Oklahoma Native Plant Record
Volume 4, Number 1, December 2004

Ecological Factors Affecting the Distribution of Woody Vegetation Near the Arkansas River, Tulsa County
with Special Reference to the Smoke-tree *Cotinus obovatus*

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Botany The University of Tulsa 1970

ABSTRACT

Ecological factors affecting plant distribution were studied over different rock strata and slope exposures above the Arkansas River, Tulsa County. Here the Wann sandstone caprock is underlain by the Iola limestone formation. The vegetation was analyzed taxonomically by a complete collection throughout one growing season. Belt transects crossing rock strata on all slope exposures permitted computation of parameters summarized by an Importance Percentage for each woody species. Differences in species populations and degree of mesophytism exist on the slope exposures. Sandstone upland dominants are post and blackjack oaks. Smoke-tree, rare in Oklahoma, and chinquapin oak are closely associated in limestone microhabitats, where each occupies a separate niche. The smoke-tree, of disjunct distribution, appears to be a relict of widespread occurrence in past geologic periods. Its survival with limited ecological amplitude is due to the continuance of the microhabitats to which it is so well adapted.

INTRODUCTION

As is evident to even the most casual observer, there is often a marked correlation between the vegetative cover of the land and the rock strata which underlie it. Abrupt changes in vegetation may well indicate distinct changes in subsurface geological formation. This fact has given rise to the rather recent science of Indicator Geobotany. Russian scientists, particularly, are utilizing vegetational analyses as a rapid, inexpensive and reasonably accurate means of evaluating soil, terrain, and hydrogeological conditions. Aerial surveys have made possible the widespread use of these methods over vast expanses of largely inaccessible land (Chikishev 1961).

Piqued by frequent field trips and residences in various sections for the country, the author has become intrigued by this trend to meld the disciplines of botany and geology into an inter-related science with certain universal applications. The purpose of this investigation was to study an area encompassing differing rock strata in order to note possible correlations between the vegetation and the underlying rock formations. A thorough examination of the Geologic Map of Tulsa County, as compiled by Malcolm Oakes in 1952, led to several possible sites. The one selected is in the southwest one fourth of Section 1, T.19 N, R.10 E, 15 miles west of Tulsa (Figure 1). It is about four miles below the confluence of the Cimarron and Arkansas Rivers whose waters are today impounded by Keystone Dam, completed in 1968 by the United States Corps of Engineers.

The location is of interest botanically, since Thomas Nuttall, the early nineteenth century botanist, embarked on the Cimarron River west of this point and proceeded down the Arkansas a short distance before returning to Fort Smith during his travels through Arkansas Territory. In his journal of September 9, 1919, he wrote, “About noon we arrived at the entrance of the Arkansa (sic) and were gratified with the taste of fresh water. Here the stream, now at its lowest depression was almost colorless and scarcely anywhere exceeding the depth of 3 feet. We traveled down it 9 or 10 miles and saw the ascending smoke of the Osages whom if possible we wished to avoid” (Thwaites 1904-07). It may also be noted that Washington Irving and his party camped at a point on the Arkansas River, known as Bear’s Glen, one and a half miles above the mouth of the Cimarron River in 1832 (Barclay 1947).

METHODS

Knowledge of the geology and identification of the rocks exposed in the area were obtained

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https://doi.org/10.22488/okstate.17.100027

from Oakes' (1952) detailed study of the character, distribution, and thickness of the formations that outcrop in Tulsa County. Mr. Allan P. Bennison, consulting geologist of Tulsa, confirmed the rock formations in the field.

Climatological data were obtained from the United States Weather Bureau office at Tulsa International Airport. Precipitation and temperature figures are based on records dating back to 1931.

A series of soil samples was taken from the upland where the parent rock consists of sandstone, and from the accumulated soil were obtained by means of a soil auger. They were analyzed by the Tulsa County Agricultural agent for organic matter and pH.

Analysis of woody vegetation was made by belt transects which crossed the rock strata on the different slope and bluff exposures. Weaver and Clements (1938) suggest the use of such transects for analysis of vegetational changes due to differences in environment such as are caused by slope exposure or other irregularities in topography or soil. Six transects five meters wide were made, one each on the south, east, and west slopes and three on the north bluff. Because of the varying widths of the strata exposed, the transects ranged in length from 62 to 108 meters. All trees and shrubs in these transects were recorded and the density, frequency, and basal area were determined for those with a diameter breast high (DBH) of three inches or more. These parameters were used to obtain the relative density, relative frequency and relative basal area of each species in comparison with the other species. The sum of the latter three figures, divided by three, determined the importance percentage of a species (Rice and Penfound 1959). The data were used in comparing the tree species on different slopes and in detecting changes as the transects passed over different rock formations.

Collections and determinations of all vascular plants occurring in the area were made over an entire growing season and are presented in Table I. Weekly trips to the study site were made to collect specimens at the time of blooming. Correlation of the vegetation with the underlying strata and with slope exposure has been corroborated by habitat records of the collections. All specimens are deposited in the University of Tulsa Herbarium

CLIMATE

The climate of Tulsa County is essentially continental with sudden temperature changes and occasional severe storms. Winters are considered to be mild and temperatures are often above 100 degrees F. The average yearly rainfall is 37.25 inches, most of which falls during the long growing season. The prevailing winds are southerly at a yearly average of 10.7 miles per hour. Violent wind storms and tornadoes may occur, particularly during spring and early summer.

For a graphic depiction of Weather Bureau data from 1931 to 1968 see Figure 2. It is evident that the overall development of vegetation is closely related to the climatic features shown. The rainfall is greatest in the spring of the year, thus permitting a fairly luxuriant growth of vegetation. By the end of summer, however, many spring-flowering species have completed their growth cycles. The vegetation then appears notably less dense with an abundance of grasses and late-flowering herbs.

GEOLOGY, TOPOGRAPHY AND SOILS

The rocks exposed in Tulsa County are predominantly shales, interspersed with beds of limestone and sandstone, all of which were deposited during the middle and upper Pennsylvanian Period of the Paleozoic Era. They are a part of the sequence of Pennsylvanian rocks so well exposed in the northern mid-continent region. Having been subsequently uplifted and tilted, they now dip in a direction slightly north of west, at rates ranging form 30-50 feet per mile (Oakes 1952).

The present topography is the result of erosion, mainly by water, which has worn away the soft shales and produced extensive plains with the eroded edges of the more resistant sandstones and limestones forming eastward-facing cuestas or escarpments overlooking the plains. West of Tulsa, where the section contains a greater percentage of hard sandstone, erosion is less advanced. The streams have generally cut narrow valleys which are flanked by steep-sided hills, broken by cliffs and protruding ledges formed by the resistant beds of limestone and sandstone. Drainage of the county is by means of the Arkansas River and its tributaries. In the vicinity of this study, the Arkansas River is deeply incised (Figure 3), the floodplain being less than two miles wide, and the hills on both sides of the river rising precipitously 200-230 feet.

The area encompasses a high bluff on the south bank of the river (Figure 4). Here the limestone, classified as the Iola formation, is conformably overlain and capped by a massive sandstone, the Wann formation. The Wann sandstone is approximately 30 feet thick, and the Iola formation is 60 feet thick (Figure 5). The Iola consists of upper and lower limestone members interbedded with shale. The limestone is very irregular and sandy, and the intervening shale layer is obscured by talus. Due to the greater erosion of the softer shale huge masses of the upper limestone member have broken from the bluff and rest as slump blocks on the slopes (Figure 6). In addition, the Wann sandstone caprock fractures into large blocks on the top of the bluff (Figure 7).

The Iola formation rests on the Chanute sandstone, which is largely covered by debris from the formation above it and is poorly exposed.

The soil analyses (Table II) indicate that the Wann sandstone is strongly acid. The very shallow soil mantle, the decomposition of the leaves of the dominant oaks, and the leaching of carbonates all tend to contribute to lowering the pH. Although the pH of the limestone ledge is approximately neutral, there is a slight increase in pH on the shale below, undoubtedly due to the leaching of the carbonates from the limestone layer.

The analyses also show an increased accumulation of organic matter from the upland to the bottom of the slopes. This can be attributed to erosion from the upland and the more abundant vegetation on the limestone and shale.

