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RECENT CHANGES OF CLIMATE AND VEGETATION IN SOUTHERN NEW ENGLAND AND ADJACENT NEW YORK

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INTRODUCTION

BOTANICAL STUDIES in the Hudson Highlands of southern New York State have suggested the present inquiry into changes which may have occurred in the vegetation during very recent geologic time. By "recent" is meant the past 3000 years or less. The configuration of timber types on the granitic hills in the Black Rock Forest fairly typifies the Highlands region, and is essentially as follows.[1]

Most of the slopes, which for the most part are steep and rocky, are clothed with a forest of red and chestnut oaks (*Quercus borealis* and *Q. montana,* respectively), associated with other trees in less abundance. Formerly the chestnut (*Castanea dentata*) was one of the primary species. In general, the red oaks are more abundant on the lower slopes, and the chestnut oaks on the upper; but in very rocky places the chestnut oak is likely to predominate even at low levels, while the red oak may predominate at high levels if the slopes are gradual. The intervales, or coves, have a mixed forest in which sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), linden (*Tilia glabra*), yellow birch (*Betula lutea*), tulip-tree (*Liriodendron Tulipifera*), red oak, and red maple (*Acer rubrum*) are the commonest species. Beech (*Fagus grandifolia*), American elm (*Ulmus americana*), black birch (*Betula lenta*), white oak (*Q. alba*), shagbark hickory (*Carya ovata*), and a few other species of similar requirements are usually present in smaller

[1]General collections and field notes were made in the Black Rock Forest in the summer of 1936. This material is to be embodied in a forthcoming, more or less detailed description of the flora and types of vegetation. For a more complete description of the Forest than appears here see Tryon, '30.

numbers. Northward-facing ravines and lower north slopes usually have a larger percentage of hemlock (*Tsuga canadensis*), and in a few restricted localities the beech becomes a primary tree. Within the Forest area most of the cove timber lies between 450 and 1100 feet above sea level.

The crowns of the hills, most of which lie between 1200 and 1450 feet above the sea, are distinguished by two types of vegetation. The southwest sides usually have an open scrub of pitch pine (*Pinus rigida*) and scrub oak (*Q. ilicifolia*) interspersed with grassy areas in which *Andropogon scoparius* var. *frequens, Danthonia spicata,* and *Deschampsia flexuosa* are the commonest species, together with some small shrubs such as *Vaccinium pennsylvanicum, V. vacillans,* and *Prunus pumila* var. *susquehanae.* The northeast sides are usually covered with a rather scrubby forest of white oak and pignut hickory (*Carya glabra*). Associated with these trees is usually a dense growth of *Viburnum pubescens* var. *Deamii* which constitutes most of the shrub cover. This association is extremely limited in extent, rarely descending below the crown of the hills, and then only on warm southern slopes. The *Viburnum* is rarely met with anywhere in the region except in these restricted areas.

There is considerable evidence that this arrangement of forest types is essentially the same as that which occurred in pre-colonial times, in spite of the long period of exploitation. This evidence, which will not be discussed in detail here, is mainly in the growth-form and position of very old trees, in the general condition of the soils, and in old records.[1]

It will be readily seen that we have here representatives of three forest types whose geographic ranges are different and fairly distinct. The cove forest is clearly a modified form of the hemlock-northern hardwood type which is commonly associated with white pine and ranges throughout much of the northern Great Lakes states and New England, sending a long tongue southward along the Appalachians (Nichols, '35). The coniferous element is poorly developed in the Highlands region; and the northern hardwoods, instead of being dominated largely by beech, sugar maple and yellow birch as they are farther northward, show a mixed facies as noted above. The chestnut oak - red oak-(formerly) chestnut association of the slopes is closely related to the forests of similar situations in the southern and middle Appalachians (Weaver & Clements, '29; Shreve, Chrysler, Blodgett & Besley, '10). The white oak-hickory association on the other hand is typically middle-western, having its best development in the Mississippi basin. This western

[1]Further discussion of this matter will be found in the writer's projected botanical report on the Black Rock Forest.

affinity is accentuated by the local abundance of *Viburnum pubescens* var. *Deamii* which is here near its eastern limit, and is a common form of the species in the middle-west.

From the standpoint of silvicultural planning it becomes of interest to know the significance of the three types. Is the present state of affairs a static one; or may it be expected to change during the succeeding generations of commercially grown trees? If the latter, may the white oak-hickory type be expected to expand over more of the slopes, with a corresponding restriction of the cove type, suggesting a warmer and drier condition; or may the commercially valuable cove timber be expected to expand up the slopes and the oak-hickory type be still further reduced than it is at present, suggesting a somewhat cooler and more moist situation? In case of the former, the chestnut oak could be expected to occupy more of the slopes than it does at present, and in case of the latter it would probably be more restricted than at present.

There is no reason to believe that the present distribution is a static one, particularly in view of the vast amount of evidence to the contrary in most of the temperate and subarctic regions of the world. To name only a few sources: the succession of vegetation shown in recent peat deposits; fossil floras of other nature involving longer periods of time; the advance of forest into prairie in middle-western United States within historic times, and the oscillation of prairie-forest boundaries in comparatively recent post-Glacial time in the same region. The major problem seems to be rather to determine which way the change is going, and its probable rate.

The present geographic ranges of the three forest types mentioned above are commonly, and probably rightly, thought to be determined by climatic and historical factors operating over very long periods of time. The climatic influences of the Appalachian Mountains on the one hand, and the increasing aridity toward the westward in the Mississippi basin on the other, acting through long periods in the evolutionary history of the deciduous forests, have led to the development of the xerophytic chestnut oak-chestnut, and white oak-hickory types respectively (Weaver & Clements, '29).[1]

[1]There is the suggestion here that we are dealing with a group of forest associations which may be as old as the species which compose them. There is some evidence that the most ancient of the group was the more mesophytic type, consisting of beeches, with ancestral oaks and chestnuts. The scanty fossil evidence indicates that these date far back in the Cretaceous, whereas the modern lobe-leaved oaks, for instance, as well as the hickories, are not known as fossils until the early Tertiary (Berry, '23). If this is the case it is not unreasonable to consider that these xeric expressions within the deciduous forest appeared under the stimulus of the aridity which developed in the interior of America early in the Tertiary.

The persistence of such forest complexes for very long periods of geologic time has

THE PRE-COLONIAL FORESTS

Oak forests in which white, red, and black oaks are predominating elements are characteristic of southern New York and most of southern New England east of the Berkshires (Mass., R. I., Conn.) (Nichols, '13; Bray, '30; Hawley & Hawes, '12). The hickories and the tulip-tree are commonly associated with the oaks, and chestnut was formerly a primary part of the association. The whole has long been classed by foresters as "sprout hardwood"[1] on account of the abundance of reproduction by this method. Except for parts of extreme southeastern New England (S. E. Conn., R. I., and Cape Cod), these oak forests are generally regarded as of secondary origin, i.e., they have come as a result of fire or clearing (Nichols, '13 and '26; Bray, '30; Hawley & Hawes, '12; Lutz, '28; Weaver & Clements, '29; Bromley, '35). The forest type which is generally considered the "climax" in this region, that most nearly in accord with the climate, is a mixed timber of hemlock and the northern hardwoods such as beech, sugar maple, and yellow birch. The white pine (*Pinus Strobus*) is usually regarded as a characteristic tree though its abundance in the primeval forest is thought to have been local at least in New England (Fisher, '33; Nichols, '13 and '35). Arguments for the recognition of this type as climax are adequately summarized by Nichols ('35); and in spite of the fact that the forest bears many characteristics of a transition from the Canadian coniferous timber of spruce and fir to the deciduous woodlands farther south, there seem to be sufficient distinctive characters to warrant its separation.

If the oak forests are to be regarded as temporary in much of southern New England, and likewise the white oak-hickory type in the Black Rock Forest, then it appears necessary to regard the secondary influences as

been pointed out by Chaney ('25), who has based his studies upon the redwood forests of California.

The silvicultural significance of this concept is readily seen. When type-mapping, cruising, or otherwise describing woodlands the forester commonly uses *groups* of species as units; but when working out his silvicultural methods and programs he is prone to deal in *single* species, encouraging or retarding them without much regard for their associational relationships. The final result of such a breaking up of natural associations cannot be predicted without much more knowledge of the species and their relationships than is now available, but the excellent results obtained when the natural associations are in large part preserved are becoming evident in those experimental stands where this is being tried (See Tarbox & Reed, '24; Cline & Lockard, '25). These results, coupled with the probable antiquity and relative permanence of our common forest associations, suggest that further knowledge of the bonds with which the latter are held together would be of great silvicultural value.

