under the influence of the drug in proportion to the dose administered (see Fig. 1). The duration of the effect similarly was correlated with the dose level. The fact that the behavioral response is sensitive to the well-known analgesic property of morphine strongly suggests that the afferent inflow controlling the lever pressing is related to pain. The method described would therefore appear to provide a useful tool for further investigations of pain perception.

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Early Pleistocene Paleoclimatic Record from Sonoran Desert, Arizona

Abstract. Three pollen spectra from lake sediments stratigraphically well below mid-Kansan fauna indicate plant associations for the Sonoran desert, Arizona, approximating those found now at elevations of 1500 ft and more above the desert floor. The presence of *Ostrya*, *Betula*, and *Artemisia* may indicate some invasion by northern species as well. A climate cooler or wetter, or both cooler and wetter, than the present climate is inferred from paleobotanical and sedimentary evidence. Correlation with the Nebraskan glacial stage is tentatively suggested.

A durable problem of paleoecology and biogeography is the effect of Pleistocene climatic fluctuations on biota of nonglaciated regions. Since this problem relates to vegetational changes, it is unlikely that any method will prove more fruitful for its solution than stratigraphic pollen analysis. Pioneering attempts to establish continuous pollen chronologies in the southwestern states have been made by Clisby and Sears (*1*) and by Roosma (*2*).

Sediments deposited in pluvial lakes that existed through part or all of the Pleistocene in the Far West are invaluable archives of lithostratigraphic and vegetational history. According to Lance (*3*), late Cenozoic [Pliocene (?)–Pleistocene] lacustrine and alluvial sediments accumulated to unknown depths in the northwest-trending structural trough of the Safford-San Simon valleys, Graham County, southeast Arizona, until nearly the middle Pleistocene. Down-cutting and degradation then became dominant processes following drainage of ponded water in the valleys. The Gila and San Simon rivers now have trenched middle and early Pleistocene sediments flooring and underlying the valleys, exposing them for several hundred feet. At several localities these sediments contain Blancan fauna (*4*). Vertebrate fossils considered transitional Blancan to Irvingtonian, or of approximate middle-Kansan age in terms of North American glacial chronology, are encountered in lacustrine-paludal sediments near the top of the exposed Pleistocene sequence (*5*) and 400 to 600 ft stratigraphically above the pollen-bearing sediments of the valley floor.

Shallow drill holes in the valley floor made during exploration for watershed dam sites (*6*) yielded core sediments that were exhaustively sampled for pollen. Well-preserved, abundant grains were obtained from only one core (Table 1, columns 2 and 3). Some core cuttings (*6*) (Table 1, column 1) also contained pollen, although sediments from outcrops were mostly barren. Sufficient stratigraphic control to clearly relate the column 1 spectrum to the others is lacking. Topographic relations suggest that this pollen horizon is higher in the lake-bed sequence than the pollen horizon from the 43- to 48-ft levels.

These single records provide rare evidence of the nature of early Pleistocene climate in the Southwest. Because additional data for the area may not be available for several years, these records seem worthy of present publication.

Elevations approximate 3000 to 3200 ft where the Safford Valley borders the Pinaleno Mountains (about 10,700 ft) to the southwest and the Peloncillo and Gila ranges (about 7000 ft) to the northeast. No available evidence suggests that these topographic relations were not stable during deposition of Pleistocene and Pliocene (?) sediments underlying the valley.

Mean annual, biseasonal rainfall is about 10 inches and is largely concentrated as short, intense thundershowers during July and August. Desert shrub—*Larrea* (creosote bush), *Atriplex* (saltbush), *Gutierrezia* (snakeweed), *Haplopappus* (burroweed), *Prosopis* (mesquite), *Ephedra*—scatters the valley floor. Major vegetational zones in the surrounding foothills and uplands, with increasing rainfall and decreasing temperatures, include desert grassland (3500 to 4800 ft), oak (juniper-pine) woodland (4800 to 6500 ft), ponderosa pine (6500 to 8000 ft), and Douglas fir–white fir (8000 ft and above) (*7*). Pollen, borne into Safford Valley by wind or water, or by both, is shown by analysis of contemporary sediments (Table 1, columns 4 and 5).