For better understanding of the influence of the soil on plant distribution, an investigation of water and mineral relationships should be made. Certain conclusions, however, can be drawn on the basis of the characteristics of the strata. It seems evident that the water moves readily through the sandstone caprock, thus limiting the vegetation on the upland to those species of low moisture requirements. The limestone very likely serves as an aquifer supplying ample moisture to support a dense vegetation, with the underlying shale, because of its small pore size, serving to retard the passage of water.

Since many of the limestone formations in Tulsa County are known to contain phosphatic nodules in significant amounts, it is probable that they are present to some extent in the Iola and may be a contributing factor in determining the vegetation on the slopes.

VEGETATION

Taxonomic Analysis

One hundred and eighty species of vascular plants were collected at the study site which covers an area of approximately 50 acres. This collection represents a total of 134 genera and 54 families (Table I). The variety of the vegetation and the seasonal changes in plant development were apparent on weekly trips to the area. These visits also revealed the segregation of certain species into distinct communities, coinciding with abrupt changes in topography, and they served to illustrate the dynamics of plant growth and reproduction.

Upland

The sandstone upland is characterized by the oak-hickory woodland of the sandstone hills area (Bruner 1931). Here the dominants are post oak (*Quercus stellata*) and black jack oak (*Q. marilandica*). Texas hickory (*Carya texana*) occurs infrequently and is of little importance. Since there are few other woody species on the upland, there is a definite uniformity of the stand as may be seen in Figure 7. Tree species with greater moisture requirements are unable to survive and reproduce.

Rice and Penfound's study of the upland forests of Oklahoma (1959) concurs with these findings. They listed post oak and black jack oak as the dominants for Tulsa County. Barclay (1947) gives post oak as the single dominant on the Wann sandstone above Bear's Glen, Pawnee County, some four miles from this site.

Slopes and Bluff

The vegetation on the slopes is in marked contrast to the upland in that many species occur and they provide a more varied cover. The west slope which forms one side of a wide ravine that drains the area is rather gentle. Chinquapin oak (*Q. muehlenbergii*), and smoke-tree (*Cotinus obovatus)* are the most significant plants. They appear near the top of the slope on the limestone ledge. Among the other trees are post oak, red haw (*Crataegus* sp.), persimmon (*Diospyros virginiana*), sand plum (*Prunus angustifolia*), white ash (*Fraxinus* *americana*), and rough leaf dogwood (*Cornus Drummondii*). An abundant grass cover occurs beneath and between the trees of the west slope.

The ravine on the east is steeper and more protected; the vegetation is, therefore, denser. Chinquapin oak and smoke-tree are prominent along the limestone ledge. On other parts of the slope are post oak, white ash, Texas hickory, shadbush (*Amelanchier arborea*), and Shumard's oak (*Quercus shumardii*). Open areas covered with grasses made up a smaller proportion than on the west exposure.

The heaviest vegetation occurs on the steep north bluff (Figure 8). Here shrubs, trees, and vines form an almost impenetrable thicket early in the growing season. Chinquapin oak and smoke-tree dominate the upper limestone ledge. Along the lower limestone outcrop, chinquapin oak is largely replaced by Shumard's oak growing in association with the smoke-tree. The Oaks are large and impressive as shown in Figure 9. The smoke-tree grows in big clumps with many trunks arising from the base (Figure 10). Other trees on the north face are redbud (*Cercis canadensis*), American elm (*Ulmus americana*), slippery elm (*U. rubra*), Texas hickory, bitternut hickory (*Carya cordiformis*), white ash, and rough leaf dogwood. Grasses occur in an open band between the limestone ledges.

The sandstone caprock on the south is extensive and slopes very gradually with no marked change in the vegetation until the limestone is exposed. Here hackberry (*Celtis laevigata*), blackhaw (*Viburnum prunifolium*), and rough leaf dogwood are present.

In general, the vegetation at this study site corresponds rather closely with that at Bear's Glen, as reported by Barclay (1947). A notable difference is the complete absence of *Cotinus* at Bear's Glen where no limestone was present. (The area is now submerged by Keystone Reservoir.) Red cedar (*Juniperus virginiana*), which was an important species at Bear's Glen, is of little significance here. Only two were encountered in this area.

RELATIONSHIP OF VEGETATION TO UNDERLYING STRATA

Analysis of Woody Vegetation

Since it was impossible to run the south transect from the top of the bluff due to the presence of a small oil field at this point, the transect was made to the east, on the south flank of an adjacent bluff (Figure 4). Because of the slight grade of the slope, this transect should probably be considered as part of the upland. The difference in elevation between the beginning of the transect and the limestone outcrop is not sufficient to cause perceptible changes in vegetation. The dominant trees here are post oak and black jack oak. The importance percentage (I.P.), computed from the transect are 65.9 for the post oak and 41.4 for the black jack oak. Rice and Penfound (1959) consider an importance percentage of 25 or more an indication of dominance.

It was evident, however, from the data obtained from the west, east and north transects that, here, both slope exposure and underlying strata are factors in determining the woody vegetation. The transects are arranged in Figure 11 so as to correlate the upper limestone outcrop on the three exposures. As will be noted from the chart, three transects were made on the north-facing bluff because of the greater variety and density of the vegetation on the north. The chart also shows that the lower limestone member outcrops only on the steep north face and is not reached on the east or the west.

The tree species with a DBH of three inches or more are plotted where they occur within the transects and their diameters are recoded. All species under three inches DBH are considered as reproduction and their counts listed (Figure 11). The presence of multi-trunked *Cotinus* is indicated within the quadrats but since the diameters of the individual trunks were under three inches, their basal areas were not determined. For this reason, although the chart shows that the smoke-tree is confined almost exclusively to the limestone strata, its relative importance and I.P. cannot be computed.

The data in Table III indicate that the three oaks: post, chinquapin, and Shumard's, are dominants on the north-facing bluff but that each occupies a particular habitat on the bluff. Post oak, dominant on the sandstone upland, is largely replaced by chinquapin oak on the upper limestone ledge, and this species is replaced by Shumard's oak on the lower limestone outcrop.

It would seem that this segregation of the oaks is due in part to moisture requirements. The post oak is best adapted to the conditions on the dry upland, chinquapin oak to the more

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mesophytic habitat on the upper part of the slope, and Shumard's oak requiring the very moist conditions below. The complete absence of Shumard's oak on the west and south exposures gives further evidence of its high moisture requirements; whereas chinquapin oak occurs sparingly on the west slope and is absent on the south.

The occurrence of post oak on the limestone on the east and west-facing slopes and on the east end of the bluff is somewhat misleading, for here erosion has dissected the limestone ledge into large blocks, with small ravines between the blocks. It is in the open, well-drained sites that post oak occurs.

Since white ash occurs almost exclusively below the limestone strata, it seems apparent that it cannot survive the aridity of the upland.

Reproduction counts on the transect chart are significant, for they suggest that each community is continuing to maintain itself. The preponderance of small post oaks on the limestone upland leaves little doubt that it will continue to dominate this location.

As the gaps between the limestone blocks on the east and west slopes enlarge and provide greater open areas for evaporation and runoff, the post oak, already established, will increase. Over a long period of time the decline and eventual elimination of the smoke-tree and chinquapin oak on these slopes seem assured. They will then probably be confined to the north-facing bluff.

Herbaceous Vegetation

It is evident from this investigation that a number of herbaceous plants are restricted to very particular habitats. Two small ferns, *Notholaena dealbata* and *Pellea atropurpurea*, although abundant, were found only in crevices on the limestone ledges or on the limestone slump blocks. Other species confined to the limestone outcrops are: *Yucca arkansana, Gerardia heterophylla, G. tenuifolia, Penstemon cobea, Cleome serrulata, Rosa setigera, R. carolina, Euphorbia hexagona, Ceanothus americanus, Liatris punctata, and L. squarrosa.* Herbaceous species limited to the sandstone were markedly fewer in number. They include *Commelina erecta, Sedum nuttallianum, Tephrosia virginiana, Lechea tenuifolia, Penstemon tubaeflorus, and Antennaria plantaginifolia.* Although no attempt was made to tabulate herbaceous materials on the basis of underlying strata, the collections indicate that the largest number of species was to be found on the talus slopes where the shale is covered with soil and with limestone and sandstone debris from the formations above.