[1]This term will be used throughout the paper to designate an association dominated by oaks (mainly white and black), hickory, and chestnut, with the tulip-tree a common constituent. For a general discussion of eastern forest classification see Toumey, '28.

having begun before the advent of Europeans. It has already been noted that in the Hudson Highlands the present distribution of types probably antedates the colonial period. Recent studies in southern New England point to the same conclusion, as expressed in a recent paper by Bromley ('35). Unfortunately the early writers cited by Bromley do not, with one possible exception, present adequate evidence on the interior uplands of the region for which information is most needed. He relies most heavily upon John Smith (1616), Thomas Morton (1632), William Wood (1634), John Josselyn (1672 and '75), and Timothy Dwight (1821). Descriptions written by the first four of these all indicate clearly that the coastal strip was forested primarily with oak and pine, but there is no indication that any of them visited the interior or obtained reliable information on it. Dwight's travels were in the early 1800's or very late 1700's, and were not published upon until 1821. It must be remembered that at this time some of the inland settlements in the Connecticut valley were over 150 years old; and even the youngest of the upland agricultural communities of central New England were at least 50 years old, and many of them twice that age. It must be noted also that the clearing of land for cultivation and pasture was approaching its maximum in many communities (Fisher, '33). It is probable, however, that Dwight was describing remnants of the original forest in some districts, particularly in the younger towns of central Massachusetts.

With these things in view it is pertinent to examine contemporary histories written during the 1700's. A number are available, but most of those found thus far by the present writer have yielded nothing of interest in this connection. The one notable exception is Peter Whitney's *The History of the County of Worcester,* published in 1793. Whitney was a clergyman who was born in 1744 in the western part of this county, in the town of Petersham. He was educated at Harvard College and held a charge at Northborough, Massachusetts, from 1767 to the time of his death in 1816.[1] His history must have been written, therefore, while many of the towns in the county were less than 50 years old; and his observations must have extended back somewhat further than 1767. There must have been relatively large areas of primeval

[1]The writer is indebted to Mrs. Mabel Coolidge of Petersham for references bearing upon the life of Peter Whitney. These are to be found in "An Address Delivered in Petersham, Massachusetts, July 4, 1854, in Commemoration of the One Hundredth Anniversary of the Incorporation of That Town," by Edmund B. Willson (Boston, 1855). That Whitney had an early interest in horticultural matters is shown by his note communicated to the American Academy of Arts and Sciences (See Memoirs of this organization, Vol. 1, p. 386) on the subject of a curious hybrid apple tree in his native town.

forest in the region during his lifetime. The history was written by towns, and in each description is a brief account of the existing timber, with notes on its earlier condition if such were available. Whitney's knowledge of the common forest trees was evidently quite extensive, for in no other way can we account for the detail with which his notes are given. Two checks upon his accuracy are available. One is the manner in which his records of scattered pitch pine plains agree with the known distribution of these. The other is the way in which the hemlock-northern hardwood forest of Winchendon and parts of adjoining towns stands out clearly, just as it does today, in a county otherwise described by him as dominated largely by oaks, chestnut, and "walnut."[1] His descriptions leave little doubt that in central Massachusetts at least the pre-colonial forest was primarily of "sprout hardwood" species. Although the hemlock-northern hardwood forest was predominant on the uplands in parts of the most northern towns, it seems to have been limited elsewhere to lower slopes and ravines.

The aborigines of southern New England were a semi-agricultural people, but there is no evidence that their clearings of the forest ever went beyond relatively small localized areas. Consequently, if a secondary agency is to account for the presence of the oak forests, fire is the only one conceivable. Bromley has cited the comments of several early writers on southern New England in support of the hypothesis that most of the forests of this region which were dry enough to burn (oak-chestnut-hickory and pine) were burned at least once a year by the Indians for centuries before the coming of the white man. It is his opinion that these forests were maintained in this condition by such recurring fires, although he suggests that some of the oak-chestnut-hickory forests in his present "white pine region" may have been edaphic on the drier sites (Bromley, '35, p. 74).

There is no question but that fire has always been a factor in the control of forests, whether set by lightning or by man; and there is abundant evidence that the Indians deliberately set fire to the woods on occasion. Furthermore, anyone who has observed the modern descendants of the red man living in the wild will attest to their common carelessness in putting out campfires. But to picture such a wholesale conflagration in Massachusetts, Rhode Island, Connecticut, and southern New York State as would involve most of the inflammable woods every year, or even every 10 or 20 years, is inconceivable. Even if the forest were not entirely destroyed as a whole, at least the undergrowth and herbaceous species, to say nothing of the animal life, would have been

[1]In the early writings "walnut" was a general term for both *Juglans* and *Carya*.

nearly or quite destroyed over large areas. Yet the country was known to be teeming with game even near the coast when the colonists arrived, and there has never been any evidence of the early elimination of large populations of woodland plants in these regions.

Two sets of facts are worthy of note in this connection. First, the significance of the early writings is open to question here as it is in descriptions of the timber itself: the coastal strip is the only area for which authentic information is available.[1] It is of interest that Peter Whitney makes very few references to fire of any kind in his history of Worcester County.

The reasons assumed by the early colonists for the firing of the forests are also of interest. They appear to have been impressed first, not by the fires, but by the openness and park-like character of the woods. They attributed it at once to the efforts of the natives, usually giving as purposes either the improvement of visibility and travel by eliminating the undergrowth, or the "improvement" of pasturage for game by encouraging the growth of grasses and other herbage in the forest.[2] Without exception these writers were western Europeans whose ancestors had lived for centuries in a region continually under the influence of civilized man; consequently it was difficult or impossible for them to conceive of open, park-like woods growing naturally, without human intervention. Natural woods was for them of necessity a dense growth, either of conifers or of coppiced hardwoods such as they knew in Europe or the British Isles.

Open, park-like woods have been, from time immemorial, characteristic of vast areas in North America. Almost anywhere one chooses to look on the periphery of the great arid plains of the interior of the continent he sees this savannah or park-land extensively developed. Its occurrence far eastward in Ohio has led to some of the most interesting and far-reaching hypotheses in American plant geography (Gleason, '23; Sears, '33 and '35a; Transeau, '35). Most of the initial reactions of Europeans to these western park-lands or open woods have been identical with those expressed by the earliest New England colonists: that they had been caused by fire, usually thought to have been set by

[1]For comment on the dearth of information about the interior of New England in 1630 see the edition of Thomas Morton's *The New English Canaan* published by the Prince Society, Boston, in 1883, with introductory matter and notes by the historian Charles Francis Adams. Morton was notably inaccurate in many lines, and was doubly so when writing of the interior. He wrote with seeming authority, but in fact quite at random, about the country around Lake Champlain, and farther south he confused the Hudson and Potomac Rivers.

[2]In addition to the early New England writers cited above see also Van der Donck (1656).

the Indians. This manner of explanation persists to the present, and recently discovered park-lands in northern Canada have been accounted for by some travellers and students in the same way.[1] No one will doubt that fire has had a significant influence in determining the presence of park-land, but wherever detailed and careful studies have been possible, fire has been slowly forced into the background as an actual *causative* factor, and fundamental climatic, edaphic, and historical factors take their rightful precedence (Sears, '33 and '35a, b; Moss, '32; Transeau, '35, p. 434).[2]

It seems necessary therefore to question rigorously or to discard in large measure the evidence of early writers for the relative openness of the woods on the inland region of New England and southern New York. Likewise it is doubtful whether the reasons they have given for the openness near the coast can be accepted at face value. Judging by what is known of park-lands and open woods in general, and particularly in view of the similarity between the southern New England oak-hickory forests and those of the middle west, it is more logical to think that the pre-colonial oak-chestnut-hickory type which prevailed in much of the region was the normal vegetational expression of the climatic-edaphic complex which had obtained here. No doubt fires helped to maintain it against the competition of the more mesophytic forests to the north and northwest, but that fires were the sole factor in maintaining it is difficult to believe.

With the antiquity of the oak-chestnut-hickory forests in this region fairly well established, the question naturally arises as to why they are almost universally regarded among foresters as temporary types except in the extreme southeastern sections. Two reasons might be suggested. One is the widespread concept that clearing and fire have caused radical changes in the composition of the forest, and that since practically all of the original forest in this region has been destroyed the present stands are very likely to be different from the original. By further reasoning along this line it is assumed that if the present stands are properly protected they should revert to this hypothetical original state. There is abundant evidence in support of this concept, particularly in southern New England where such a large percentage of the land was allowed to

[1]For discussion and citations in this connection see Raup, '34.

[2]Gleason postulated two advances of prairie vegetation into the middle west. The first he thought was due to an extension of arid climates, but the second he accounted for by the appearance of the Indians who drove the forest back with prairie fires. The forest advance of modern times he attributed to the protection from fire which was afforded by white settlement. It seems more probable, in the light of Sears' correlations of evidence from many regions, that the recent advance (providing there were two of them) was due also primarily to a more arid climate.

return to forest after being cleared or under cultivation for several generations. The well-defined succession of facies in abandoned fields thoughout this region is enough to account for the whole idea.

