THE CASTALIA PRAIRIE[1]

PAUL B. SEARS

Department of Biology, Yale University, New Haven, Conn.

ABSTRACT

The Castalia Prairie in northern Ohio developed on 3000 or more acres of calcareous deposit averaging 6 to 7 feet in thickness and representing an interval of some 8000 years. Below it, at 54 feet, are lake sediments that accumulated on till during an interval of about 5000 years.

Pollen analysis shows a transition from spruce dominance to deciduous forest and grassland conditions just above the lake sediments, with a subsequent increase in herbaceous (prairie) pollen. However, peaks of prairie pollen occur within the (coniferous) lake sediments, indicating that representatives of the grassland community had already migrated eastward during the time of glacial retreat and were at hand to become established at the onset of xerothermic conditions around 3600 years ago.

The Castalia Prairie extends north and west of the village of Castalia, Ohio, which is located at 41° 24′ N, 82° 49′ W. The prairie lies irregularly between the 580 ft. contour along Sandusky Bay of Lake Erie and the 650 ft. contour which marks the boundary of a limestone escarpment at the southeastern edge of Castalia.

Its original outline is difficult to determine. Of the original survey (Ludlow, 1808), only the field notes concerning the western boundary of the Connecticut Western Reserve, which runs through the prairie, have been located; those of the east-west lines are missing. A manuscript note in the Firelands Museum at Norwalk, Ohio, shows that an unsuccessful search for these notes was made in the General Land Office at the request of my grandfather, Stephen R. Harris, presumably when he was a member of Congress during 1894–6.

Figure 1 is based upon three sources. The *Andropogon furcatus* (Big Bluestem or Turkeyfoot grass) prairie, as mapped by E. E. Kopf (personal communication, 1966), is shown in outline. The distribution of the muck or organic soils are based upon soils maps furnished by the Ohio Geological Survey and shown in stipple. Not shown is an extension of the prairie northeastward, as figured in an old sketch map hanging in the Firelands Museum. Clearly the main part of the prairie, both wet and dry, lay in Township 6 N, Range 24 W (Margaretta Township, Erie County, Ohio).

The close relationship of the Castalia Prairie to the grassland province is evident from a comparison of Moseley's *Sandusky Flora* (1899) and Peterson's *Flora of Nebraska* (1923). Without going into the subtleties of nomenclature or taking account of species not mentioned as coming from Castalia because of wider distribution in the area (e.g. *Andropogon* sp.), 21 Nebraska prairie species are listed for Castalia. In addition, 46 genera of herbs and 3 genera of shrubs occur in both lists, although the Sandusky flora includes more than a dozen families not listed for Nebraska.

The Ohio prairies and associated oak-hickory woodlands were found on a variety of habitats and parent soil materials. These included poorly drained ground moraine and shallow lake beds, as well as drier sites underlain by gravel or sand. Until recently, the cactus *Opuntia rafinesquii* was present both on the Cedar Point sands and the thin layer of soil over limestone in Erie County. In addition, the prairies were confined within the limits of glaciation. These facts, as well as western floristic affinities, strongly support the view that they are relicts of a more continental type of postglacial climate than that which prevails now, thus favoring their invasion of newly vacated terrain (Gleason, 1923; Sears, 1932).

Their persistence in the face of climatic change is a more difficult problem.

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Tree establishment is known to be difficult in a closed prairie turf. Until eradicated by recent "progress," remnants of prairie communities could be found along rights of way where they had been recorded in original surveys of the late 18th and early 19th centuries. They were not aggressive, however, a further indication that their original establishment had been under more favorable conditions of climate.

The site of the Castalia Prairie was covered by the Erie Lobe of the Wisconsin glaciation, whose retreat, circa 13,000 B.P. (before present) (Goldthwait, 1965)