THE IMPORTANCE OF *Cotinus obovatus*

Taxonomy

Cotinus obovatus, or smoke-tree, is a small tree or large shrub up to 35 feet tall, in the family Anacardiaceae. It has alternate, simple, entire, obovate leaves four to six inches long and two to three inches wide, which form dense summer foliage (Figure 12). The plants are usually dioecious with small flowers, many abortive, in loose terminal thyrses. The slender pedicels elongate after flowering and those on the abortive flowers become plumose-villous. The name "smoke-tree" alludes to the "smoky" appearance of the inflorescences. The species tends to grow in clumps and to reproduce asexually by means of root or stump sprouts.

The genus consists of three or more species found in Eurasia and eastern North America. It is represented in the western hemisphere by the single species, *C. obovatus*, of interrupted distribution in southern United States. Although *Cotinus* was originally classified with *Rhus*, recent studies indicate that the two genera are not closely related. According to Engler, *Cotinus* represents a branch of evolution different from but having a common origin with that of *Rhus* (Brizicky, 1962). The European species, *C. Coggygria*, because of its more feathery panicles, is cultivated as a popular ornamental in the United States and Europe.

Distribution

The American smoke-tree is found in disjunct populations on wooded, rocky cliffs and river bluffs, generally on lime stone. It occurs in the mountains of Tennessee, in Daviess County, Kentucky, where it may have been introduced, in southwestern Missouri, in northwestern Arkansas and eastern Oklahoma, and in the canyons of the Edwards Plateau in Texas (Sargent 1965).

Cotinus is reported from several stations in Oklahoma (Figure 13). The earliest record of it was made by Nuttall on a trip up the Grand River in 1819. In his journal of July 18 he wrote, "The morning was find and we embarked at sunrise. About 8 o'clock we passed a bend called Eagle's Nest, a mile above which, and its island (sic), a facade of calcareous rock appears, inlaid with beds of whitish hornstone. While examining these cliffs, I recognized as new a large shrub, and to my great surprise found it to be a simple-leaved *Rhus*, scarcely different from *Rhus. Cotinus* of the south of “Europe and our gardens” (Thwaites 1904-07). In 1928 Palmer reported finding the smoke-tree in a steep, rocky ravine near the base of Rich Mountain in Le Flore County and Little (1942) found it in the Cookson Hills in Cherokee County. Dr. Harriet G. Barclay, of the University of Tulsa collected it in a ravine near Garnett, Rogers County, in 1932. *Cotinus* has also been collected from a location in Tulsa County approximately three miles east of the present study (Clark 1960). Dr. Albert P. Blair of the University of Tulsa, reports finding it in the vicinity of Spring Creek and Little Spring Creek in Cherokee County. In addition, the author has observed it growing in a canyon five miles west of Claremore, Rogers County.

Ecological Requirements

The abundance of the disjunct, *Cotinus,* in this area presents a fascinating picture. The species occurs in large clumps on the upper and lower limestone ledges or on the blocks of limestone that have slumped off the ledge (Figure 6). The largest and most impressive specimens are found on the upper limestone ledge of the north-facing bluff. Here, apparently, its requirements for sunlight and moisture are met most successfully. The roots penetrate the limestone fissures and branch profusely, even when exposed. Many trunks are broken and twisted, but the species has the capacity to produce new shoots, not only from the base, resulting in multiple trunks, but also from the upper branches, making a pollarded effect (Figure 14).

An important relationship between the smoke-tree and the chinquapin oak has become evident in this study. In every location where the author has found the smoke-tree, chinquapin oaks have been present. These two species, unrelated, taxonomically, have become adapted to the same micro-habitat, but they make somewhat different demands upon the environment and fill different niches in the community. The smoke-tree, with the ability of its roots to penetrate the limestone fissures, and its growth habit of proliferating from the base, can gain a foothold on the eroding rock. The chinquapin oak grows so close to the smoke-tree that it overtops the latter although it roots at the base of the limestone ledge. The two species thus seem to complement each other and not to compete. It is noteworthy that a similar relationship exists in Europe where *C. Coggygria* grows in association with another oak (*Q. pubescens*) and the association is described as the Quercito-Cotinetum forest (Penzes 1958).

Hanson and Churchill (1961) have observed this close association within a community. “The individual plant, in order to live, must establish successful relations with its physical environment as well as with other plants and animals. In nature plants usually grow in groups, not as isolated individuals. These groups may consist of a single species but more often the groups comprise individuals of several species constituting a community.... The kinds of plants that grow in a particular habitat must have the ability to grow not only under the prevailing physical environmental conditions but also in association and competition with neighboring plants.”

It could be assumed that since the smoke-tree occurs on limestone it is a calciphilous species. It is possible, however, that the physical character of the rock and the ecological niche of the smoke-tree account for its limestone habitat rather than the chemical properties of the rock. The acidity of the Wann sandstone upland may be a factor, in addition to the dryness, in explaining the almost complete absence of the smoke-tree in the habitat. It should be noted that native specimens of *Cotinus* already well developed have bee transplanted and grow well in the Tulsa area on sandstone soils if given sufficient water. Such alteration of the usual habitat is thought to be possible only because of its extensive vegetative growth.

Cotinus grows along the limestone ledge on the east slope where the ravine is narrow and sheltered from the drying southerly winds. On the west slope which is more exposed, the clumps are scattered and on the south they are completely absent. It seems evident that the ecological amplitude of the species is small. When exposed to the greater solar radiation and drying winds it is unable to survive. Hanson and Churchill (1961) define ecological amplitude as the “characteristic potentiality for growth of a species with a limited range of environmental conditions”. It often determines whether or not a species will be present in a certain habitat or community.

Paleo-History

The peculiar distribution pattern of *Cotinus obovatus* in North America and its isolation from the European species require consideration of its paleo-botanical record. According to Cain (1944), “Major disjunctions seem almost exclusively to have resulted from historical causes which have produced the disjunction in a once more nearly continuous area, through destruction or divergent migrations caused by climatic or some other changes.” Since fossil records give the most reliable evidence of paleo-history, it may be noted that the most important fossil members of the Anacardiaceae belong to the genera *Rhus, Pistacia,* and *Anacardites*, the latter being a form genus for anacardiaceous foliage of uncertain relationship. Many fossil species of *Rhus* have been named but not all of them can be considered authentic. *Rhus* dates from the upper Cretaceous Period, but it seems to have been most prominent in the Oligocene and Miocene (Arnold 1947). According to Barkley (1937) *Cotinus* is well represented in the Miocene, and Little (1942) traces it as far back as the Cretaceous with *Cotinus cretacea* Hollick.

In trying to piece together the past history of the *Cotinus* genus an attempt must be made to trace the evolution of woody angiosperms in North America. Berry (1937) states, “The greatest impediment to a botanical or zoological approach to geologic history is the general lack of realization of the enormous lapse of time involved, and consequently, a complete lack of perspective or orientation.” Nevertheless, the challenge is there.

It is the opinion of most authorities that the major part of angiosperm evolution involving the principal modification of flowers took place during the Mesozoic Era. Woody angiosperms appear in abundance in the early part of the cretaceous Period, about 100 million years ago. By the beginning of the Cenozoic Era most of North America, Europe, and Asia were covered by a mixed hardwood forest, the original undifferentiated climax forest. Fossil evidence is sufficient to prove the great extent of this forest, designated by Braun (1950) as the Pan Climax of the Tertiary. It is believed that modern disjuncts of tropical and temperate climates had a continuous range at that time. Later, under the stress of changing climates, new species and ecotypes of woody angiosperms evolved. By the Miocene Period there was undoubtedly a complete separation between the mesophytic forest of North America and Eurasia except for boreal species such as *Picea, Salix, Betula,* and *Acer* (Stebbins 1950).

The latter part of the Tertiary saw the rise of great mountain chains in many parts of the world, including the Alps, Himalayas, Western Cordilleras of North America, and the Andes, which brought about the appearance of semi-arid steppes and deserts in the rain shadows of these mountains, greatly restricting the areas occupied by mesophytic plants of both tropical and temperate climates (Stebbens 1950). In North America the forest contracted. There was a gradual shrinkage from west to east due to increased aridity of the interior caused by the rising of the Rocky Mountains and a later retreat of the forest southward due to the climatic fluctuations brought about by the Pleistocene glaciation. The result was a segregation of communities on a basis of moisture requirements and a retreat eastward of those of highest demands (Braun 1935).