The generally high percentages (Table 1, columns 1 to 3) of juniper, sagebrush, pine, and oak indicate a marked departure for early Pleistocene vegetation from the prevailing lower Sonoran flora of Safford Valley. These genera apparently invaded the sclerophyllous shrub and desert grassland of the lower valley and upper desert slopes, while mesophilous trees and shrubs [walnut, hackberry, sycamore (?), ash] clustered in nearby draws on flood plains of streams and possibly at the lake margin. The base of the sequence (43 to 48 ft) suggests an open savanna-parkland [juniper–oak–pine–(shrubby [?] sagebrush)] with intervening grasses and some forbs and perennial shrubs typical of lower slopes and valley floor. Woodland assumed increased importance in the uppermost horizon with pine a dominant at low elevations though probably above the lake margin (*8*). The pollen of several boreal and subalpine genera [alder, birch, Douglas-fir (?), fir, hop hornbeam, maple, spruce] evidently sifted to the lowlands from forests well above the valley. The limited but consistent occurrence of several of these pollen types supports other floral evidence favoring depression of vegetational zones in this area during the early Pleistocene.

The finding of elm pollen provides a range extension for a genus no longer indigenous to the Southwest; at least two northern Arizona species (hop hornbeam, birch) reached this latitude in the early Pleistocene. High percentages of sagebrush pollen may indicate immigration of a northern shrubby *Artemisia* into southeastern Arizona lowlands, although it seems possible that increased abundance of a local herbaceous species, under altered climatic conditions, might account for the high frequency of sage pollen in these sediments (*9*). Pure stands and high concentrations of the most conspicuous of the shrubby artemisias, *A. tridentata*, do not now occur south of the Mogollon Rim, at elevations below 5000 ft. The herbaceous *A. dracunculoides* and *A. ludoviciana*, though readily overlooked in the field, are common though somewhat local members of southeastern Arizona vegetation at low and moderate elevations (*10*). Fletcher (*11*) indicates the root perennial *A. carruthii* to be widespread and common in the bordering foothills and adjacent uplands (3500 to 8000 ft) of the Pinaleno Mountains, although it does not occur in high concentrations. According to Fletcher and Goodding, this species may flower in both spring and fall. A possible biseasonal anthesis, combined with profuse flowering and large amounts of pollen shed, make this species a potentially important factor in the pollen rain. Nevertheless, the limited quantity of sage pollen now encountered in contemporary southern Arizona sediments (*12*) provides a paradox which makes the high percentages of *Artemisia* pollen in the Safford Pleistocene spectra inexplicable in terms of the distribution and frequency of herbaceous species now inhabiting the area.

A climate at least temporarily cooler and probably wetter than the climate today is indicated for early Pleistocene southeast Arizona. The apparent shift in valley vegetation from open mixed parkland to more closed (?) pine woodland stresses the climatic alteration. K. Clisby suggests, further, the possible significance of the inverse ratio between tree pollen plus sage and chenopods in fossil and contemporary spectra in underlining moist-to-dry climatic change. The climate projected from pollen analysis is corroborated by past lacustrine conditions in the Safford–San Simon valleys. The lake beds are on the order of 2000 ft thick and extend over an area of at least 35 miles; water-level changes within them, inferred from sedimentary evidence, suggest climatic oscillations possibly of interstadial magnitude (*13*). Equatorward shift of the Pacific winter cyclonic storm track, now scarcely extending into Arizona, is postulated to explain atmospheric conditions requisite for lake expansion in now arid-semiarid middle latitudes during times of glaciation to the north (*14*). Thus it seems probable that winter rains played a more significant role than they do currently in the predominantly summer-shower region of southeastern Arizona. The abundance of sagebrush may suggest a pluvial phase shift in the seasonal precipitation pattern.