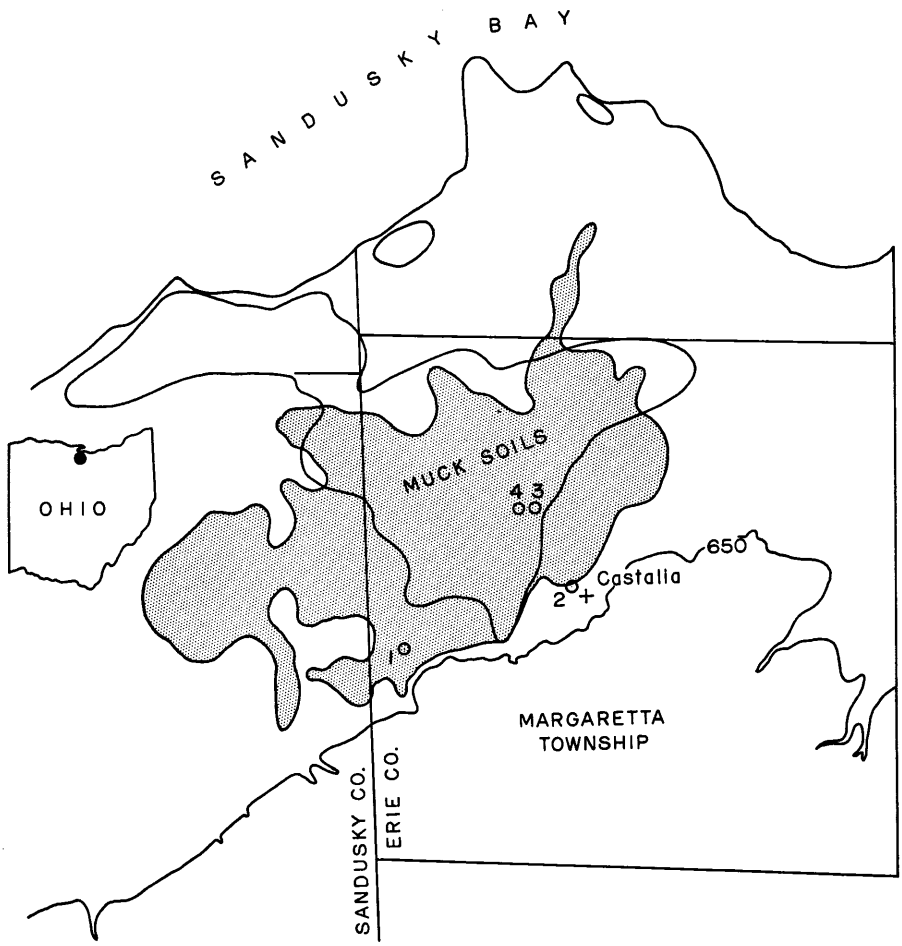

FIGURE 1. Outline of Andropogon prairie. Muck soils shown by stippling. Inset, location of Castalia area. Sample sites labeled as follows: 1) Moss sample 2) Potter core 3) C-526 4) 2-E, 2-F, and X-7.

gave rise to a sequence of lakes, the first of these being Lake Maumee I at 800 ft. (fig. 2). As the area was cleared of ice, lake sediments were deposited on top of till until well after the disappearance of the final phase of Lake Lundy, last of the ice-dammed lakes, whose surface was at 615 ft. elevation (Sears, 1966).

Thereafter the site was occupied by deciduous forest (Goldthwait and Burns, 1958), which in turn was swamped by the discharge of north-flowing subterranean, calcareous water. The effect of this discharge was to produce a deposit of marl and tufa, with seams of peat and muck formed in surface depressions.

Upon this accumulation of sediments there were at the time of the original survey both wet and dry prairie associations, composing one of a number of grassland enclaves within the generally forested state of Ohio (Sears, 1926; Gordon, 1966). Howe (1896) described it as "a beautiful prairie of about 3,000 acres," while Ludlow (1808) pronounced the whole area as "not worth a farthing," presumably because it was unsuitable either for timber or agriculture. A century later it was profitably exploited as a source of material for cement. Because of the flooding of these excavated areas, much of it serves today as a wildlife refuge. At Castalia, the Blue Hole, a crater-like spring said to have erupted following the damming of Cold Creek to generate water power during its descent of 57 feet to Sandusky Bay, is a picturesque tourist attraction.