If we assume that *Cotinus obovatus* evolved during the Pan-Climax of the Tertiary it would appear that the species displayed little change while other species were adapting to the diversifications of their environment. Little (1950) states the problem as follows: “Its rarity, discontinuous distribution and lack of related species in the New World, and occurrence as a pioneer species on rocky cliffs all suggest that *Cotinus obovatus* is an old species formerly of general distribution but now approaching extinction.”

It is of interest to consider the record of the close associate of smoke-tree, the chinquapin oak. It is believed that modern members of the Fagaceae were derived during the upper Cretacious Period from the extinct genus *Dryophyllum. Quercus* is one of the most frequently encountered genera of the upper Cretaceous and Cenozoic. Practically all of the early oaks were of the unlobed or chestnut type. The prominently lobed leaf was rare until the Miocene (Arnold 1947). Since the chinquapin oak is of the chestnut type, it would seem possible that it may be derived from that ancient line.

While *Cotinus* seems to be past maturity as a genus, its relative, *Rhus*, has survived and increased its range. The latter genus exhibits wide ecological amplitude and it is represented by over 100 species. It is distributed throughout

North America from Canada to southern Mexico and from coast to coast. It is also widely distributed in the southern hemisphere and in Eurasia (Sargent 1961). Stebbins (1950) suggests that changing environments have caused the expansion and variation of some groups, the decline and extinction of others and have left some groups relatively unchanged. The ability of a group to respond to environmental change depends on certain biological characteristics of the group.

Present Status

It seems consistent with the above considerations to call the American smoke-tree a relict, since its present survival appears to be but a remnant of past distribution and importance. In ecological terms, according to Weaver and Clements (1938), a relict is a species or community which has remained after some change has resulted in the elimination or modification of an earlier vegetation, often a climax. “Vegetational analysis of relict communities combines observation, scrutiny of scientific reports and records, experimentation, and interpretation; but its essential feature is the search for areas continuously protected against disturbance.” Because of their rugged topography, *Cotinus* habitats have been relatively undisturbed by man. In this particular study, the land is of little economic importance due to its irregularity and the impurity of the limestone. According to the present owner of the study area, it has not been used except to pasture a few cattle from time to time. It is believed that Indians, particularly the Osages, camped on these bluffs before the coming of the white man, for Indian arrowheads and artifacts have been found.

SUMMARY

A high upland and bluff above the Arkansas River, encompassing different rock strata and slope exposures, was studied to determine the ecological factors affecting plant distribution. Here the Wann sandstone caprock overlies the Iola formation, well exposed on the north bluff, and consisting of upper and lower limestone members interbedded with shale. The soil on the upland contrasts with that of the slopes in pH and quantity of organic matter.

A complete collection of plants was made throughout the area during an entire growing season, and is entered in the University of Tulsa Herbarium.

A small percentage of the herbaceous species is definitely related to the underlying strata. The woody vegetation was analyzed by belt transects which crossed the different strata on all slope exposures. The dominants on the upland are post oak, with an Importance Percentage of 65.9, and blackjack oak, with an I.P. of 41.4. The dominants on the limestone are chinquapin oak, with an I.P. of 34.9, and Shumard’s oak, with an I.P. of 34.9, with the former confined largely to the upper limestone, and the latter to the base of the lower limestone outcrop. The transects on the different slope exposures showed marked changes in species populations and in degree of mesophytism.

A significant tree on the limestone is the American smoke-tree, *Cotinus obovatus*, a comparatively rare species in Oklahoma. Its multipletrunked growth form and its freely branching root system adapt it to the eroding limestone ledges. It grows in close association with chinquapin oak, the two species unrelated taxonomically, but occupying different niches in the same microhabitat. It is notable that the European smoke-tree is also closely associated with an oak. The disjunct distribution of the American smoke-tree indicates that it was probably widespread in former geologic periods. Its survival as a relict with limited ecological amplitude is due to the continuance of the microhabitats to which it is so well adapted.

ACKNOWLEDGEMENTS

Grateful acknowledgements are due to the many, who have been of assistance in the preparation of this thesis – most especially to Dr. Harriet G. Barclay for direction of the study as well as her inspiration and encouragement, to Dr. Paul Buck who has helped in many ways, and to Mr. and Mrs. A.W. Swift who so generously gave permission for the use of their property for this study, to Miss Sandra Forehand, a frequent companion on “collection” trips, and to Mrs. Jean Hamilton for her help in the collection and identification of grasses. To my husband, Walter, whose patience has been unflagging, I express my deepest thanks.

LITERATURE CITED

Arnold, Chester A. 1947. An introduction to Paleobotany. New York and London, McGraw Hill Book Company, Inc.

Barclay, Harriet G. 1947. The woody vegetation of Bear's Glen, a Washington Irving stopover. Proc. Okla. Acad. Sci. 28: 39-57.

Barkley, Fred A. 1937. A monographic study of *Rhus* and its immediate allies in North and Central America, including the West Indies. Annals of the Missouri Botanical Garden 24: 300-303.

Berry, E. W. 1937. Tertiary floras of eastern North America. Botanical Review 3: 31-46.

Braun, E. Lucy 1935. The undifferentiated deciduous forest climax and the association segregate. Ecology 16: 514-519

........1967. Deciduous Forests of Eastern North America. New York and London, Hafner Publishing Company.

Brizicky, George K. 1962. The genera of Anacardiaceae in the southeastern United States. Journal of Arnold Arboretum Vol. XLIII No. 14, pp. 366-68.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monogr. 1: 99-188.

Cain, Stanley A. 1944. Foundations of Plant Geography. New York and London, Harper and Brothers.

Chickshev, A. G. ed. 1961. Plant Indicators of Soils, Rocks, and Subsurface Waters. Conference on Indicator Geobotany. Moscow. Authorized translation from Russian. New York, Consultants Bureau, 1965.

Clark, Maxine. 1960. Interesting plant collections from Tulsa County. Proc. Okla. Acad. Sci. 40: 7-8.

Hanson, Herbert C., and Churchill, Ethan D. 1961. The Plant Community. New York, Reinhold Publishing Corp.

Little, Elbert L., Jr. 1942. American smoke-tree (*Cotinus obovatus* Raf.), one of Oklahoma's rarest tree species. Proc. Okla. Acad. Sci. 23: 21-23.

Oakes, Malcolm. 1952. The geology and mineral resources of Tulsa County Oklahoma. Oklahoma Geological Survey Bulletin No. 69.

Penzes, Dr. A. 1958. Data to the ecology and taxonomy of the *Cotinus* genus. Acta Botanica Sinica 7: 167-169.

Phillips, E. A. 1959. Methods of Vegetation Study. New York, Henry Holt and Co., Inc.

Rice, E.L., and Wm. T. Penfound. 1959. The upland forests of Oklahoma. Ecology 40: 593-608.

Sargent, Charles Sprague. 1961. Manual of Trees of North America, Vol. 2. New York, Dover Publications, Inc.

Stebbins, G. Ledyard, Jr. 1950. Variation and Evolution in Plants. New York, Columbia University Press.

Thwaites, Reuben Gold 1853-1913, ed. 1904-07. Early Western Travels 1748-1846, Vol. 13. Cleveland, O., The A.H. Clark Company.

Weaver, John E. and Clements, Frederic E. 1938. Plant Ecology. New York and London, McGraw Hill Book Company, Inc.

Waterfall, U. T. 1966. Keys to the Flora of Oklahoma, 3rd. ed. Stillwater: Privately published.

Yearbook of Agriculture. 1955. Water. Washington, D. C., U. S. Govt. Printing Office.

Editor's notes:

As a charter member of Oklahoma Native Plant Society, Anne Long was an influential figure in its organization. It is with honor that we present her master's thesis as an important historical study to be used by future researchers, teachers, and leaders for native plant conservation and education.

