia and **Myriophyllum** are aquatic flowering plants indicative of permanent water. **Ruppia** commonly occurs in stagnant or perhaps brackish water. Pollen of **Myriophyllum** has been recorded only once before in sediments from the Southwest (Bent, 1960), and **Ruppia** has not been reported previously.

The abrupt rise in pollen of the Cheno-Ams[1] may also be significant because today they occur most abundantly in moist, saline or alkaline, fine-textured soils on the shores of lakes in arid or semi-arid regions, exploiting habitats which other species are unable to utilize due to high soluble salt content.[2] It is likely that a ring of Cheno-Ams enclosing the lake would move in response to fluctuating lake level, either advancing or retreating from the center of the lake with lowering or rising of lake level. Changes in the relative abundance of Cheno-Am pollen in lacustrine sediments may then reflect only the advance and retreat of lake margins and an increase or decrease of salinity — in other words, the stability of the shoreline. If this hypothesis is true, the high relative abundance of Cheno-Ams at the bottom of pollen zone I may indicate drier conditions with Cheno-Ams growing nearer the center of the modern basin of Laguna Salada, at a time when salt content was not prohibitive as it appears to be at present.

Pollen zones II through IV are from shore and nearshore sediments of ancient Laguna Salada, and were obtained from the banks of West Arroyo in which two distinct lithologic units are exposed: a sterile, buff sandy unit below; and a polliniferous, gray mud unit above, the latter being divisible into brownish and grayish subunits.[3]

Pollen zones II and III may be characterized by rising percentages of non-arboreal pollen types, and decreasing relative abundance of arboreal pollen types with almost total absence of aquatic flowering plants as well as low percentages of algae, suggesting climatic conditions more or less similar to the present.

The pollen of zones II and III may be distinguished by maxima of Cheno-Ams and Compositae (Sunflower family) respectively, and, on the basis of radio-carbon dates indirectly related to the pollen diagram, may be assigned to the time period generally referred to as the Altithermal (5500-2000 B.C.) or Hypsithermal (7500-0 B.C.), a post-glacial interval generally conceived to have been warmer and drier than the present (Antevs, 1955; Deevey and Flint, 1957). If Cheno-Ams do respond to changing levels of water, as suggested above, then the maxima of Cheno-Ams in pollen zone II might suggest a climate at least as warm and arid as the present under which the lake level was declining.

While there is no clear palynological evidence from Laguna Salada of an Altithermal that was either warmer or drier than the present, there is clear evidence of an earlier important climatic change. This change, which begins at the close of pollen zone IV, is apparently one of

[1]This is a condensed version of a longer paper under the title, "Paleoecology of Laguna Salada" to be published soon in Fieldiana (Anthropology).

[1]The term "Cheno-Ams" was proposed by Martin, Schoenwetter, and Arms (1961) to encompass pollen of the goose-foot family (Chenopodiaceae) and of pig-weed (**Amaranthus**) of the Amaranthaceae.

[2]Cheno-Ams characteristically occur in disturbed sites; saltbush (**Atriplex**) and pig-weed in particular occur along margins of streams and washes, as well as areas of human occupation. In these non-lacustrine habitats, environmental implications other than disturbance may be more complex (see Martin, Schoenwetter, and Arms, 1961).

[3]For a more detailed description of the lithologic and stratigraphic relationships of the arroyo and lake sediments (see Cooley, this guidebook).