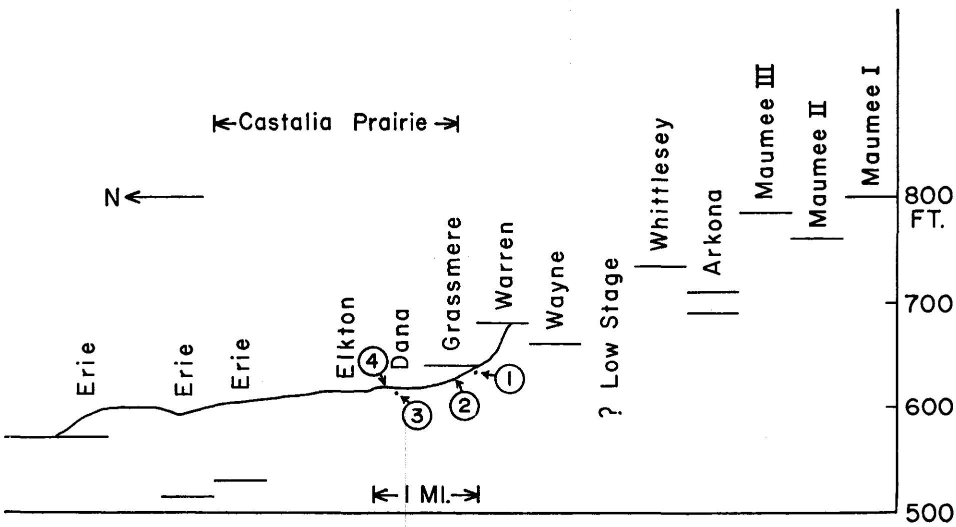

FIGURE 2. Generalized profile showing sequence of lake levels and location of prairie.

Combining, as it does, a disjunct example of the grassland biome and a clear-cut late- and post-glaciation history, the Castalia prairie offers in its sediments an opportunity to investigate changes in vegetation and climate subsequent to glacial retreat, using the method of pollen analysis. Of particular interest is the suggestion that eastern prairie enclaves were relicts of a more continental climate than that which prevails today.

The Ohio prairies were accompanied by buffer zones of oak-hickory woodland more xeric than the beech-maple and mixed mesophytic forests characteristic of present conditions (Sears, 1926). The first pollen studies in Ohio dealt with forest pollen (AP) chiefly, thus the evidence of a warmer, drier post-glacial interval rested until recently upon a minimum of beech and a maximum of oak-hickory, now bracketed between 1300 and 3600 years ago (Ogden, 1966).

In addition to previous work by Goldthwait and Burns (1958) and by Potter (1947), the present study is based upon moss collected by R. J. Bernhagen, my own hand samples, and a 62.8 ft. core obtained by the Ohio Geological Survey under the direction of J. W. Reynolds. The location of these samples is shown in figure 1.

Potter (1947), in his study of 22 bogs in northern Ohio, cored 4.5 feet into sand near the southern edge of the prairie and just northwest of the village of Castalia. He reported no pollen below the 2.5-foot level, but above it he found spruce, pine, hemlock, birch, beech, and oak (fig. 4B). Hemlock at the 1.5- and 2.5-foot levels was replaced by beech in the surface mixture of clay, peat, and shells. This shallow, compact, and possibly disturbed record, taken at about the 630-foot contour indicates that a transition from coniferous to deciduous forest conditions followed the fall of Lake Lundy from its earliest (Grassmere) phase at 640 feet elevation.

Further evidence of this transition comes from the sample of moss furnished by R. J. Bernhagen (personal communication, 1950) of the Ohio Geological Survey, who reported "considerable amounts of peat moss . . . at a depth of about 6 feet below the surface directly beneath the tufa beds which are being excavated by the cement company." This places it on the lake sediments that preceded tufa formation and therefore, since the sample was taken at 6 feet below the 640-foot contour, or at about 634 feet elevation, it must, like Potter's profile, be post-Grassmere.

The moss, identified by A. J. Sharp (personal communication, 1952) as *Drepanocladus fluitans* var. *typica*, belongs to a genus identified by Wynne (1944) as "circumpolar in both hemispheres, notably lacking in tropics except at high altitudes. Present range coincides well with maximum extent of Pleistocene continental glaciation. Species are either arctic-alpine or boreal montane." This sample of moss also contained abundant pollen (table 1, fig. 4C).

TABLE 1

Moss at contact of lacustrine and terrestrial sediments

Juniperus	09	Carex	06
Larix	01	Compositae	02
Picea	32	Gramineae	07
Pinus	01	Nymphaea	01
%CONIFERAE	43	Typha	04
Acer	01	Bryophyta	Abundant
Alnus	02	TOTAL % NAP	20
Betula	11	TOTAL POLLEN COUNTED	161
Castanea	01		
Fagus	01		
Quercus	17		
Salix	03		
%DECIDUA	36		
TOTAL % AP	79		

Carbon-14 dates of this moss as determined by J. G. Ogden, III, are:

OWU-168	13,911 ± 418
OWU-168-A	15,172 ± 746

"Both dates (J. G. Ogden, III, personal communication, 1966) are considerably older than expected. It was noted in processing the samples that a considerable amount of small gastropod shells were present. It is entirely possible that fractionation and/or incorporation of paleozoic lime carbonate in the moss sampled may have resulted in anomalously old age determinations."