While time has misplaced the original sources for several of her figures, modern technology has provided updated and visually improved ones as noted. [SAS]

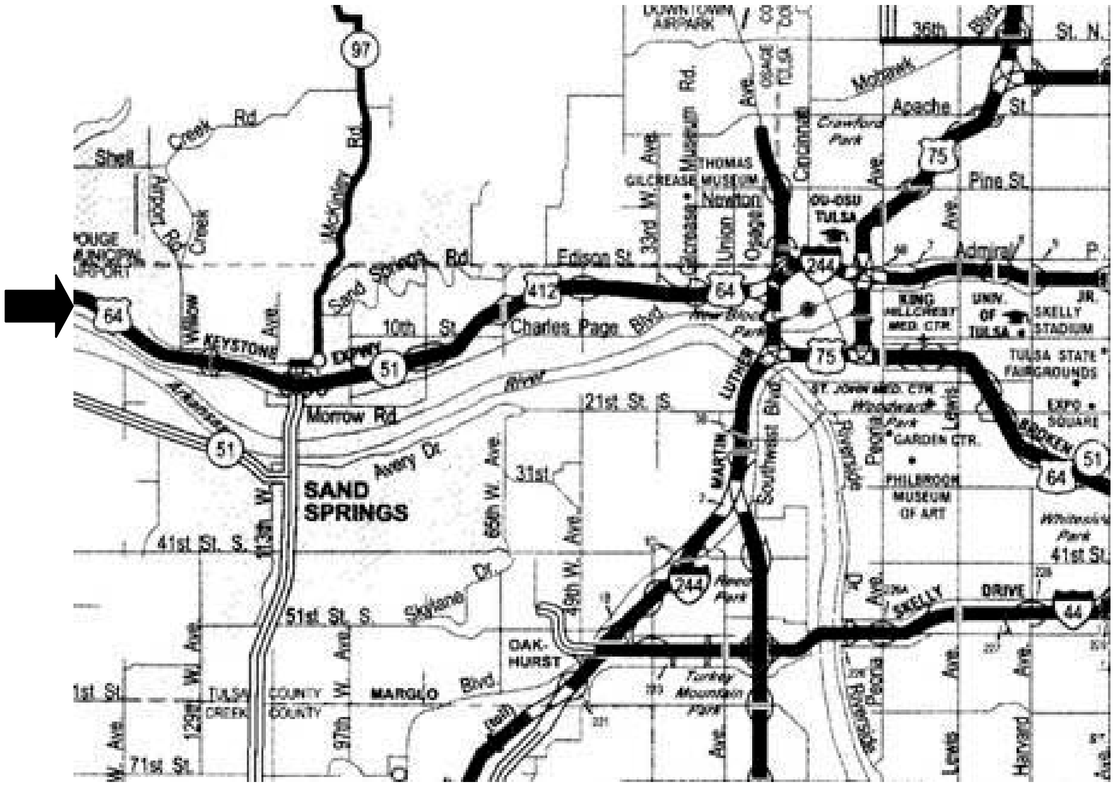

Figure 1 Arrow indicates location of study site with reference to Tulsa County and the Arkansas River. [Map substitution courtesy of the Oklahoma Department of Transportation.]

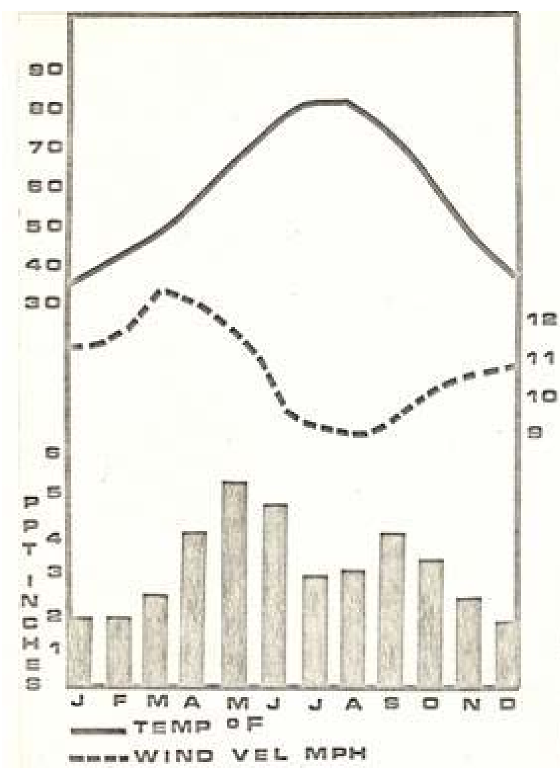

Figure 2 Average monthly temperature, precipitation, and wind data for Tulsa County. From U.S. Weather Bureau (1931-68).

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Figure 3 Aerial photograph of S ½ of section 11, T.19 N., R.10 E., Tulsa County. By Aerial Photo Service 2669. Scale: 1"=1000'. [Study site border appended for comparison to contour map.]

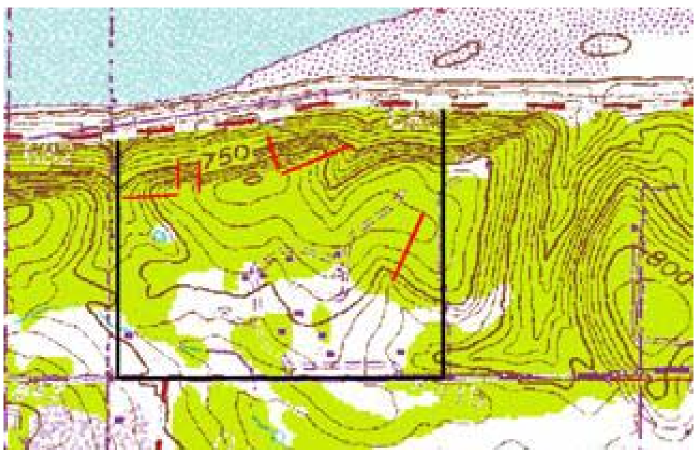

Figure 4 Contour map of study site and environs. Study site border and transects indicated. Contour Interval = 10' Scale 1" = 1000'. [Geo Information Systems, University of Oklahoma (www.geo.ou.edu), substituted with permission.]

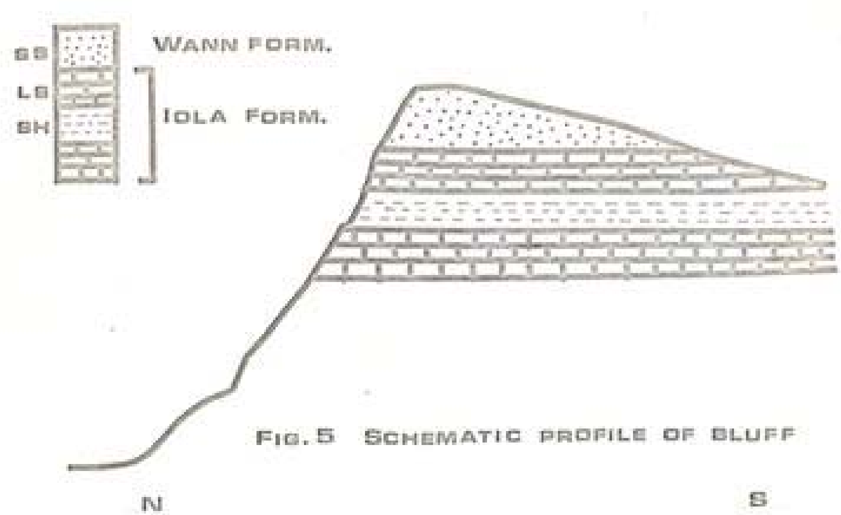

Figure 5 Schematic profile of bluff

Figure 6 Isolated slump block of Iola limestone showing smoke-tree.

Figure 7 Wann sandstone caprock.

Figure 8 Dense tree growth on the north-facing bluff.

Figure 9 Upper ledge of Iola limestone, with smoke-tree and large chinquapin oak.

Figure 10 Multiple-trunked smoke-tree on limestone.