Another reason which might be advanced is that there is an actual progressive elimination of the oak-hickory forests from the region, and a corresponding advance of the hemlock-northern hardwood type. A great deal of evidence has accumulated which supports this. Old field timber at the Harvard Forest in Petersham, Massachusetts, tends to develop toward a forest of northern and "transition" hardwoods rather than toward one of white and black oaks and hickory[1] (Fisher, '18 and '28; Griffith, Hartwell & Shaw, '30; Spaeth, '20; Averill, Averill & Stevens, '23; Cline & Lockard, '25). The wide extent of this tendency in the northern half of Worcester County, adjacent Franklin and Hampshire Counties, and adjacent New Hampshire is shown in a recent survey of old field pine lands by McKinnon, Hyde & Cline ('35). Of 225 stands examined, involving approximately 2023 acres, only 15 stands covering 132 acres could be classified as of white oak-hickory type, and these were all in the southern part of the district. All of the remainder were noted as of northern or "transition" hardwoods, mainly the latter in which red oak, white ash, white and black birch, red and sugar maple are the predominant trees. Over a large proportion of this very region Peter Whitney described oak-chestnut-"walnut" forests early in the history of the settlements. Towns with such woods were Petersham (part), Athol (part), Oakham, Paxton, Barre (part), Sterling, Lunenberg, Harvard, Holden, Leominster, Westminster, Hardwick and Rutland. It is of interest that in a few places he recorded that the "walnut" seemed to be increasing. This was probably due to the opening of the oak-chestnut forests and may be observed throughout the oak-hickory regions of the middle west where clearing of old growth commonly gives rise to dense stands of sprout hickory very soon afterwards.[2]

[1]It is presumed that the oak-chestnut-hickory forest described by Whitney involved white and black oaks more prominently than red. This is based upon the present known relationships of these species. The red oak is a primary constituent of the so-called transition hardwoods, in which the hickories do not play an important part; the latter are usually most abundant in association with white and black oaks in this region.

[2]An outstanding feature of the New England forests during the past 75-100 years has been the growth of white pine on abandoned farm lands. Vast acreages seeded in to nearly pure stands of pine very soon after they were abandoned, and produced a wealth of lumber during the latter part of the last century and the first of the present one. In fact most of eastern Massachusetts, northeastern Connecticut, and northern Rhode Island has come to be known as part of the "white pine region" (See Sargent, 1884; Hawley & Hawes, '12; Bromley, '35). It is thought, however, that in the hypothetical virgin forest of hemlock and northern hardwoods the white pine was "a normal, although minor, constituent," and that its presence in the climatic climax association was due to local, more or less accidental openings in the

The tendency for the hemlock and more northern hardwoods to succeed the oaks and hickories has been noted repeatedly in Connecticut. Nichols has this statement in a recent paper: "Not without significance also may be the fact that in Connecticut and elsewhere along the southern borders of this region [hemlock-white pine-northern hardwood] the hemlock and northern hardwoods gain successional ascendency over oaks and other relatively southern trees when competing with them on the better soils . . ." (Nichols, '35). Lutz ('28) concluded, on the basis of a careful study of forest successions in southern New England, that the major trend was toward a hemlock-hardwood type, and Bromley ('35) appears to be of the same opinion.

There is good evidence therefore that within the past 200–300 years some of the more southern elements in the forests of central New England, notably the hickories and walnuts, have been partially eliminated, and that the secondary forest successions in southern New England east of the Berkshires generally are trending toward a forest of hemlock and northern or transition hardwoods rather than toward one involving white and black oaks and other "sprout hardwoods." If the pre-colonial forests were primarily of oak-chestnut-hickory over most of this region, then we are confronted with the question of how this distinctly southern and western phase of the deciduous forest came to predominate in a region which now appears to be largely unsuited to it.

Although generally adhering to the idea that the sprout hardwoods in Connecticut were due to the influence of man, Nichols expressed some doubt in his early papers on the vegetation of that state as follows: "But the forest is by no means uniform in structure throughout the state. Most widely disseminated and of greatest economic importance is the "sprout hardwood" type which represents the usual climax formation over fully five-sixths of the state. . . . To what extent these modifications in forest composition should be attributed to contemporaneous factors cannot be definitely decided. In a measure the presence or

hemlock-hardwood stand (Nichols, '35; Fisher, '33). A question naturally arises as to the source of the large quantities of white pine which appear to have been available to the early settlers. With the pine so much in demand, it was the first of our forest trees to be seriously depleted in many regions. There is, therefore, a further question as to the source of the seed which produced the immense development of old field pine during the last century.

If the pre-colonial forest was mainly of oak, chestnut, and hickory, it might be expected that the white pine was far more abundant when the settlers came than is now supposed. This forest would have been relatively open and considerably drier than the hemlock-northern hardwood type, and more subject to fire. Under these conditions a considerable amount of second-growth pine could have developed during the period prior to wholesale abandonment of farms, this later to maintain a supply of lumber and to seed in the open fields. It is notable that Whitney records an abundance of white pine during the early history of many towns in Worcester County.

absence of particular species may be the result of geographic position, but it seems more likely that this scarcity or abundance is determined by physiographic or climatic factors" (Nichols, '13, p. 100). Bromley, on the theory that fire was the cause for the prevalence of the oak-chestnut forests, found it necessary to postulate extremely frequent conflagrations, extending over most of southern New England, and during centuries of time. The early colonial writers mention only the burning of oak-chestnut forests, since these were the only ones which were common near the coast; and Timothy Dwight (Letter VIII) states that the oak-chestnut and pine lands were the only ones regularly burned because only they were dry enough. If this was the case, then we must either assume that the "dry" forest of oak and chestnut was here before the Indian arrived, or that an ancient forest of hemlock and northern hardwoods very gradually succumbed to very frequent fires started on a few dry sites and encouraged by occasional dry years.

As suggested above, the absence of good evidence that such intense burning occurred on the interior uplands, or that it was significant on the coastal strip, must now be coupled with doubt as to the actual function of fire in originally *causing* the prevalence of sprout hardwoods. It seems necessary to look at climatic or edaphic influences of long standing in the region as a whole for further light on the matter, and to study the history of the vegetation with this broader aspect. Nichols suggested this in 1913, as indicated above; and Bromley has noted that climate might have been effective: "As we do not as yet have pollen analyses of peat bogs from New England, we do not know exactly how or when one forest type succeeded another. It is known, however, that in the middle west, a dry period occurred about 3000 years ago which resulted in a dominance of xeric species, principally oaks. Although there is no present evidence of such a period in southern New England, it is not unreasonable to suppose that such did occur and very probably was the basic reason for the establishment of oak and pitch pine forests which were maintained by the Indians' fires until the white occupancy" ('35, p. 68).

If a warmer and drier climate existed in southern New England within the past 3000 years it is reasonable to expect that there should be some evidence of it remaining. With this in view, and remembering that a warm-dry period in the southern Great Lakes states was first recognized entirely upon floristic grounds, without benefit of pollen analysis, the present writer has attempted to gather such evidence as could be found. Various lines of inquiry have yielded results: botanical, zoological, paleontological, and archaeological, and these will be presented in the following discussion.

ZOOLOGICAL EVIDENCE

The occurrence of a "Virginian" element in the New England-Acadian coastal fauna was pointed out as long ago as 1862 in a paper by John Willis which incorporated the observations and suggestions of Sir William Dawson. In later years the data have been greatly amplified, and various hypotheses advanced to account for them. An excellent summary of the problem to the time of its publication is in a paper by W. F. Ganong in 1890. He listed 28 species of molluscs and echinoderms, besides a group of marine algae, which are of southern affinity but scattered northward along the coasts of New England and the Maritime Provinces. The form most commonly cited as an example of this dispersal is the oyster, which now occurs only in a few places in these waters, but which was evidently much more abundant in colonial times. There are repeated references to oyster banks, for instance in the Charles River basin at Boston (Hubbard, 1680; Josselyn, 1638 and 1663; Wood, 1634; Higginson, 1629), although these have long been extinct. Their abundance at various places along the coast in former historic times is proved by other early writings and by Indian shell heaps composed almost entirely of oyster shells. One of the largest of these heaps is in the estuary of the Damariscotta River in Maine. It has been studied recently by R. P. Goldthwait who also summarizes the present distribution of oysters on the Maine coast: "In Maine oysters are restricted to rocky current swept estuaries. Although numerous oyster beds thrive in the protected Gulf of St. Lawrence, further north, the relic colonies at Oyster River almost in Maine (Durham, New Hampshire) and at Sheepscott Falls, adjacent to the Damariscotta River, live in swift water nearly ten miles from the open ocean. These are the only known beds in hundreds of potential locations, and even they threaten to expire" ('35, p. 5).

There is abundant fossil evidence that oysters as well as many other southern forms were more common and widespread in northern waters in recent geologic time. Ganong reported the common occurrence of fossil oysters brought up from beds off-shore on the coasts of the Maritime Provinces (1890, p. 175). Upham summarized data from the vicinity of Boston in 1892 as follows: "Taken as a whole, the twenty-five species comprised in the identified fauna . . . belong in their present geographic range to a somewhat more southern and warmer portion of our coast. Fourteen are distinctly southern, and reach their northern limits at Cape Cod or in Massachusetts Bay, and in one instance near Portland, Maine; excepting that several of them occur in isolated colonies far north of their general and continuous range, as in Casco and

Quahog Bays, Maine, and especially in the shallow southern part of Acadian Bay of the Gulf of St. Lawrence, from Cape Breton Island to the Bay of Chaleurs. The occurrence of these southern molluscs, which are mostly now absent, or local and rare, north of Cape Cod, shows that the sea during some part of the Recent epoch has been warmer than at the present time" (1892, p. 203). Regarding the extinction of southern forms he states: "During the time of the accumulation of the aboriginal shell-heaps . . . of Maine, and even within the 270 years since the first white settlement in Massachusetts, very significant restriction and extinction can be shown. For example, Professor Verrill, 1874, states that dredging reveals the occurrence of great beds of oyster shells a few feet beneath the harbor mud at Portland, where they are associated with the quahog (*Venus mercenaria*), scallop (*Pecten irradians*), and other southern species; and that the oysters and scallops "had apparently become extinct in the vicinity of Portland Harbor before the period of the Indian shell-heaps, for neither of these species occurs in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay" (1892, pp. 208–9). Upham concludes that: "The extinction of oysters, and of their southern associates has been rapidly going on from Nova Scotia to Cape Cod since the earliest settlement of the country, due probably not so much to their exhaustion by being gathered for food, or to any and all other causes, as to the progressive refrigeration of the sea; . . ." (1892, p. 209).