However, the strong showing of deciduous pollen in this sample, as compared with data from the lake sediments to be shown below, is evidence that the shift from coniferous forest followed exposure to terrestrial conditions. It is further clear from the work of Goldthwait and Burns (1958) that a deciduous forest developed upon lake sediments before the formation of marl. From a forest bed, covered by six to eight feet of marl at the 620-foot contour and hence not more than 614 feet in elevation, Burns reported the wood of ash (*Fraximus*), dated by Libby (1951) as C–526 at 8513±500 years B.P. This date was accepted for Lake Lundy at 620 feet until Hough (1963) pointed out that the date was too recent to account for the ice barrier at Niagara that had been necessary to maintain the Lundy level.

Actually this level of 620 feet was an arbitrary figure, as Lundy includes three phases: Grassmere at 640, Dana at 620 and Elkton at 615 feet elevation (Forsyth, 1959). The forest bed lies, not at 620 feet but at least 6 feet lower, thus below the Elkton or minimum Lundy phase, on a surface exposed long enough to permit the growth of forest. Burns (1958), in reporting his finds of ash, blue beech, hickory, and dogwood, notes them as indicating improved drainage of swamp forest. So does the presence of *Juniperus virginiana*, which, although ranging into boggy habitats as well as calcareous upland, survives today on the nearby well-drained limestone soils of the Catawba peninsula and the Lake Erie islands. Finally, it is now known that the ice front 8000–9000 years ago lay far north of the Niagara outlet. On all counts the C–526 date is considerably younger than Lake Lundy (Sears, 1966).

In 1953 the Ohio Geological Survey obtained a 62.8-foot core (OGS599, our X–7) at a point 0.4 mile northwest and 0.3 mile west of the city limits of Castalia (Location 4 in fig. 1). The log of this core, furnished by J. W. Reynolds, shows:

0– 6.2 ft.	Marl with peat, shells and other inclusions
7.1–10.6 ft.	No recovery
10.6–54.0 ft.	Clays and silts
54.0–62.5 ft.	Till
62.5 ft.	Bed rock

Of special interest is the occurrence of laminated clay at 10.6–13.1 ft. and 46.2–51.4 ft., because such laminations are characteristic of ice-dammed lakes.

I also took hand cores nearby, 2–E at 0–6+ ft. (73 in.) and 2–F at 6.5– (79 in.) 11 ft. (Location 4 in fig. 1). As marked on the 1901 15-minute Bellevue quadrangle with 10-foot contours, these samples were taken at about 620 feet elevation, near the site of C–526 of Burns, although the more detailed 1959 7.5-minute quadrangle with 5-foot contours would place them at about 615 feet.

Whether the 620-foot surface at the sites of coring as shown on the older map or the 615-foot elevation on the newer is correct cannot now be determined, but in either case the 6.2-foot thickness of terrestrial deposits places their beginning below the lowest (Elkton) phase of Lake Lundy.

From 7.1 to 10.6 ft., a mixture of fine materials and compact lumps was lost in drilling. Above this, a depth of from 6.2 to 7.0 feet, only traces of pollen were found, suggesting that the entire zone from 6.2 to 10.6 feet may represent a beach deposit on top of the unquestionably lacustrine deposits below it. In the hope of bridging this gap, my hand samples, 2–E and 2–F, which as noted were taken nearby, were analyzed along with those of the deep core. The results are shown in Table 2, where percentages have been calculated for total pollen counted.

In some respects the results are equivocal, for there are some differences at corresponding levels of the deep and shallow cores. While disappointing, this might have been expected. Although the calcareous deposit here was still in place, there had undoubtedly been some disturbance due to mining. Again, deposition above the lake sediments, due to calcareous discharge distributed over 3000 acres more or less, must have been irregular and certainly slow. According to Goldthwait, et al. (1965), "The earliest post-till dates on trees submerged by the rising water of Lake Whittlesey in the early Erie Basin are 13,000–14,000 years ago (14,300±450, W–198, in northwest Ohio; 13,600±500, W–33, at Cleveland;

12,900±400, W–430, south of Sandusky)." At Castalia the lacustrine deposits of sand, clay, and silt extend from a depth of 6.2 feet to a contact with till at 54 feet, a thickness of 47.8 feet, with the forest bed dated at 8513±500 B.P. (C–526) (Libby, 1951) between them and the subsequent terrestrial sediments. Thus the 47.8 feet of lake sediments are bracketed within an interval of something like 5000±years, while the 6.2 feet of tufaceous material above them represent the much longer period of more than 8000 years.