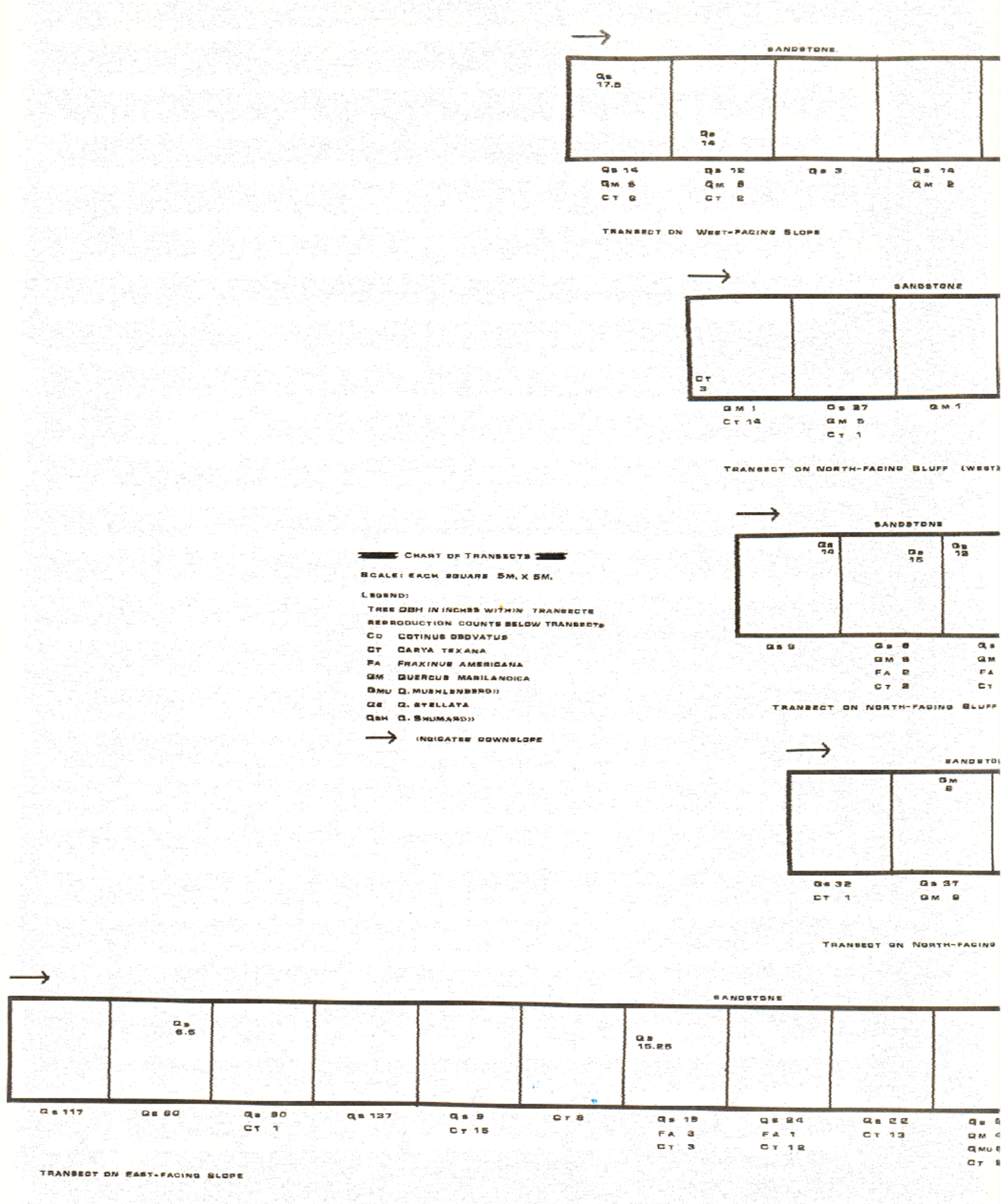

Figure 11 Chart of transects.

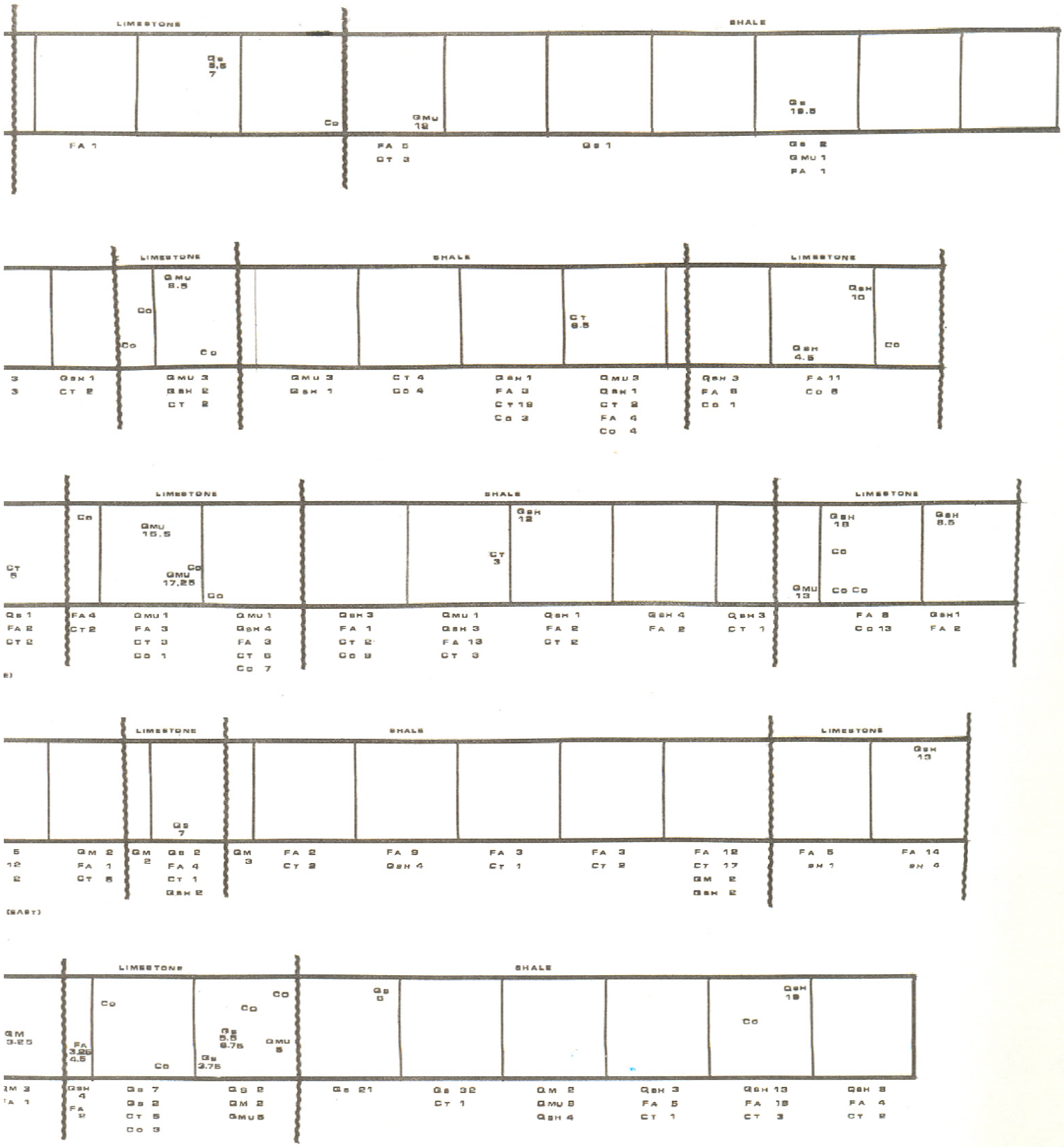
LIMESTONE
SHALE
Qs 9.5 7
Co
QMu 19
Qs 19.5
FA 1
FA 5
CT 3
Qs 1
Qs 2
QMu 1
FA 1
LIMESTONE
SHALE
LIMESTONE
QMu 8.5
Co
Co
Co
CT 6.5
QsH 10
QsH 4.5
Co
QsH 1
CT 2
QMu 3
QsH 2
CT 2
QMu 3
QsH 1
CT 4
Co 4
QsH 1
FA 3
CT 19
Co 3
QMu 3
QsH 1
CT 2
FA 4
Co 4
QsH 3
FA 8
Co 1
FA 11
Co 8
LIMESTONE
SHALE
LIMESTONE
Co
QMu 15.5
CT 5
QMu 17.25
Co
Co
CT 3
QsH 12
QsH 10
Co
QMu 13
Co Co
QsH 8.5
Qs 1
FA 2
CT 2
FA 4
CT 2
QMu 1
FA 3
CT 3
Co 1
QMu 1
QsH 4
FA 3
CT 6
Co 7
QsH 3
FA 1
CT 2
Co 9
QMu 1
QsH 3
FA 13
CT 3
QsH 1
FA 2
CT 2
QsH 4
FA 2
QsH 3
CT 1
FA 8
Co 13
QsH 1
FA 2
LIMESTONE
SHALE
LIMESTONE
Qs 7
QsH 13
QM 2
FA 1
CT 8
QM 2
Qs 2
FA 4
CT 1
QsH 2
QM 3
FA 2
CT 2
FA 9
QsH 4
FA 3
CT 1
FA 3
CT 2
FA 12
CT 17
QM 2
QsH 2
FA 5
FA 14
(EAST)
LIMESTONE
SHALE
Co
Co
Co
QM 3.25
FA 3.25 4.5
Qs 5.5 6.75
QMu 5
Qs 3.75
Co
Qs 6
QsH 19
Co
QsH 4
FA 2
Qs 7
Qs 2
CT 5
Co 3
Qs 2
QM 2
QMu 5
Qs 21
Qs 32
CT 1
QM 2
QMu 8
QsH 4
QsH 3
FA 5
CT 1
QsH 13
FA 18
CT 3
QsH 8
FA 4
CT 2