More recent findings corroborate the above. Shimer, reporting in 1918 on the subway excavations in the Boston Back Bay district, describes the recent submergence of the coast, and the deposit of shell muds: "The shells inclosed in the mud deposited upon the peat since its submergence beneath the sea give evidence of two climatic periods,—an earlier period (4a) warmer than the present and a later colder period (4b) extending to the present . . . 4a This fauna, representatives of which are rare or altogether wanting off our coast today, is now dominant off the coast of Virginia, though it ranges from Cape Cod to Cape Hatteras. Of the sixty some species noted . . . about half no longer occur north of Cape Cod, or only rarely in sheltered places, but find their perfect environment farther south" (Shimer, '18, p. 456; Antevs, '28a, p. 93).

J. Brooks Knight ('33) has recently summarized the facts regarding the distribution of the southern gastropod, *Littorina irrorata*. This species was formerly abundant in a few sheltered places in Long Island Sound, but apparently became extinct there about the middle 1800's.

Its shells have been found abundantly, however, in a fossil fauna underlying a salt marsh near New Haven, and have also been found in Indian shell heaps in that vicinity.

The preceding notes on the coastal faunas of this region point clearly to a comparatively recent period when the waters were warmer, permitting an extensive northern dispersal of species now more or less confined to the coasts south of Cape Cod. The effects of the refrigeration of these warmer waters appear to have continued into historic times, as shown by the progressive elimination of species to the present. Furthermore, during at least a part of this time there was a subsidence of the coast. There can be no question that the final causes for the elimination of the oyster from our shores can be laid to invading Europeans, but this will not apply to the many species of no particular food value which have also been progressively restricted or eliminated, even within historic times.[1]

The pre-colonial distribution of land animals in New England is greatly obscured by the changes which have occurred with settlement. A suggestive finding along this line is in a paper on the former distribution of the wild turkey, by Professor Glover M. Allen ('21). This southern bird extended northward along the coast at least to the Kennebec and probably to Penobscot Bay. Inland it did not range north of southern New Hampshire and Vermont, getting as far north in the former as Concord. Its northern limit is thus roughly coincident with the northern boundaries of the former oak-hickory-chestnut forests noted above. In fact, Professor Allen has suggested a definite relationship: "The limit of its range thus corresponds roughly to the transition faunal area, and was possibly more or less coextensive with the area over which red and white oaks were sufficiently abundant to furnish food in reasonable quantity. Possibly the apparent absence of the Turkey from most of Vermont is explicable through the comparative scarcity of oaks, whose place in the more limy soils seems to be in part taken by sugar maple, beech and butternut."

Many other southern birds can be cited as examples of the same range which have not been destroyed by the coming of the white man. Professor Allen ('02) notes the following in his study of the birds of New

[1]Some recent investigations indicate cyclic fluctuations in the temperature of the inshore water on the New England coast. These studies have been made in connection with the recent increase of the shipworm, *Teredo navalis*, a boring mollusc which does great damage to marine pilings. Several other southern organisms are enumerated which also appear to be increasing in New England, but whether or not their coming may be related to minor climatic changes is not determined. The water temperatures show a rise since 1925, approaching a level which was previously held for several years prior to 1920 (See first and second progress reports of the New England Committee on Marine Piling Investigation, Boston, 1934-'35, 1935-'36).

Hampshire: green heron, bob-white, yellow-throated vireo, grasshopper sparrow, Bartramian sandpiper, and cowbird. Still others scarcely extend north of the northern boundary of Massachusetts (Forbush, '25–'29), either as residents or casual visitants: Acadian flycatcher, orchard oriole, white-eyed vireo, blue-gray gnatcatcher, yellow-breasted chat, mocking bird, golden-winged warbler, prairie warbler. The relative abundance of these species in pre-colonial times in comparison with their present condition is largely conjectural. The elimination of the wild turkey can be laid to man, but another striking disappearance from New England is that of the dickcissel, a bird having no direct food relationship to man. It is characteristic of the Great Plains region, extending westward to the Rocky Mountains. Forbush states that it "formerly bred on the Atlantic slope from Massachusetts to South Carolina and Georgia, but [is] now very rare or casual in that region." Nuttall noted that it was common in eastern Massachusetts in the early 1800's. It is not improbable that the tendency indicated here has had some effect upon the ranges and relative abundance of many other animals whose optimum living conditions are found far to the south and west.

ARCHAEOLOGICAL EVIDENCE

With a view to finding whether there have been changes in the aboriginal life of New England which might be interpreted in terms of climatic alteration, the writer has ventured into the archaeological literature touching upon the region. There is excellent proof that the Indians lived here during at least a part of the period of warm water coastal fauna as well as during the time of refrigeration. The finding of the remains of a fish weir set in the glacial clay beneath the shell muds of Boston's Back Bay has been studied and described by Shimer ('18) and Willoughby ('27). Some 3 to 4 feet of the lower section of the shell muds were deposited after the weir was built, and these contain the southern fauna noted by Shimer in his horizon "4a" (see above).

Dr. Paul B. Sears has recently advanced the hypothesis that the Mound Builder cultures of our middle western states may be correlated causally and in point of time with climatic changes in that region. These cultures were based upon the successful growth of maize, and constitute an agricultural development in a region which otherwise had supported a culture based in large measure upon the chase (Shetrone, '20). One of these cultures, the Hopewell, is known to have extended westward to Iowa, and it is suggested that the development came during a period when more arid climates caused an extension of prairie and park-land eastward into Ohio where such types of vegetation now occur only as relics (Gleason, '23; Sears, '26). Sears ('32) has summarized these suggestions as follows:

"It must be emphasized that whoever the inhabitants of the Ohio valley were at this time, or whence they came, they enjoyed the optimum conditions afforded during post-glacial time for the development of a successful agricultural civilization. Rich and varied soils of glacial origin, abundant game including the bison, open country with numerous groves of useful kinds of wood, streams easily navigable and full of fish, all favored such a development.

"The intrusive[1] character of the highest mound cultures and the subsequent repossession of their lands by Algonkians is exactly what we might expect if the eastward extension of the corn-belt conditions was a significant factor in such mound cultures."

With regard to the timing of these events Sears states: "If we may judge by the persistence of relict vegetation in favorable localities many effects of this dry period . . . may have long outlasted the actual climatic turn toward the more humid conditions of today. This is significant. Although dry conditions were at their maximum about 3000 years back, we must remember that such was their influence that any final assignment of dates for the higher cultures in Ohio up to 900 years ago is not unreasonable" (See also Sears, '32a, '35a, b, '33).

That the "intrusive" nature of the Mound Builder culture was not confined to Ohio is shown by investigations in New York and New England. There is some evidence that the mound-building people themselves reached western New York State (Parker, '20; Ritchie, '32). The aboriginal history of this state has been divided into three periods of Algonkian occupation. The earliest is represented by crude implements, and evidently featured a woodland, hunting culture. The second is characterized as follows by Ritchie ('32, p. 410): "The combination of brachycephaly with such distinctly new elements as clay and steatite pottery, the pipe, grooved ax, polished slates, and marine shell beads has compelled the writer to postulate a southern source for the Second Algonkin culture of New York. These artifacts occur together over much of the south Atlantic as well as the Mississippi-Ohio area . . ." These people also brought agriculture, and are thought to have originated in the region about Chesapeake Bay. "A later phase of this period was certainly influenced by small bodies of mound-building people entering the state through the southwestern counties"; and "The mound influence may be credited with the presence in New York of the

[1]Judging by recent attempts at a new classification of these cultures it may be necessary to consider that they were local evolutions rather than intrusions.

following: the platform pipe, stone tubes, bar amulet, boat stone, native pearl beads and considerable copper in the form of axes, spears and beads" (Ritchie, p. 412).

The third period is related to the Iroquois invasion. "The migration [of the Iroquois] into the state through its southwest corner and probably up the Susquehanna from northern Pennsylvania brought them into contact with the Algonkin of the Second Period, and the writer believes that this influence constituted the impetus behind the cultural alterations which differentiate the Third Algonkin Period" (Ritchie, p. 413). "The elbow-type pottery pipe, noted in a crude form from the Second Period, reaches its acme of artistic perfection in the Third . . . The bone harpoon, both unilaterally and bilaterally barbed, recorded only once from a Second Period site, becomes an important implement at this time. There is, however, a total absence of the grooved ax, gouge, plummet, polished slates, ocean shell beads, and copper" (Ritchie, p. 414).