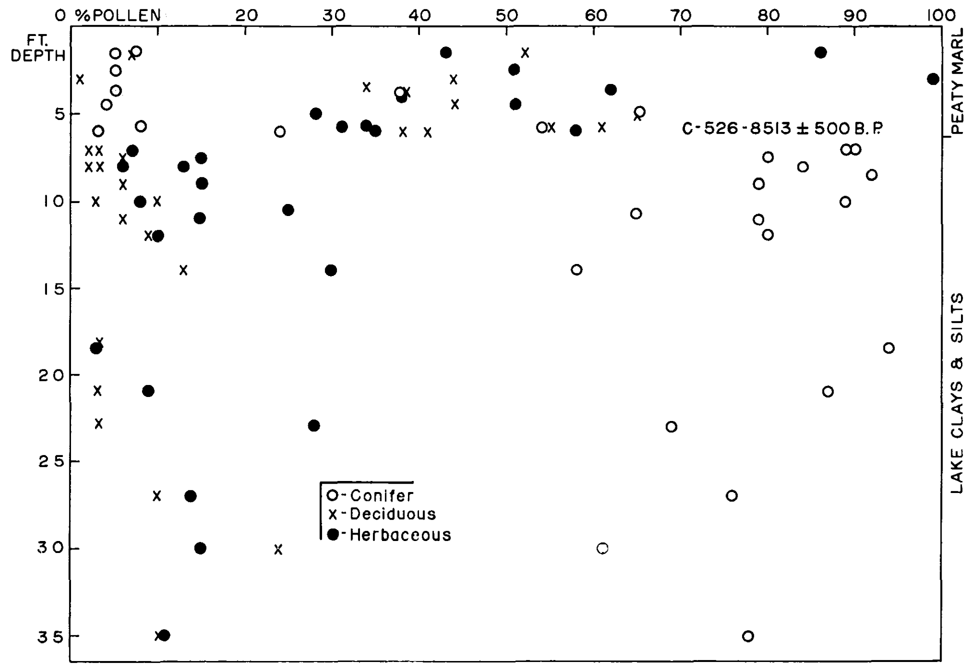

FIGURE 3. Profile showing distribution and amounts of coniferous, deciduous, and herbaceous pollen with depth. Castalia sediments at right. See Table 2 for pollen below 35 ft.

Given such slow and irregular accretion in the top 6.2 feet, it seems futile to look to it for a precise and orderly sequence, or to be surprised at apparent anomalies. In Figure 3 are plotted, against depth, the percentages of conifer, deciduous, and herbaceous pollen from all samples (for sediment types, see Fig 4). The shift from coniferous dominance at the contact between the lacustrine and terrestrial sediments is evident. So, too, is the roughly similar record of deciduous and herbaceous pollen. Table 2, taken in conjunction with Burns' (1958) record of *in situ* forest and the later development of prairie, suggests that much of the tree pollen shown in the upper part of the diagram came from the adjacent environs rather than the prairie itself.

In Figure 4, instead of the conventional pollen diagram, the pollen percentages from the deep core (our X–7, OGS 599) are grouped into somewhat arbitrary ecological categories, as follows:

Arboreal Pollen:	Coniferous	—Spruce
		Pine
	Deciduous	—Alder, Beech, Birch, Hemlock, Linden
		Ash, Elm, Maple, Poplar, Sycamore, Willow
		Oak, Hickory
	Miscellaneous	