Figure 12 Summer foliage of smoke-tree.

Figure 13 Distribution of Smoke-tree in Oklahoma. [State map substitution courtesy of Geo Information Systems, University of Oklahoma @geo.ou.edu.]

Figure 14 New shoots of *Cotinus* from upper branches.

TABLE 1 COMPLETE COLLECTION OF VASCULAR PLANTS MADE OVER THE GROWING SEASONS OF 1967-8 AT THE STUDY AREA, LISTED BY FAMILIES. NOMENCLATURE ACCORDING TO U.T. WATERFALL (1966). *Editor's note:* Species nomenclature has been updated according to Kartesz (1994) and USDA-NRCS (16 June 2004). Asterisks denote name changes; revisions follow in brackets. [PAF]

Ophioglossaceae
Ophioglossum engelmannii Prantl.

Polypodiaceae
**Notholaena dealbata* (Pursh) Kunze
[*Argyrochosma dealbata* (Pursh.) Windham]
Pellaea atropurpurea (L.) Link,
var. *atropurpurea*
Woodsia obtusa (Spreng.) Torr.

*Gramineae [Poaceae]
Andropogon gerardii (Vitman,
var. g*erardi*
**Andropogon saccharoides* Sw.
[*Bothriochloa laguroides* (Sw.) Rydb.]
**Andropogon scoparis* Michx.
[*Schizachrium scoparium* (Michx.) Nash
Aristida purpurescens Poir.
Bouteloua curtipendula (Michx.) Torr.
Digitaria filiformis (L.) Koel., var. *filiformis*
Elymus virginicus L., var*. virginicus*
forma *virginicus*
Eragostris capillaris (L.) Nees
Eragrostis hirsuta (Michx.) Nees
Eragrostis intermedia Hitchc.
**Eragrostis oxylepis* (Torr.) Torr.,
var. oxylepis
[*Eragrostis secundiflora* J. Presl.
ssp *oxylepis* (Torr.) Koch]
Eragrostis spectabilis (Pursh) Steud.,
var. *sparsihirsuta* Farwell
Gymnopogon ambiguus (Michx.) B.S.P.
Muhlenbergia sobolifera (Muhl.) Trin.
Panicum capillare L., var. *capillara*
**Panicum lanuginosum* Ell., var.
fasciculatum (Torr.) Fern.
[*Dicanthelium acuminatum* (Sw.)
Gould & C.A. Clark,
var. fasciculatum (Torr.) Freckmann
**Panicum oligosanthes* Schultes, var.
Scribnerianum (Nash) Fern.
[*Dicanthelium oligosanthes* (J.A.
Schultes) Gould,
var. s*cribnerianum* (Nash) Gould.]
Panicum virgatum L.
**Setaria geniculata* (Lam.) Beauv.
[*Setaria parviflora* (Poir.) Kegguelen
Sorghastrum nutans (L.) Nash
Sporobolus clandestinus (Biehler) Hitchc.

Commelianaceae
Commelina erecta L. var. *erecta,*
forma *intercursa* Fern.
Tradescantia ohiensis Raf.,
forma *pilosa* Waterfall

Liliaceae
Allium perdulce S. V. Fraser
Camassia angusta (Engelm. & Gray)
Blankenship
Nothoscordum bivalve (L.) Britton
Smilax bona-nox L.
Smilax glauca Walt., var. *glauca*
Yucca arkansana Trel., var. *arkansana*

Iridaceae
Sisyrinchium campestre Bickn.,
forma *campestre*
Sisyrinchium campestre Bickn.,
var. *kansanum* (Bickn.)
Steym.

Orchidaceae
Spiranthes cernua (L.) Richards

Juglandaceae
Carya cordiformis (Wang) K. Koch
Carya texana Buckl. (C. Buckleyi Durand)

Fagaceae
Quercus marilandica Muench.
Quercus muehlendbergii Englem.,
var. m*uehlenbergii*
Quercus Shumardii Buckl.,
var. s*chneckii* (Britton) Sarg.
Quercus stellata Wang.

Ulmaceae
Celtis laevigata Willd.
Ulmus americana L.
Ulmus rubra Muhl. (U. fulva Muhl.)

Moraceae
Morus rubra L.

Nyctaginaceae
Mirabilis albida (Walt.) *MacM. [Heimerl.]

Portulacaceae
Claytonia virginica L.
**Portulaca mundula* Johnston
[*Portulaca pilosa* L.]
Talinum parviflorum Nutt.

Polygonaceae
Polygonum tenue Michx.

Ranunculaceae
**Delphinium virescens* Nutt.
[*Delphinium carolinianum* Walt.,
var. *virescens* (Nutt.) Brooks]

Capparidaceae
Cleome serrulata Pursh.
Cruciferae
Draba cuneifolia Nutt., var. *cuneifolia*
Draba reptans (Lam.) Fern., var. *reptans*
Lepidium virginicum L.
Crassulaceae
Sedum Nuttallianum Raf.
Saxifragaceae
**Ribes odoratum* Dougl.
[*Ribes aureum* Pursh, var. *villosum* DC.]
Rosaceae
Agrimonia rostellata Wallr.
Amelanchier arborea (Michx. f.) Fern.
Crataegus sp.
Prunus americana Marsh.
Prunus angustifolia Marsh.
Rosa carolina L.
Rosa setigera Michx.,
var. *tomentosa* T. & G.
Leguminosae
Acacia angustissima (Mill.) Kunze,
var. *hirta* (Nutt.) Robinson
Amorpha canescens Pursh.,
forma *canescens*
Amorpha fruticosa L.
Amphicarpa bracteata (L.) Fern.,
var. *bracteata*
Astragalus crassicarpus Nutt.,
var. *crassicarpus*
**Baptisia leucophaea* Nutt.
var. leucophaea
[*Baptisia bracteata* (Nutt.)
Kartesz & Ghandi
var. *leucophaea* Muhl.ex. Ell.]
**Cassia fasciculata* Michx.
[*Chamaecrista fasciculata* (Michx.)
Greene]
**Cassia nictitans* L.
[*Chamaecrista nictitans* (L.) Moench]
Cercis canadensis L., var. *canadensis*
Clitoria mariana L.
Dalea purpurea Vent., sen. lat.
Desmanthus illinoiensis (Michx.)
MacM.
Desmodium canescens (L.) DC Wood
Desmodium glutinosum (Muhl.) Wood
Desmodium sessilifolium (Torr.) T. & G.
Galactia volubilis (L.) Britton,
var. *mississippiensis*
Lespedeza violacea (L.) (Pers.)
Lespedeza stuevei Nutt.,
forma *stuevei*
**Psoralea tenuiflora* Pursh.
[*Psoralidium tenuiflora* (Pursh) Rydb.]
Stylosanthes biflora (L.) BSP.,
var. *hispidissima* (Michx.)
Pollard & Ball
Tephrosia virgjniana (L.) Pers.,
var. *virginiana*
Linaceae
Linum sulcatum Riddell
Oxalidaceae
Oxalis corniculata L.
Oxalis violacea L., var *violaceae*
Geraniaceae
Geranium carolinianum L.
Euphorbiaceae
Acalypha virginica L.
Croton glandulosus L.,
var. *septentrionalis* Muell. Arg.
Euphorbia corollata L. var. corollata
Euphorbia hexagona Nutt.
Euphorbia spathulata Lam.
Tragia urticifolia Michx.
Anacardiaceae
Cotnius obovatus Raf.
Rhus aromatica Ait., var. *aromatica*
Rhus copallinum L., var. *latifolia* Engl.
Rhus glabra L.
*Rhus Toxicodendron L.
[*Toxicodendron pubescens* P. Mill.]
Aquifoliaceae
Ilex decidua Walt.
Celastsraceae
Celastrus scandens L.
Rhamnaceae
Ceanothus americanus L.,
var. Pitcheri T. & G.
Vitaceae
Vitis aestivalis Michx.
Malvaceae
Callirhoe alcaeoidesi (Michx.) Gray
**Sphaeralcea angusta* (Gray) Fern.
[*Malvastrum hispidum* (Pursh) Hochr.
Guttiferae*
[Hypericaceae]
Hypericum punctatum Lam.
Cistaceae
Lechea tenuifolia Michx.
Violaceae
Viola pensylvanica Michx.,
var. *leiocarpa* (Fern. & Wieg.) Fern.
Lythraceae
**Cuphea petiolata* (L.) Koehne
[*Cuphea viscosissima* Jacq.]
Onagraceae
Oenothera laciniata Hill, var. *laciniata*
Oenothera linifolia Nutt.
Oenothera speciosa Nutt.
Umbelliferae
Daucus pusillus Michx.