Further references to the intrusive mound cultures are as follows: "One is led to believe that the later Algonkian copied to a large extent the material culture of a more advanced division of the race that came from the south and west, but which after a certain time was either absorbed or unable to maintain itself in the eastern section" (Parker, p. 48); and "Certainly the material culture of the eastern Algonkins seems to have been considerably modified by this culture [mound], just as later New England tribes were modified by the Iroquois. It is quite possible, therefore, that the mound culture people intruded into the hunting grounds of certain Algonkin bands and established themselves" (Parker, p. 94). "The mound-building people seem to have disappeared from New York at or before the time of the coming of the Iroquois into their area of recognized occupation . . . A survey of the earliest Iroquoian sites, especially in western New York, leads us to believe that the earliest Iroquoian immigrants were measurably influenced by the mound-building culture" (Parker, p. 97). It is thought that the Iroquois did not become established in this region until 500 or 600 years ago.

The evidence just outlined suggests that in western New York State, as well as in the Ohio region, an agricultural, somewhat sedentary people who mastered the use of stone and copper for implements and ornaments succeeded a more primitive, apparently non-agricultural, nomadic people whose arts had never been so highly developed. These were in turn succeeded by the war-like Iroquois who, although they remained in large measure agricultural, apparently lost or never acquired many of the arts of their predecessors in the use of stone and copper.

The intrusion of these arts into New England has been remarked upon by several students. "That the eastern Algonkin received a great cultural impetus from the intruding strangers cannot be doubted. We have some realization of this when we note the thinning out of the polished slate objects in eastern New England, southern New York, Pennsylvania and the region north of the St. Lawrence basin . . ." (Parker, pp. 49–50).

The Europeans found the New England Indians culturally divided into two groups (Dixon, '14; Willoughby, '35). Those north of a district approximated by the northern boundary of Massachusetts (Abnaki and Pennacook groups) were mainly woodland hunters although they practiced agriculture to some extent. Their racial affinities were apparently to the north and northwest, and they made extensive use of birch bark for shelters and utensils. The tribes of Massachusetts, Rhode Island, and Connecticut on the other hand were in large measure agricultural and had a rather highly developed social organization. When the Pilgrims first came to Cape Cod these Indians had already, either directly or indirectly, been in contact with European civilization for many years, so that their actual status as a primitive race is difficult to fix (Willoughby, '35).

Willoughby makes a division of Indian history in New England not unlike that of Parker and Ritchie for New York State. He thinks that an early primitive people unacquainted with agriculture was succeeded by a group related culturally or racially to the Mound Builders west of the Appalachians. "The third culture group to occupy New England was probably an outgrowth of the second. The material culture of these later Indians underwent a marked modification during the period of their virtual separation by the Iroquois from their western kindred. Contact with the Iroquois seems to have been in a measure responsible for this, and in later times intercourse with the many European fishing and trading vessels throughout the greater part of the sixteenth century was a strong factor in the deterioration of certain of their native arts" (Willoughby, '35, p. 2). The distinction between a primitive, non-agricultural people ("pre-Algonquian") and later more highly civilized ones ("Old Algonquian") appears open to some question, although a few sites have been found which indicate a primitive culture which did not include pottery; that is, to assume a *consecutive* arrangement of "primitive" and "non-primitive" sites cannot always be done with assurance (See Delabarre, '25).

However, that there was an *evolution* in the native arts during the so-called second period in New England, influenced by western culture, seems clear. Ritchie suggests (p. 411) that "Shell middens on the Connecticut, Maine and Nova Scotia coasts, apparently related to certain inland sites, probably mark a northward extension of the Second Algonkin occupation of New York, for they contain such characteristic artifacts as stamped pottery, the grooved ax, plummet, broad-bladed projectile points, perforated animal teeth, the bone gorge, and hematite." If this relationship is correct, these people probably brought agriculture to New England, as they did to New York State, and likewise developed their culture further under such partial influence of the Mound Builder civilization as penetrated the east. A tradition of the southern New England Indians as recorded by Roger Williams (1643) was that their corn and beans had been brought from the southwest.

It has been suggested above that the Iroquois invasion had already marked a notable change in the culture of the southern New England Indians before the arrival of the Europeans. Their history seems to have had the same general pattern as that of the Indians of New York State. Possibly following an early primitive hunting culture there came southern peoples who brought agriculture. This was amplified to produce a semi-sedentary group which could live in large villages and have enough leisure to develop a degree of art. The impulses which led to this development apparently came from more southern and western tribes. The establishment of the Iroquois, as noted by Parker, was probably not over 600 years ago, so that we may regard the so-called "Old Algonquian" culture as having persisted nearly or quite into the period of European discovery.

There is considerable archaeological evidence, therefore, of a rise and decline of certain of the Mound Builder cultural influences in New York State which can be correlated with similar changes in the middle west; and in southern New England there is evidence of an evolution of agricultural civilization during approximately the same period as in New York. If the changes in the middle west can be traced to the influence of climatic and vegetational variation, we can properly expect that the same influence was effective in the east. A warmer and drier climate in southern New England would have greatly facilitated primitive agricultural development, since competition between man and the forest for the occupancy of cultivated lands would not have been so rigorous as under earlier or present conditions.

THE PROBLEM OF COASTAL SUBSIDENCE

Attempts to interpret climatic changes on the New England coast are inextricably entangled with the problem of coastal subsidence.

This is especially true of attempts at dating the changes. It is not intended to go into a detailed discussion of this problem here, but a brief statement of it is in order. There seems to be general acceptance of the idea that there has been either a relative rise of the sea with respect to the land, or an actual subsidence of the land, in comparatively recent post-Glacial time. There is, however, considerable controversy as to whether this so-called subsidence is still going on, or whether we must insert into the chronology an indefinite period of stability following the period of subsidence. In the present inquiry it is of interest to know whether the faunal and floristic changes which occurred *during* the period of subsidence were finished at some remote time when sea level is supposed to have become stabilized, or whether the changes have actually approached the present in point of time.

Evidence that subsidence has continued to the present or to very recent times has been gathered from drowned forests and freshwater peat beds, the structure of shore marshes, measurements of tide levels over a period of about 70 years, and the youthful character of rocky shores.

Drowned forests and peat deposits have been described at many sites along the New England-Acadian shore. An account of them was published by Ganong in 1903 for the region of the Bay of Fundy, where they were first described by Dawson (1855) and later by Chalmers (1895). Well-preserved stumps have been found in place more than 30 feet below high tide, and Chalmers found a peat bed 20 feet thick beneath 80 feet of marsh mud. The drowned forests range from these greater depths to more recently extinct ones which now appear between high and low tides (Bartlett, '09; Antevs, '28; Lyon & Goldthwait, '34). In general the wood in these deposits is remarkably well preserved, indicating a relatively recent origin.

An outstanding feature of most of the New England salt marshes is that the underlying peats do not contain a succession of forms representative of high and low tide floras; but the high tide forms are more apt to be found at considerable depths, often underlain by freshwater peat. This situation was interpreted many years ago by Mudge (1858), and later corroborated by Davis ('10; Bastin & Davis, '09) and Johnson ('25), as indicative of deposit during slow submergence of the land. The same conclusion was reached by Nichols ('20), studying the salt marshes of Connecticut. Marshes of the "Fundy type" (Johnson, '25) have been interpreted in the same way (Dawson, 1855; Ganong, '03), although they are formed differently, and composed largely of silt rather than peat. It was Davis's opinion that the submergence has continued to the present time ('10; Bastin & Davis, '09); and Nichols ('20) and Bartlett ('09) present evidence for the same conclusion. Nichols points out that on a stationary shore no succession of types [fresh to salt] should be apparent in the peat deposits, and that only where the rate of upbuilding exceeds that of submergence could there be a succession in peats similar to the littoral "zoning" of vegetation postulated by Shaler (1886). Since succession of a "retrogressive" or reverse order to this is common on the New England coast, there seems only one explanation: that the coast is subsiding, or at any rate is being invaded by the sea. That the invasion has been slow is shown by the absence of breaks in the deposits of plant parts *in situ*, often through several feet of depth. Furthermore, these "retrogressive" successions appear to have continued to the present time, as indicated by their presence in the most recent deposits. Bartlett has described the recent invasion of *Chamaecyparis* bog by salt marsh at Woods Hole, with fresh-water deposits a foot beneath the surface over a large area of the present marsh. Johnson ('13), on the other hand, cannot agree that such evidence is reliable, and conceives that Bartlett's bog may have reached its present condition by local shrinkage or sinking.

Records of the relationship between the heights of tides or of mean sea level, and certain "fixed" objects on the shore are open to criticism on account of the relative instability of the fixed objects. Frost action, local undermining, and various sorts of human disturbance are likely to cause movement; and since the reputed sinking of our coast line must be extremely slow, even small shifts in these bench marks are likely to greatly affect the comparison. Nevertheless, making due allowance for such factors, John R. Freeman published in 1903 an exhaustive study of the supposed subsidence at Boston. Basing his figures on records made at the dry dock of the Charlestown Navy Yard in 1831, he concluded that during the succeeding 72 years the subsidence had been 0.71 foot. Records from tide gauges at India Wharf showed approximately the same rate of subsidence over a period of 34 years, and calculations of the so-called "Boston base" showed about the same rate over 35 years. Other evidence of this nature, but less precise, comes from records of high storm tides, and from records of the depth of rocks, particularly near Salem (J. H. Sears, 1894).