TABLE 2

Pollen percentages from 2–E, 2–F and X–7, calculated on basis of total counts

Pollen %	Feet Depth 2–E										2–F					X–7																				
	1.5	3	4	5	5.8	6	6.5	7	7.5	8	7	8	9	10	11	1.5	2.5	3.6	4.5	5.7	6	6.2	6.5	7	10.6	12	14	18.5	21	23	25	27	30	35	40	50
Abies								01	*	*			*	02	*			*	*						*	01	*	*		02		01	02	02		
Juniperus											*																						01			
Larix	01				01							*							01																	
Picea	02	*	14	02	*	02	*	87	75	90	74	72	68	81	71	05	03	04	01	04	12	*		*	53	75	50	85	79	63	*	62	54	59		*
Pinus	03		09	05	10	01	*	02	05	02	15	12	11	06	08	02	02	01	01	04	11	*	*	*	12	04	07	09	08	05	*	13	04	17	*	*
Taxus					*																															
Tsuga	*				01																*															
% CONIFERAE	05	*	23	07	12	03		90	80	92	89	84	79	89	79	07	05	05	04	08	24				65	80	58	94	87	69	*	76	61	78		
Acer	01		*	*	01									*			03		01	01	03						01		*							
Aesculus				*																																
Betulaceae	02		*	*	02	22		01	01	*		01	02	01	02	*	04	*	02	01	*		*		02	02	03	*	*	02	*	03	13	03	*	
Carpinus-Ostrya	*			*	01		*							*	*			*			*				*	02	*									
Carya	08		02	05	07	02			01	*	*	*	*	*	*	*		03		04	*		*						*		*	01	01			
Castanea	01		01													*	01	01	01						*							01				
Celtis				*	*																					01										
Fagus	02		*	01	01	*			*	*			*		*		02		*	02					01	01		*				01		02		*
Fraxinus	01			*	01	04			*									*	*	01					*		01		*			02		01		
Juglans	03																																			
Liquidambar	*																																			
Liriodendron	*																																	01		
Nyssa	*																			*								*								
Platanus	01		23	07					*				*		*					13	03				02	01		*								
Populus	03		*	*	01											01	*	*	01														01			
Quercus	22	01	04	22	32	05			01	*	*	01	02	01	02	01	08	02	23	20	18	*	*		03	01	04	*	*		*	02	06	03	*	
Salix	03		01	22	03	01			*				*	*		04	17	22	13	14	12	*		*			03	*	01		*					
Tilia	02		02		03	02						*	*				02					*														
Ulmus	03		03	03	*	01		01	*			*	*	*	01		06	04	02	05	03	*			*		*		*	01	*	01	03			
% DECIDUA	52	01	38	65	54	38	*	02	06	02	03	03	06	03	06	07	44	34	44	61	41	*	*	*	10	09	13	03	03	03	*	10	24	10	*	*
Alisma					*																															
Alnus	*				*					*	01		*	01	01											01			*					01		
Ambrosia	11	98	02	02	04	09	*	02	07	02		01	01	01	02	01	07	02		*	04	*	*	*	04		03	*	02	02		02		01		
Araliaceae	*			*																01									*							
Artemisia	*		03	02		*		*	01	*		01	03	02	05		*		*	01	01				03	01	05	02	03	05	*	03	01	02	*	
Caryophyllaceae																					*						*	*								
Cheno.-Am.	01		01	*	*	*				*			*		*		02	01	01		*				*		01			01						
Clethra													*													02	*							01		
Clintonia																											*									*
Compositae	05		14	03	02	22		*	*		*	01	01	*	01	15	04	07	04	03	02	*		*	01		03	*	01	01	*	01	03			
Cornus	01				01				*				*								01															
Corylus					01	02						*	*				*	01							01		*		*				02			

Cruciferae				*									*	*		02	*		*	*																
Cuscuta	01		01	01	01							*		*	*			*		01	01						01			02						
Cyperaceae	08			03	04						02	06	04	02	04	*	01		04		01						04			03						
Epilobium	*																																			
Ericaceae													*	*																						
Geraniaceae									*																											
Gramineae	07	01	09	09	02	02		03	04	03	*	01	03	01	02	08	05	04	02	05	11	*		*	08	02	04	*	02	08		01	01	07	*	
Hamamelis	*				04								*		*	*	10	12	14							01				02						
Hypericum	*			*									*		*	01		*		15	05		*		*	01										
Ilex																	*																			
Impatiens																	*		01																	
Juncus	*																																			
Labiatae														*							*															
Ledum					*																															
Liliaceae	02		04	01	01	01					*	*	*			12	06	18	11	02	02		*		01	02			*							
Menyanthes																											*									
Myrica																									*											
Myriophyllum	*																															01				
Nymphaea															*										*											
Oxalis																						*														
Pedicularis													*																							
Plantago					*										*	42	01	*									*					01				
Polygonaceae	*				01								*	*	*	*	02																			
Potamogeton	01				03						*						04	08	02	01													02			
Prunus				*																																
Pyrus																		01									*			*						
Ranunculus						*										*	01		02		*			*		01						01	01			
Rhamnaceae	01		*	*	03			*					*	*	*			01	*																	
Rhus	*				01	02									*	*	*	*									*									
Rosaceae	01		01	02	02	01		*	*		*	01	*		*	03	02	05	07	01	01		*	*	03		*	*		01		01	01			
Rubiaceae	*																																			
Rumex	02		01	*	01	02				*					*			*	01		01						02					01	01			
Sagittaria																											*						01			
Sambucus	*																																			
Sassafras								*																												
Saxifragaceae			*																		*															
Solanum												*																				03				
Sparganium					01				*																							01	01			
Thalictrum														*	*																					
Typha	01			02					01		02	*							*	01							*									
Umbelliferae			*		01	14		*								*			*								*						01			
Urtica																													*				01			
Vaccinium																	*																			
% NAP	43	99	38	28	34	58	*	07	15	06	07	13	15	08	15	86	51	62	51	31	35	*	*	*	25	10	30	03	09	28	*	14	15	11	*	*
TOTALS COUNTED	778	87	209	293	268	162	67	244	249	539	161	301	1099	887	928	231	187	222	238	238	206			17	158	96	206	378	407	86	35	119	124	144	5	12