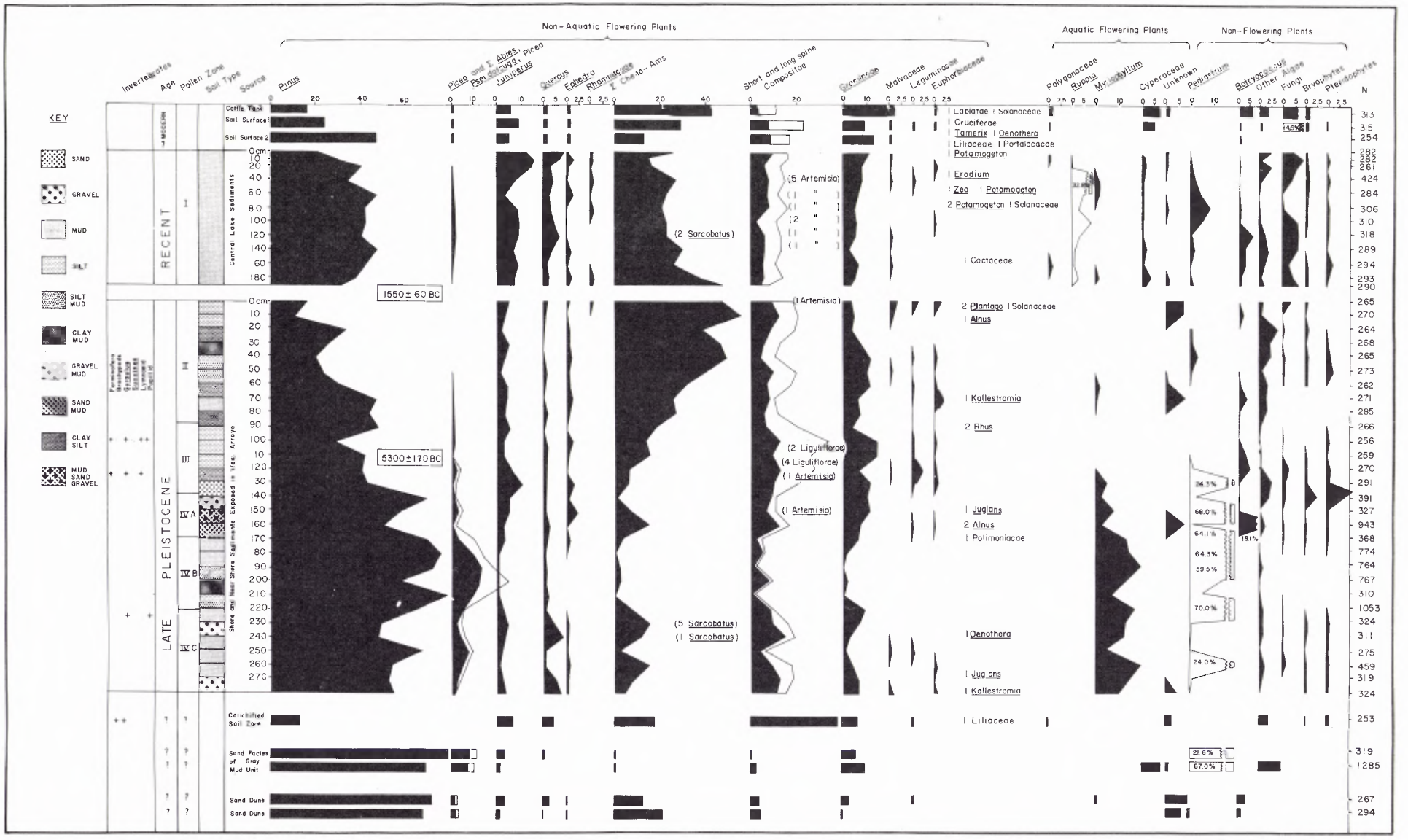

Figure 1. Pollen diagram of Laguna Salada sediments showing related invertebrate fauna (determined by Drake, 1962) and radio-carbon dates.

increasing aridity during which spruce, fir, and pine retreated from the margin of ancient Laguna Salada into the White Mountains, surviving there in refugia. Evidence of increased aridity is also afforded by the aquatic plants, which decline in relative abundance and are replaced by Cheno-Ams as the lake margin dropped. Despite evidence of increased aridity in comparison to pollen zone IV, climatic conditions at least within portions of pollen zones II and III appear to have been more moist and cooler than the present.

Pollen zone IV is characterized by high relative abundance of arboreal pollen, and of aquatic flowering plants such as **Myriophyllum**, but terrestrial flowering plants such as Compositae and Cheno-Ams are present only in relatively low percentages. It would appear that under pluvial climatic conditions spruce, fir, and pine descended to the margin of ancient Laguna Salada. It is noteworthy that pollen of sagebrush or wormwood (**Artemisia**), which is frequently encountered in other pluvial records from the southwest (c.f. Bent, 1961; Hafsten, 1961; Hevly and Martin, 1961) is relatively scarce in the pollen record from Laguna Salada.

In addition to the lake and near-shore deposits,aeolian sediments on the eastern shore of Laguna Salada, as well as sediments believed to be of fluvial origin in West Arroyo, were sampled to determine, if possible, their relationship to the lake and near-shore sediments. Examination of surface samples of the dust dunes discloses a pollen record similar to that of pollen zone IV, but the grains are very poorly preserved. Pollen of pine in particular shows about 50% breakage in the sand dunes, while in the near-shore sediments the breakage rarely exceeds 30%, suggesting that the pollen is reworked from pollen zone IV. Further work will be necessary to determine the time and environment of dune formation, which classically is considered to have occurred under an arid climate similar to that inferred by other workers for the Altithermal.

The putative fluvial sediments occur in a filled channel cut by West Arroyo, and they are apparently a sandy facies of the lower brownish portion of the gray mud unit. The pollen which they contain is very similar to that obtained from pollen zone IV, except in the absence of **Myriophyllum**. This difference is easily explained as a difference of fluvial and lacustrine environments, **Myriophyllum** being restricted to the latter. It would appear then that pollen at this site is not sorted to the extent of other sediment types, being equally represented in sandy and muddy facies of the same units, and showing only poorer preservation in coarser sediments.

SUMMARY AND CONCLUSIONS

1. A comparison of modern pollen rain with pollen profiles obtained from lake and arroyo sections at Laguna Salada discloses late Pleistocene climatic change from a humid, cool, pluvial climate (high percentages of spruce, fir, pine, planktonic algae, and aquatic flowering plants) to a warm, arid climate similar to the present (pollen counts resemble the modern pollen rain in high percentages of Cheno-Ams, Compositae, and Gramineae). Similar records from shorter sections have been obtained elsewhere in the Southwest.

2. Two C_{14} dates of 1550 ± 60 B.C. and 5300 ± 160 B.C. may be related indirectly to the post-pluvial portion of the pollen sequence. The period of time spanned by these dates is approximately that suggested for the Altithermal, but the present incomplete pollen record does not support the notion that the climate was either warmer or drier than the present.

3. Pollen analysis at Laguna Salada provides a convenient tool for determination of past climate, corroboration and elucidation of the depositional environments responsible for sedimentary facies change, and may eventually reveal the vegetational history associated with such geological events as the formation of dust or sand dunes along the shores of playa lakes.

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