There remains the evidence from shore lines on rocky coasts. A clear statement of this has been made by Flint ('30, p. 225), and will bear quoting: "The shoreline of Connecticut is in a youthful stage of development. Its status as a shoreline of submergence is indicated by its indented, ria character, and is abundantly proved by facts adduced in an earlier part of the discussion. Certain abnormalities in its aspect show that the submergence either has stopped but recently or is still in progress. For example, the bedrock along the shore, even on the most exposed promontories, has not been so much as trimmed by wave-erosion. If the sea had been standing long at its present level, the result would have been a cliffing of the headlands even by the relatively small waves generated in a body of water protected from the open sea."

Ranged against this somewhat formidable array of evidence are mainly the studies of D. W. Johnson and his coworkers at various points along the coast, and some recent investigations of the Damariscotta shell heaps. Johnson ('17; '29) has been unwilling to admit of any recent subsidence on the New Jersey coasts or in the district around New York City, and his studies of the development of the beach at Nantasket (Johnson & Reed, '10) also indicate coastal stability. He has also been inclined to discredit much of the botanical evidence of subsidence on the basis of what he calls the "fictitious appearance of changes of level" ('10; '13). These are caused by local modifications in the configuration of the shore line, mostly in the form of tidal scouring and the opening of barrier beaches during great storms. He attributes most of the cited changes in high tide levels to these causes, and not to general subsidence. Another factor emphasized by him to account for submerged peats is the advance of barrier beaches over peat beds resulting in the bending down of the latter to points below sea level.

Goldthwait ('35) has studied the relationship of the Indian shell heaps in the estuary of the Damariscotta River, in Maine, to local water levels; and he has concluded that the shore has been stable for about 1000 years. His reasons are that none of the shell heaps proper are below high tide level as they might be expected to be if submergence has occurred; and that if submergence had occurred a rocky barrier in the estuary below the heaps might have prevented the growth of the oysters. His figure of 1000 years is based upon an estimate of the time it took to build the heaps.

Without making any pretence at finality or expertness in these matters, the present writer is inclined to believe that subsidence has continued to the present or that it has just stopped (See LaForge, '32, pp. 86–7, 102). Most of the evidence for stability brought forward by Johnson is of a negative nature, and it seems that the local physiographic agencies he invokes could operate with equal facility in either direction. If the coast has been stable, then for every case of the invasion of fresh marsh by salt, we ought to find, somewhere on this complex coast, a place where high tide levels had been *lowered* by the formation of barrier beaches, so that fresh marsh could invade salt. Furthermore, if this had been the rule in ages past we should find frequent interchanges between salt and fresh peat in our sections, or at least breaks in the deposits of salt peat. Two of the outstanding features of the New England salt marshes, however, are first the common occurrence of thick beds of marine peat of a homogeneous nature extending to ten feet or more below the present marsh. These beds have been formed largely of plants whose range is only in the upper tide levels where they are reached by salt water but a short part of each day (*Spartina patens* and *Distichlis spicata*). Second, at varying depths under this deposit is commonly found a layer of fresh-water peat which rests on the mineral substratum. Local changes of tide level such as Johnson postulates might account for a small thickness of peat (2 feet or less) made out of the high tide grasses, but not for much greater depths without a general subsidence of the whole bed. The fact that salt peat almost invariably overlies fresh peat argues against the effectiveness of a reverse change such as must have occurred if Johnson's theories are correctly applied (See also Bartlett, '11). Further, these peat deposits have been formed in places where the physiographic changes suggested by Johnson have not always occurred (Davis, '10).

Johnson & Reed's conclusions from a study of Nantasket beach seem to the writer to be open to doubt because of the many uncertain physiographic variables involved. Of somewhat similar nature are Goldthwait's conclusions, but here an ingenious bit of reasoning is involved that should be noted. The great heaps of oyster shells on the Damariscotta estuary are found to be just *above* a narrow gut which has, at ordinary low tide, a depth of not over three feet and a width of about 60 feet. This barrier is composed of large stones. Goldthwait suggests that if the water stood much lower than now it would not have passed so freely up the estuary, and hence the salinity and probably the temperature of the latter would have been altered. If the current estimates of subsidence are true, then only within the past few hundred years could oysters have grown here, and Goldthwait estimates that it took somewhere between 800 and 1800 years to accumulate the shell heaps, prior to the 17th century when Europeans first arrived on the scene. Some physiographic influences do not seem to have been taken into consideration, however, and open the whole matter to question. One is the relative permanence of the rocky bottom of the gut which contains the barrier, and related to it is the possibility of a change in the rate of flow of fresh water from inland sources which would alter the channels of the estuary.

Another would be local modification of tide levels by physiographic changes farther down the estuary.

The rate of submergence has been estimated in a few cases, and although there can be no expectation of precision in the figures, yet their general agreement is significant. Freeman ('03), from his studies of tide and mean sea levels at Boston concluded that about 12 inches per century was not unreasonable. Davis ('10; Bastin & Davis, '09) set it at the same figure after an extensive study of peat sections, and probably influenced also by Freeman's findings. Bartlett ('09), basing his figures on Shaler's estimate of the rate of peat deposit, thought that the submergence at Woods Hole had been about 10 inches per century. Shimer ('18), working from the rate of mud deposit in Back Bay, at Boston, suggested about 8 inches per century.

It seems entirely justifiable, in the light of the above notes, to assume that there has been no serious break in the progress of subsidence at least during the past 2000–3000 years, and that the change has been fairly steady and slow, perhaps not exceeding a foot a century. By the same reasoning we may assume that no period of indefinite length must be inserted between the present time and the last period of warmer climate on the coast. If the approximate close of this warm period may be set, for the Boston region, at the time when the warm water fauna in the Back Bay was superseded by the present fauna characteristic of cooler waters, then the time may be estimated at about 1000 years ago. Taking the whole region into consideration, the change to a cooler climate must have been a gradual one, and its effects can very well have persisted into the 17th century when oysters were far more abundant on the New England coast than they are now, and when the gastropod *Littorina irrorata* was still common in Long Island Sound.

BOTANICAL EVIDENCE

Using the concept of the close correlation between major climatal and vegetational boundaries as a point of departure, the trends in the vegetational development of southern New England contain rather strong evidence of climatic change. One of the most significant correlations ever adduced between these boundaries is that worked out by Transeau ('05) for the ratio of precipitation to evaporation. A map of isoclimatic lines drawn up from this ratio was found to correspond remarkably well with the configuration of forest types in eastern North America. The correlation was somewhat improved by Livingston and Shreve ('21) with the insertion of a "duration factor" for the length of the average frostless season, and was further refined when a period of

30 days prior to the average frostless season was also involved. The isoclimatic line for the ratio value of 0.110 is found to follow very closely the southern limit of the northern coniferous forest in New England.[1] A glance at the map of precipitation-evaporation ratios shows, however, that the area for values *below* 0.110 in reality sends a long tongue eastward into southern New England which would be more noticeable if the line turned southward along the Appalachian Mountains. This it unquestionably does although the map fails to indicate it due to lack of data from this region. If a warmer and drier climate should develop this boundary could be expected to move northward much as the eastern boundary of the prairie must have moved eastward in the Ohio valley during the "xerothermic" period in that region.[2]

The apparent progressive elimination of the southern hickories and walnuts from central New England, and the tendency for southern hardwoods generally to be replaced by northern hardwoods and hemlock, are indications of a southward movement of climatic boundaries. Although part of the vegetational change seems to have happened during historic times, yet the climatic influences may have occurred long before, and the oak-chestnut-hickory forest was merely persisting,[3] as Bromley suggests, and has not been able to cope with exploitation by Europeans except on the drier sites. If we thus postulate a warmer and drier climate for this region in comparatively recent time, it is necessary to assume that it was intrusive following the amelioration of glacial climate, and that there may have been more than one intrusion. We have at present little evidence for similar southward shifts in other boundaries such as that between the spruce-fir forests and the northern hardwoods, but these can be expected. There is some indication of local retreat of the coniferous forests at the Straits of Belle Isle (Fernald, '11); and Abbe ('36) has suggested that the isolation of some species on the northeastern coast of Labrador may be related to recent changes of climate.

[1]A recent classification of North American climates by Thornthwaite ('31) on the basis of temperature efficiency offers a fairly good correlation with vegetational boundaries also (See Nichols, '35, pp. 418-19).

[2]It is of interest in this connection that Gleason did not think the effects of the xerothermic climate were felt to the eastward of the Appalachians, nor in the Ozark uplands to the southwest. His conception of the consequent forest migrations apparently did not involve these regions. The vegetation of the Ozarks, however, has been studied extensively by Palmer ('21) and later by Palmer & Steyermark ('35), who find abundant evidence of prairie expansion and the movement of forest boundaries within comparativ℮ly recent geologic time.

[3]This tendency on the part of species and vegetation types to persist, or "lag," after conditions have become generally adverse to them has been noted in several lines of inquiry. For discussions of it see Cowles, '01, pp. 79 and 179; Fernald, '25; Clements, '34; Rübel, '35.