Non-Arboreal Pollen: Hydrophytes—Sedges, Aquatics
Grasses
Xerophytes —Ambrosia, Artemisia, Chenopods, Composites
Miscellaneous

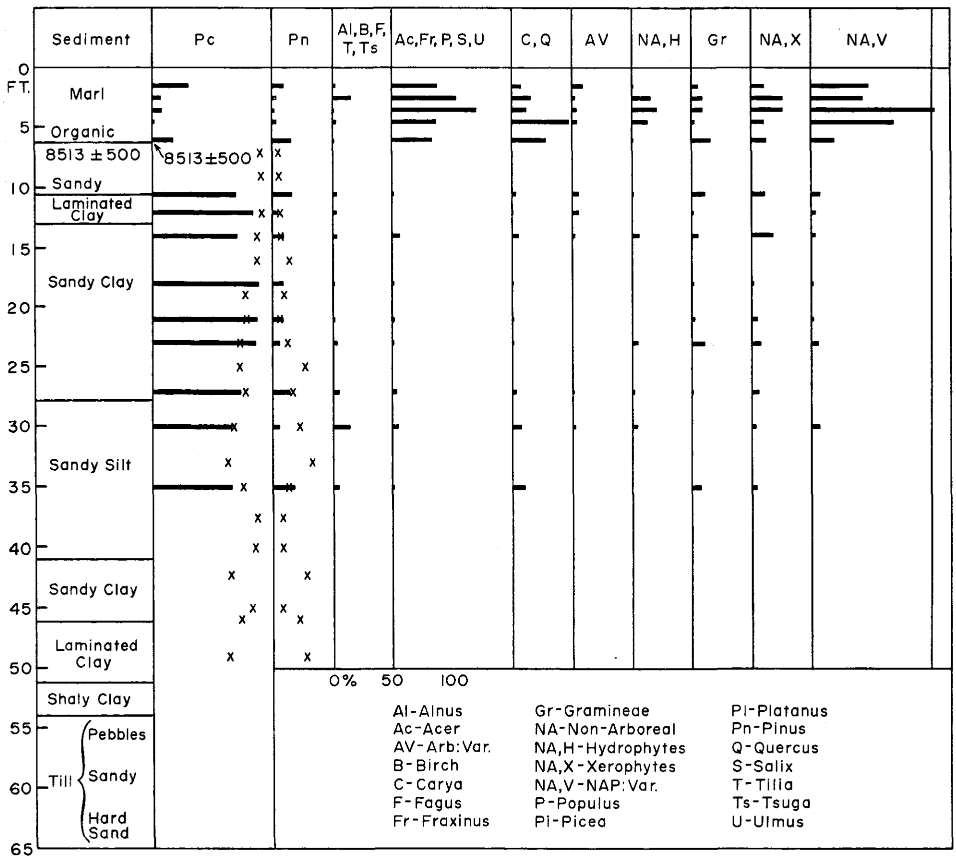

FIGURE 4. Profile of pollen percentages from deep core, plotted for ecological groupings of plants according to depth.

Readers may prefer some modification of this grouping, based on Table 2, but it is not likely to change the interpretation very much. Evident is the sharp change between 10′6″ and 6′2″, from predominantly conifer to deciduous, quite in agreement with the forest bed at 6′± described by Burns and dated at 8513±.

Figure 5 is still more generalized. The horizontal position, A, treats the upper 7 feet as a homogenate, D the 47+ feet of lake sediments likewise, thus contrasting the prairie-deciduous and coniferous zones. Between them B is the aggregate spectrum from Potter (1947) and C is the moss spectrum—both clearly transitional mixtures of conifer and deciduous pollen, with the moss at 634 feet elevation probably older than the Potter samples at 630.

What does emerge from these two diagrams is the persistence of boreal forest conditions (spruce dominance) to the top of the lake deposits and the transition to deciduous forest and rich herbaceous flora in the interval preceding calcareous sedimentation. Thus the pollen profile confirms the finding of Burns (1958) that climatic conditions 8000–9000 years ago had moderated sufficiently to foster the growth of deciduous or hardwood forest and associated nonwoody vegetation.