From (i) the stratigraphic position, (ii) the presence of a "cool" flora, and (iii) the availability of a large, possibly deep, lake as deposition site, it seems probable that the Safford spectra register climate within some phase of the Nebraskan glacial stage. Or, they may indicate a pre-Nebraskan cooling corresponding to the Donau stage of the recognized European glacial sequence. More knowledge about past rates of regional sedimentation and additional stratigraphic and paleobotanical control are necessary, however, for more exact correlation with glacial events of the early Pleistocene (*15*).

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Table 1. Percentage frequency of pollen and spores in early Pleistocene (columns 1–3) and contemporary (columns 4, 5) sediments of the Safford-San Simon valleys. Depth is depth below the surface. Figures in parentheses are number of grains.

	1	*2*	*3*	*4*	*5*
Group, family, or genus	Kennecott core (depth, 257–272 ft; *N*, 1642; el., about 3300 ft)	Safford core (el., 2995 ft)		Gila River mud (*N*, 715; el., 2930 ft)	111 Ranch water storage tank (*N*, 962; el., 3400 ft)
		Depth, 43.5 ft; *N*, 1108	Depth, 48.0 ft; *N*, 1137		
Juniperus-Cupressus	4.2	15.7	26.9	2.9*	0.4 (4)
Quercus	3.5	11.4	6.7	3.9	0.6 (6)
Pinus	52.6	5.0	10.6	3.0	1.4
Artemisia	11.0	13.5	13.5		0.1 (1)
Compositae (other)	4.0	22.8	14.4	34.8	20.5
Liguliflorae	0.06 (1)	†	0.1 (1)		
Gramineae	9.5	11.3	6.2	3.2	9.0
Chenopodiaceae–					
Amaranthus	6.3	6.3	9.9	38.9	41.7
Sarcobatus	3.6		0.5 (6)		
Tidestroemia	0.06	0.1 (1)	0.4 (4)	0.3 (2)	
Abies	0.43 (7)	0.2 (2)	0.3 (3)		
Acer (see *A. negundo*)			†		
Acacia	† (?)		†	0.3	0.6
Alnus	0.12 (2)		0.2 (2)		
Betula	0.12				
Celtis		0.4 (4)			0.1
Cereus-type					0.1
Ephedra spp.	0.36 (6)	†	0.1	2.0	0.7 (7)
Ericaceae					0.1
Fraxinus	0.06	0.3 (3)	0.6 (7)		
Garrya	†		†		0.1
Juglans	0.18 (3)	0.6 (7)	0.3	0.1	
Opuntia				0.1 (1)	
Ostrya	0.24 (4)	1.5	0.3		
Picea		0.1	0.2		
Platanus (?)			0.4 (5)		
Prosopis					10.2
Pseudotsuga (?)	0.12				
Salix (?)	0.06				
Ulmus	0.06	0.3	0.1		
Vitis			0.1		
Cyperaceae	0.49 (8)	1.4	0.6		
Epilobium-type	0.06	0.1			0.2
Eriogonum aureum-type	0.06		0.1	0.3	0.2
E. albertianum-type					1.2
Erodium					0.1
Euphorbiaceae					0.2 (2)
Gilia-type	†	0.1	0.1	0.1	0.2
Liliaceae					0.2
Linanthus-type			†		
Nyctaginaceae			†	0.6 (4)	0.3
Plantago	0.06				
Sphaeralcea-type	0.06	0.1	†	1.7	2.1
Thalictrum	0.06				
Typha angustifolia	1.0	0.6	0.2		
Polypodiaceae (?) (monolete, trilete spores)	0.06		†	†	0.1
Selaginella		†	†	†	
Pediastrum	†	†	†		
Botryococcus	†		†		
Unidentified pollen	1.6	8.2	7.2	7.4	9.5

* Higher percentages of juniper, oak, and pine in the river mud than in storage-tank *gyttja* may indicate limited water transport of these grains from the upper reaches of the Gila River in the Gila Range. † Scanned.

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9. *Artemisia* pollen species are not readily distinguished; morphological variation among fossil grains suggests the presence of more than one species.
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15. This report is contribution No. 41 of the University of Arizona's program in geochronology; the research was supported by the Rockefeller Foundation through the university's "Utilization of Arid Lands" program.

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