As noted above there is some evidence that the white pine was abundant in the pre-colonial forests, and that it passed through a period of decline during the early days of the settlements. Its meteoric rise to prominence in the abandoned fields of the last century can probably be laid to its habit of prolific seeding. The heavier fruited hickories and walnuts with their associates among the oaks could not do this once their sprouts had been removed from pastures and cultivated lands. It is possible to look upon the white pine as a relic of a warmer and drier climate, along with the hickories and their sprout hardwood associates. Unlike the latter, however, it had a new opportunity when the opening of western lands started the decline of New England agriculture, and a new expansion of its habitat appeared in fields abandoned and ready for its seed. Its prosperity is doomed to be short-lived if we may judge by the course of succession now seen in old field stands; and unless new openings are made on a large scale it will probably take the minor place commonly assigned to it in the hemlock-northern hardwood forest, or have a local abundance on very dry soils.

Soils, topography, and local climates in New England are so varied that no matter which way large vegetation boundaries might move, remnants of their former arrangement would be almost certain to survive in localities made favorable by special conditions. The southern remnants of northern vegetation left when the post-Glacial climates retreated have long been objects of study, particularly on the mountains and in bogs. The bogs, usually dominated by black or red spruce, are of common occurrence in most of the northern hardwood region and far southward into the sprout hardwood country. The coastal expression of the bog vegetation in southern New England is in the dominance of the southern white cedar, *Chamaecyparis thyoides*. Nichols has studied these habitats in upland southeastern Connecticut ('13, p. 99), and concluded that the cedar invaded the spruce bogs in comparatively recent geologic time. There is some indication that the white cedar has enjoyed in rather recent times a happier existence in southern New England. Bartlett studied a Chamaecyparis bog at Woods Hole, Massachusetts, and has this to say of the cedars: "Some of them, between three and four feet in diameter, were larger than any trees of this species now found in the vicinity of Woods Hole. The wood is still solid and wonderfully preserved"; and "Soundings in this part of the bog [the modern part] show that its history as a Chamaecyparis bog has been unbroken. It has never been submerged below sea level, for there is no stratification of the peat which would indicate this. In recent times, however, there have been no trees in this part of the bog as large as those found at depths of three or four feet, which correspond in age to those exposed in the peat at the edge of the salt marsh" (Bartlett, '09). Although a correlation between the above two sets of observations may be proved impossible, yet there is the suggestion that the southern coast white cedar has intruded into our bogs, particularly on the higher lands, within comparatively recent time, and that it may have passed an optimum on the coast.

There is some evidence that the Island of Nantucket "had many more forest-covered areas, when first patented, than at present, but historic and botanic evidence show that the larger portion of the main island was treeless" (Harshberger, '14). Yet there is also evidence that large oak forests formerly grew there, and a section from a large oak stump on the island is deposited in the Botanical Museum at Harvard (See Wilder, 1894).

A period of pronounced desiccation has been noted in sections of peat deposits on the New England coasts. One phase of this evidence was cited by William C. Alden, based upon a personal communication from C. A. Davis: "Certain fresh water peat beds on the New England coast that are now below sea level supported a dense forest of large white pines. These beds are widely enough distributed to warrant the assumption that in the comparatively recent time in which they were formed, the climate was drier than now for a time long enough to permit the development of two or three generations of these long-lived trees, not less than 500 years, and possibly twice as long. Under existing climate, the white pine has not been observed growing in dense old forest on peat deposits although often observed as an occasional constituent of the swamp forests" ('10, p. 363).

From a bog at Rockwood Park, near St. John, New Brunswick, G. F. Matthew described the following section: "After the sea withdrew from this valley a small pond was left which gradually passed into the condition of a marsh from the growth of grasses and sedges along its borders. The marsh changed to a peat-bog and continued thus for a length of time; eventually, however, the peat disappeared and was replaced by a brown mould or humus, forming a bed nearly a foot thick. Thus conditions favourable to the growth of peat had disappeared and a forest had replaced the peat-bog. The forest, of which this humus was the soil and débris, contained numbers of hardwood trees, and would be the result of a warmer and drier climate taking the place of the moist and cool one which had encouraged the growth of peat. . . . This mild climate, however, did not last long, for the Rockwood bog area was soon again invaded by a sphagnous growth and the hardwood forest destroyed.

There was not, however, such a continuous peaty growth as in the earlier peat-bog, as a second mould bed of some importance appears a short distance above the main one, and the oscillating border of the forest from time to time, showed that the wet climate was not so persistent as in the earlier peat-bog. In the closing stages of the growth of the bog, however, we note that the peat was encroaching on the forest growth around the margin of the bog, which would show that there would not be any amelioration of climate in later years, but rather that there had been a tendency to a moister and cooler climate" ('10, p. 380).

Dachnowski-Stokes has described a similar formation at the Lubec "heath" in southeastern Maine, and has summarized this and other findings as follows: "Toward the bottom appears a buried forest of trees consisting of stumps with numerous roots. . . . The layer is about 1½ feet thick and seems to be present over the entire peat area. The specimens examined were derived from pine, tamarack, spruce, and possibly fir. A similar basal layer of woody peat appears to prevail in the heaths of Veazie and Denbo, at Jonesport, Trescott, Columbia Falls, Pushaw Lake, and Herman Center, and the abundance of roots and stumps has been reported also for the peat deposits of northeastern Canada. The recent account of Auer ['27 (see also '30)] describes layers of stumps at the bottom of cross sections in peat deposits which are being cut away and exposed by the action of the waves in the Gulf of St. Lawrence. As layers of woody peat are present also in peat areas farther inland, it is logical to assume an extensive development of forests, spreading over wide stretches of country under conditions of environment which no longer exist. The climate, and probably coastal marine currents of this period, must have been warmer. The whole region must have passed into a drier stage throughout, and climatic conditions must have set in that were in consequence more continental and southerly in character than it is now in Maine" ('30, pp. 129–30).

Lyon and Goldthwait, in a recent unsuccessful attempt to cross-date trees in drowned forests on the New England coast, made the following observation of interest in the present study. The site was at Ft. Lawrence, Nova Scotia. "Another surprise came when the 24 trees in this collection were identified as representatives of 8 different species. Most of the trees sampled in the lower part of the tract were fir balsam, while those of the inshore and higher area were either pine or hemlock. This suggests a possible change of climate during the advance of the sea from lower to higher levels. Beech, maple, and spruce were represented by only four sections" ('34, p. 608).

F. H. Knowlton, commenting in 1910 on the post-Glacial flora of the

Atlantic coastal plain, could find no large paleontological evidence for a recent warmer climate in that region. However he cites several species (*Taxodium distichum, Pinus Taeda, Nyssa biflora, Ilex Cassine*) of which recently fossilized remains have been found considerably farther north than they now occur ('10, p. 369).

The occurrence of southern species scattered through parts of New England, the Maritime Provinces and Newfoundland has long been the object of study and hypothesis. Many of these plants are isolated from their southern relatives by hundreds of miles, while others represent straggling extensions of range. Approximately 35% of the flora of Newfoundland is of southwestern affinity, either common to the New England-Acadian coast, or to the coast south of Cape Cod (Fernald, '11). Something over 50% of the flora of the Island of Nantucket has a distinctly southern affinity (Bicknell, '19; Fogg, '30). Fernald stated in 1918 that approximately 200 isolated remnants of the more southern coastal plain flora were then known north of New Jersey, some of them extending as far as Newfoundland (Fernald '18). Most of the plants whose ranges have these northern extensions, and certainly those which have been studied in most detail, appear to be of the coastal plain flora; but if we may look upon scattered northern representatives of such a forest complex as that of oak and hickory in the same light, then a large and distinctly non-coastal element may be added to the list of isolations or northeastern extensions. A glance at the northeastern ranges of a great many plants characteristic of the more southern Alleghanian forests will show the same type of scattered distribution in New England and the Maritime Provinces. This was noted many years ago by the geologist C. H. Hitchcock (1874, vol. 1, p. 543), who cited the case of *Rhododendron maximum,* stating that "Its occurrence in insulated swamps suggests a former abundance in intermediate localities, and the presumption of a climate more like that of Pennsylvania, to enable it to flourish within our borders [New Hampshire]." Professor Glover M. Allen ('02, p. 42) has also noted this range, and adds the mountain laurel, *Kalmia latifolia,* the tupelo, *Nyssa sylvatica,* and the climbing fern, *Lygodium palmatum.* One of the more striking disrupted ranges is that of the bur oak, *Quercus macrocarpa,* which is known in eastern New England only in isolated localities such as that in the Penobscot valley near Waterville, Maine (Fernald, 1899).