Because one of my objectives has been to get information as to the origin of prairie in Ohio, peaks in the herbaceous pollen profile are pertinent. There is one of 25 per cent at 10.6 feet in the conifer zone, composed chiefly of *Ambrosia*, *Artemisia* and grass. There is another of 30 percent at 14 feet due principally to *Ambrosia*, *Artemisia*, Compositae, grass, and Cyperaceae, the first four assignable to dry prairie, the last to the wet phase in depressions. Still another of 28 per cent occurs at 23 feet. Further investigation might show these to be related to

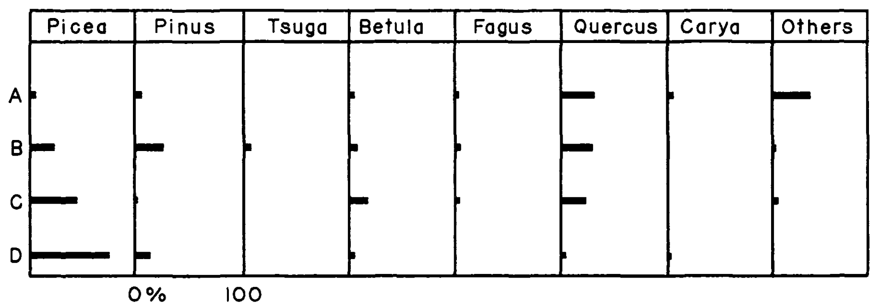

FIGURE 5. Zone or aggregate spectra. A) 0–7 ft. B) Potter samples C) Moss sample D) 7–35 ft.

temporary retreats of the ice while climate suitable to spruce still prevailed. In any event, it is evident that prairie plants grew near enough to contribute pollen before climatic conditions inaugurated extensive development of prairie communities.

Any clue as to when this development took place must lie around the 3–4-foot level, where an herbaceous peak of 86 per cent (*Ambrosia*, grass, *Plantago*) and another of 95 per cent *Ambrosia* occur. It is not out of the question that fire may have been involved, yet the position of these peaks above the forest bed at 8513±500 is significant in view of Ogden's (1966) date for the xeric interval as between 1300 and 3600 years B.P.

The extent to which ablation from dryness may have combined with melting due to warmth to cause glacial retreat is not yet wholly clear, but whatever the proportions may have been, the impact must have been great. Either or both types of climate could have favored an eastward shift of the gradient between grassland and forest, in which case the advance guard of the prairie would have been in a position to take over from retreating competitors when environmental change gave it a decisive advantage. On the evidence available, I am inclined to look upon the development of prairie in Ohio as the outcome of a gradual and orderly migration, with its components at hand to take advantage of optimal climatic conditions instead of being obliged to make a sudden, catastrophic leap.

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REFERENCES

Forsyth, J. L. 1959. The beach ridges of northern Ohio. Ohio Geol. Surv. Inf. Circ. 25: 1–10.

Gleason, H. A. 1923. The vegetational history of the Middle West. Ann. Assoc. Am. Geog. 12: 39–85. (Contr. N. Y. Bot. Gard. No. 242.)

Goldthwait, R. P. and **G. W. Burns.** 1958. Wisconsin Age forests in western Ohio. Ohio J. Sci. 58: 209–230.

——— et al. 1965. Pleistocene deposits of the Erie Lobe. In *The Quaternary of the United States* (Wright and Frey eds.) p. 89. Princeton.

Gordon, R. B. 1966. Natural vegetation of Ohio. Ohio Biological Survey map.

Hough, J. L. 1963. The prehistoric Great Lakes of North America. Am. Scient. 51: 84–109.

Howe, H. 1896. Historical collections of Ohio. 1: 584, Norwalk, Ohio.

Libby, W. F. 1951. Radiocarbon dates II. Science 114: 291–296, C–526, p. 292.

Ludlow, M. 1808. Western boundary of the Firelands. Firelands Pioneer 19: 1868–1870, 1915.

Moseley, E. L. 1899. Sandusky flora. Ohio State Acad. Sci., Special Papers No. 1, 1: 167.

Ogden, J. G., III. 1966. Forest history of Ohio I. Radiocarbon dates and pollen stratigraphy of Silver Lake, Logan County, Ohio. Ohio J. Sci. 66: 387–400.

Petersen, N. F. 1923. Flora of Nebraska. Lincoln, Nebr., 220 p.

Potter, L. D. 1947. Post-glacial forest sequence of north-central Ohio. Ecol. 28: 396–417.

Sears, P. B. 1926. The natural vegetation of Ohio. II. The prairies. Ohio J. Sci. 26: 128–146.

———. 1932. Postglacial climate in eastern North America. Ecol. 13: 1–6.

———. 1966. Lake Lundy time. Science 152: 386.

Wynne, F. E. 1944. Studies on *Drepanocladus*. II. Phytogeography. Am. Midl. Nat. 32: 643–668.