Spermolepis echinata (Nutt.) Heller
Torilis japonica Houtt. DC

Cornaceae
Cornus drummondii Meyer

Ebenaceae
Diospyros virginiana L., var. *virginiana*

Oleaceae
Fraxinus americana L., var. americana

Gentianaceae
Sabatia campestris Nut., forma *campestris*

Apocynaceae
Apocynum cannabium L.,
var. *pubescens* (Mitchell) A. DC.

Asclepiadaceae
Asclepias tuberosa L.
Asclepias verticillata L.
Asclepias viridis Walt.
Asclepias *viridiflora* Raf., var. *viridiflora*

Boraginaceae
Heliotropium tenellum (Nutt.) Torr.
Myosotis verna Nutt.
Onosmodium hispidissium Mack.

Verbenaceae
**Lippia incisa* (Small) Tidestrom
[*Phyla nodiflora* (L.) Greene]
**Verbena canadensis* (L.) Britt.
[*Glandularia canadensis (L.) Nutt.*]
Verbena stricta Vent., forma s*tricta*

*Labiatae [Lamiaceae]
Monarda fistulosa L., var. fistulosa
Salvia azurea Moench.,
var. *grandiflora* Benth.
Scutellaria parvula Michx. var. *parvula*
Teucrium canadense L., var. virginicum
(L.) Eat.

Scrophulariaceae
**Gerardia heterophylla* Nutt.
[Agalinus *heterophylla* (Nutt.) Small]
**Gerardia tenuifolia* Vahl.,
var. *parviflora* Nutt.
[*Agalinus tenuifolia* Vahl, Raf.
var. *parviflora* Nutt. Pennell]
Penstemon cobaea Nutt.
Penstemon tubiflorus Nutt.
**Linaria canadensis* (L.) Dumont,
var. *texana* (Scheele) Pennell
[*Nuttalanthus canadensis* (L.) D.A.
Sutton, var. texana (Scheele)Sutton]

Solanaceae
Physalis pubescens L.,
var. *integrifolia* (Dunal) Waterfall
**Solanum Torreyi* Gray, forma *Torreyi*
[*Solanum dimidiatum* Raf.]

Acanthaceae
Ruellia humilis Nutt.

Plantaginaceae
Plantago Purshii R. & S., var. Purshii
Plantago virginica L.

Rubiaceae
**Diodia teres* Walt., var. *setifera* Fern. &
Grisc. [var. *teres*]
Gallium aparine L.
Hedyotis nigricans (Lam.) Fosb.

Caprifoliaceae
Symphoricarpos orbiculatus Moench
Triosteum perfoliatum L.
Virburnum prunifolium L., var. *ferrugineum*
Torr. & Gray

Campanulaceae
**Specularia biflora* (R. & P.)
Fisch. & Mey.
[*Triodanis perfoliata,* var. *biflora*
(R. & P.) Bradley]
**Specularia leptocarpa* (Nutt.) Gray
[*Triodanis leptocarpa* (Nutt.) Nieuwl.]
**Specularia perfoliata* (L.) A. DC.
[Triodanis *perfoliata* (L.) Nieuwl.]

*Compositae [Asteraceae]
**Achillea lanulosa* Nutt., forma *lanulosa*
[*Achillea millefolium* L.]
Ambrosia artemisiifolia L.
**Antennaria plantaginifolia* (L.) Richards
[*Antennaria parlinii* Fern]
**Aster azureus* Lindl.
[*Aster oolentangiensis* Riddell]
Aster ericoides L. (A. multiflorus)
Aster patens Ait., var. *patentissimus*
(Lindl.) T. & G.
**Aster sagittifolius* Wedemeyer
[*Aster cordifolius* L., var. *sagittifolius*
(Wed. ex Willd.) A.G. Jones]
Astranthium integrifolium (Michx.)Nutt.
**Cacalia plantaginea* (Raf.) Shinners
[*Arnoglossum plantigineum* Raf.]
Chrysopsis pilosa Nutt.
Cirsium altissimum (L.) Hill.
Erigeron strigosus Muhl. Ex. Willd.
Erigeron philadelphicus L.
Eupatorium altissimum L.
Gnaphalium obtusifolium L.
**Gutierrezia dracunculoides* (DC) Blake
[*Amphiachris drancunculoides* (DC)
Nuttal]
Helianthus hirsutus Raf.,
var. *trachyphyllus* T. & G.
**Kuhnia eupatorioides* L.,
var. *corymbulosa* T. & G.
[*Brickellia eupatorioides* L.,
var. *corymbulosa* (T. & G.) Shinners]

Liatris punctata Hook,
var. *nebraskensis* Gaiser
Liatris squarrosa (L.) Michx.,

var. hirsuta Rydb. Gaiser
*_Pyrrhopappus scaposus_ DC.
[_Pyrrhopappus grandiflorus_ (Nutt.)]
Ratibida columnifera (Nutt.) W. & S.
Rudbeckia hirta L.
Solidago missouriensis Nutt.,
var. _fasciculata_ Holz.
Vernonia baldwinii Torr., var. _Baldwinii_

	sandstone				limestone				shale			
	C	S	N	Av.	C	S	N	Av.	C	S	N	Av.
pH	4.9	4.1	5.9	5.3	7.2	7.0	5.9	7.0	7.5	7.7	7.8	7.7
Organic matter	28	35	34	32.3	46	50	34	43.3	70	70	51	63.7

TABLE II. Soil data for pH and organic matter correlated with slopes and strata.

C __ Composite samples from north, east, and west slopes.
S __ Samples from south slope.
N __ Samples from north slope.

Analysis by Tulsa County Agricultural Agent.

	SANDSTONE							LIMESTONE						
	Den-sity	Fre-quency %	Domi-nance	Rela-tive Dens. %	Rela-tive Freq. %	Rela-tive Domn. %	I.P. %	Den-sity	Fre-quency %	Domi-nance	Rela-tive Dens. %	Rela-tive Freq. %	Rela-tive Domn. %	I.P. %
Quercus Stellata	.32	32	38.33	61.5	61.5	88.7	70.6	.37	18.7	10.7	33	27	9	23
Quercus Marilandica	.107	10.7	3.88	23	23	9	18.3							
Quercus Muehlenbergii								.31	25	39.4	27.7	36.3	40.8	34.9
Quercus Shumardii								.31	25	33.02	27.7	36.3	40.6	34.86
Carya Texana	.07	7.1	.95	15.3	15.3	2.2	10.6							
Fraxinus Americana								.125	6.2	1.5	11	9	1.9	7.3
Cotinus Obovatus								.875	50		43.7	61.5		

TABLE III. Comparison of parameters of tree species on sandstone and limestone. Quantitative values after Phillips (1959)