The current explanation for the northern extension of the coastal plain flora is based upon an ancient emergence of the continental shelf from the sea (Fernald, '11; Nichols, '13, pp. 98–9; Barrell, '15; Martin, '25. A similar hypothesis has recently been applied to the distribution of land snails by Brooks, '36). This would give the necessary pathway along which plants could migrate as far as Newfoundland. Due to geological exigencies the time of this dispersal is now pushed back to the late Tertiary or to the early parts of the Pleistocene (Fernald, '33; Johnson, '25). But such an explanation is not easily applied to similar northern extensions of upland forest types or individual species. Whether the earlier continuous dispersal which brought about these extensions can be dated far back in the Pleistocene or late Tertiary depends upon whether it was possible for the plants to find refuge during the glaciation somewhere in this region. This is thought to have been the case with isolated remnants of the coastal plain flora in the Maritime Provinces and Newfoundland (Fernald, '33). There is reason to believe that parts of central New England were not covered by the last ice invasion (Bryan, '36); but the climate (Bryan, '28) during this late period must have been exceedingly rigorous, and it seems impossible that such southern plants as *Rhododendron maximum* and *Nyssa sylvatica* could have survived in upland regions between lobes of the ice, far removed from any ameliorating influence which the sea coast may have had upon local climates. Even in areas near the sea there is evidence of intense frost action in deposits of earth which do not appear to have been directly disturbed by the last ice. A northward extension of warm climates into New England in post-Glacial time, with a subsequent partial retreat of the same would do away with the necessity for such a long and hazardous persistence of southern forest species as is suggested above. However, even though we place the original dispersal of these species at a remote period, their present scattered and disrupted northern ranges can be interpreted in terms of a retreating warmer climate within comparatively recent time. This hypothesis gathers force with corroborative evidence for such a climatic change from several different lines of inquiry.

A discussion of the possible causes for this change of climate is beyond the scope of the present paper. Most of the theories expressed by the students of the coastal fauna have been in terms of changes in the courses of local warm or cold ocean currents, these in turn brought about by elevation or subsidence of shore lines and the continental shelf (Verrill, 1874; Ganong, 1890; Upham, 1892). It is notable that the time estimate given above is consistent with recent findings in the old Norse settlements in Greenland (Hovgaard, '25; Nörlund, '24). These studies have established beyond question the fact that when the Norsemen first went to Greenland the shores were remarkably free of ice and the ground was deeply thawed for a portion of each year. Coffins buried to a depth of several feet are found to have been penetrated by the roots of plants. At this time the Eskimo had retreated to the northward, although there were evidences that they had formerly lived on the ground occupied by the settlements. The change which occurred has been admirably summarized by Brooks ('26, p. 399) as follows: "But in the second half of this century [the 10th] the climate was already deteriorating, and about A.D. 1000 there came a foretaste of the coming ice. After this, conditions apparently improved slightly, and the colony appears to have prospered during most of the eleventh and twelfth centuries. Towards the close of the twelfth century deterioration again set in, and ice conditions rapidly became very bad. The summer thaw became shorter and shorter, and about A.D. 1400 the ground became permanently frozen. Communication with the mother-country was broken, life became too hard to bear, and the colonies finally perished."

Willoughby has already pointed out that the warm period on the New England coast which obtained when the ancient Indian fish weir was built in the Boston district can be correlated with the latest warm era in the middle western states postulated by Sears. The latter placed the climax of this era about 3000 years ago, as noted above, with a rather long subsequent period of "tapering off" in which effects were probably felt as late as 900 A.D. Similarly, there is evidence for a drier, and perhaps warmer climate in northern Europe during approximately the same time (Godwin, '34; Antevs, '25).[1]

Whether or not all these changes were due to the same set of causes, they appear to have been fairly coincident in time, and to have been effective throughout northeastern North America, northern Europe, and about the north Atlantic generally.

[1]Smaller variations in climate have been studied from various viewpoints and shown to be, at least in part, of periodic occurrence. These variations all appear to be of a smaller order of magnitude than those discussed in the present paper, but should prove to be of considerable significance for many phases of forest management. Thus Kincer ('33) has shown that during the past 50-75 years there has been a slight but steady rise in temperature throughout temperate North America; and that for one station at New Haven, Conn., for which a long record was available (153 years), a former upward trend culminated about 120 years ago and was followed by a decline. This is compared with a somewhat similar curve for Copenhagen, Denmark, where a record of 134 years was available showing a peak about 100 years ago. Rainfall cycles of short period duration have been noted by Pack ('33) and Kincer ('34), but trends as long as those noted for temperature have not appeared. Lyon ('36) has analyzed tree ring growth in the hemlock (*Tsuga canadensis*) in New England, and has shown that notable periods of physiological dryness have occurred during the past 3 centuries, but he does not detect any cyclic effects. On the other hand cyclic changes are clearly indicated by tree ring studies in southwestern United States (See Douglas, '19, '28).

SUMMARY

The writer is fully aware that the evidence presented above is not all of equal value, and that there may be numerous errors scattered through it. This is particularly the case with regard to timing and sequences. None-the-less it has seemed worth while to gather it into one place, rather to stimulate inquiry than to arrive at conclusions.

Investigations along several lines have produced evidence of changes in general living conditions in New England and adjacent New York during the past 3000 years, with effects lasting into more recent time. (1) A "Virginian" element in the marine invertebrate fauna of the New England-Acadian coast has long been recognized, and there is abundant evidence that it was much more widely distributed in recent geologic time. Its remnants have persisted to modern times in areas especially suitable to them. (2) It is clear that Indians lived in southern New England during at least a part of the period of warm water coastal fauna. The northern boundary for the southern, more agricultural aborigines of New England was roughly coincident with the probable former northern boundary of the oak-hickory-chestnut forests, that is, northern Massachusetts-southern New Hampshire and Vermont. There is reason to believe that these southern New England Indians came from the southwest, possibly superseding an earlier nomadic, hunting people. They developed their maize culture apparently under the strong influence of peoples to the southwest of them, and under that of the agricultural Mound Builders of the middle west. This culture seems to have persisted to the time of the Iroquois invasion, probably not more than 600 years ago. Its evolution is roughly coincident with that of the Mound Builders, and might be interpreted as due to an advance toward the northeastward of conditions suitable to the easy cultivation of maize.

(3) The ecotone between the northern and southern hardwood forests appears to be moving southward, with possible attendant effects upon other forest boundaries. (4) Numerous woodland plants common to the more southern Appalachians have a scattered distribution in the uplands of New England, indicating a former, more continuous range. (5) White oak-hickory forests in restricted tracts of the Hudson Highlands have a structure characteristic of regions farther west. (6) The coast white cedar of the southern New England region, characteristic of the Atlantic coastal plain farther south, formerly grew to larger size in our region than it does now, as shown in peat bogs. (7) There is some evidence that oak trees of large size formerly grew on the island of Nantucket. (8) The presence of the remains of white pine and hardwood forests in peat deposits along the New England-Acadian coast

suggests a period of desiccation in comparatively recent times, and (9) certain drowned forests indicate a succession from fir to hardwood types in the lower part of their sections. (10) There is indication that some of the coastal plain trees had a wider range northward in comparatively recent time, as shown by recently fossilized remains in New Jersey.

From this body of evidence we may infer that a warmer and drier climate has occurred in New England within the past 3000 years. The trend since the peak of the warm dry era has been in general toward the cooler and more moist, but probably with minor variations in the opposite direction. There is evidence, further, that the warm dry climate was so recent that the effects of it are still with us in the form of disrupted ranges for southern animals, plants, and forest types. Judging by various estimates related to the rate of subsidence and of peat deposition at the shore, it is thought that the warm water fauna was still abundant on our coast about 1000 years ago, a figure which places the warm period in general coincidence with similar eras in the middle western states, in northern Europe, and in Greenland.

It is suggested that any plan for the utilization of our natural woodlands in southern New England and adjacent New York, involving as it does several generations of long-lived, slow-growing trees, should take this trend into consideration. If the climatic trend continues toward a cooler, more humid condition, or even if it remains for a time as it is, we may expect the oak-hickory and chestnut oak associations to be further restricted in area and in timber value. We may expect the northern hardwood-hemlock forest to develop greater mesophytism and to occupy a somewhat larger area than it now does, not only advancing laterally but also invading the lands within its present range which have been heretofore edaphically unsuited to it. In silvicultural planning for most of southern New England and adjacent New York initial decisions must frequently be made with regard to the ultimate, relative economic advantages of the sprout hardwoods such as white, black, and chestnut oaks, the hickories, and the tulip-tree, as against the more northern hardwoods such as sugar maple, red oak, the birches, beech, and white ash. This study suggests that the decisions should be tempered by the probability that the sprout hardwoods are persisting here under a set of conditions which have tended to become fundamentally adverse to them, and that in the normal course of succession they will be greatly restricted or eliminated over large areas.

The writer wishes to express his appreciation of the invaluable suggestions given by a number of persons during the course of this study. These gentlemen have not always agreed with his opinions and tentative conclusions, especially with regard to the many controversial and speculative matters touched upon, but their rigorous discussion and criticism have been most helpful and stimulating. Particular thanks are due to Prof. Kirk Bryan, Prof. I. W. Bailey, Prof. M. L. Fernald, Prof. Glover M. Allen, Mr. W. J. Clench, and Mr. William Darrah, all of Harvard University at Cambridge; to Mr. A. C. Cline, Dr. P. R. Gast, and Mr. N. W. Hosley of the Harvard Forest at Petersham, Mass.; to Dr. C. F. Brooks, Director of the Blue Hill Meteorological Observatory of Harvard; to Dr. G. E. Nichols and Dr. H. J. Lutz of Yale University; to Mr. Douglas S. Byers and Mr. Frederick Johnson of the Museum of American Archaeology at Phillips Andover Academy; and to Mr. H. H. Tryon and Mr. H. L. Mitchell of the Black Rock Forest at Cornwall-on-Hudson, N. Y.

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