
THE WOODY VEGETATION OF BEAR'S GLEN, A WASHINGTON IRVING STOPOVER*

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A wooded ravine near the joining of the Cimarron and the Arkansas Rivers has been definitely identified by James H. Gardner (1933) as the overnight camp site of the Washington Irving party which crossed Oklahoma in 1832.

******Editorial note approved by the Publications Board.* At the author's urgent insistence and as a measure of practical expediency, certain rules in punctuation, adhered to elsewhere in this volume, have been suspended in the present article. This circumstance is not to constitute a precedent for similar digressions in the future.

In Irving's (1835) *Tour on the Prairies* this location is described with care and referred to as "the wild rocky dell." Another member of the party, Charles Joseph Latrobe (1835), found good reason to call it "The Bear's Glen."

Partly because of the historical interest, but also as a unit of the woody vegetation of northeastern Oklahoma, Bear's Glen was selected for critical study as to composition, statistical analysis, habitat comparisons, and successional relations.

LOCATION AND PHYSIOGRAPHY

The ravine was located by Irving as being half a mile from the Arkansas River at a point one and a half miles above the mouth of the Cimarron River. Gardner placed the glen in the southeast corner of Pawnee County, mainly in Secs. 19 and 20, T. 20 N., R. 10 E. (Fig. 1). It can be reached by going north from Keystone on Highway 64 to the point where a dirt road continues north as the highway turns northwest. This dirt road shortly turns east, cuts down to the old floodplain level of the Arkansas and veers northeast past the openings of several ravines which have cut back into the sandstone upland bordering the Arkansas River valley. The second such ravine, approached in this manner, is the one where, more than one hundred years ago, eighty men and their horses found protection for a night after a difficult crossing of the Arkansas.

This upland is the so-called Washington Irving sandstone of Desjardins. It belongs to the Wann formation of the Pennsylvanian, as indicated by the symbols of Malcolm Oakes on the Aerial Geology Map of Tulsa County used in Fig. 1. The ravine or canyon which is the location of the present study consists of a U-shaped break in the sandstone bluff, with the wider and older portion facing the east toward the Arkansas River. It is traversed by an intermittent stream which was once a tributary of the Arkansas but now spreads its seasonal run-off over the cultivated floodplain east of the road which skirts the opening. The ravine is flanked by vertical rock walls or undercut ledges which are 102 meters (334.6 feet) apart at the entrance. The rock walls are 12 feet high, with the total relief of the ravine approximately 50 feet at this point. From the base of the rock in this wider part of the glen, soil-covered slopes meet the small floodplain which has been built up in the bottom. The ravine extends approximately 275 meters (902.0 feet) west, gradually becoming narrower with the floodplain disappearing and with the slopes increasingly rocky. Here the erosion is seen to be cutting back into the upland in two directions, with the smaller branch heading in a southwest direction. The main part becomes a narrow gorge with large boulders and it extends in a northwest direction 30 meters (98.4 feet) from the bend to its head which is a 9-foot drop in the bedrock of the stream. This forms the upper section of a falls when there is sufficient water. The present study was continued only 17.5 meters (57.4 feet) beyond the falls because here the slopes between the rock ledges designated as upland and the bedrock of the stream are narrow and support vegetation quite similar to the upland. There is still considerable rise from this point to the general level of the sandstone upland. The intermittent stream, which passes over the falls and courses through the ravine, comes from the higher upland through which it has cut a second ravine. It is intended to make this V-shaped ravine the subject of a second study in this area.

METHODS

The composition of the woody vegetation of Bear's Glen was studied by listing the trees and shrubs in the entire area after identifications had been made. Statistical analyses were based on chart belt transects and list quadrats. A comparative study of the upland was made by ten 10-meter quadrats, in which all trees and shrubs one inch or more in diameter were listed and their diameters breast high (inches D. B. H.) were recorded. In the ravine, six transverse belt transects, each ten meters wide, were spaced at the intervals shown in Fig. 2, and one lengthwise five-meter belt transect was run down the center. The location of each tree and shrub was charted and the D. B. H. recorded in all seven transects. The charts for the six transverse transects

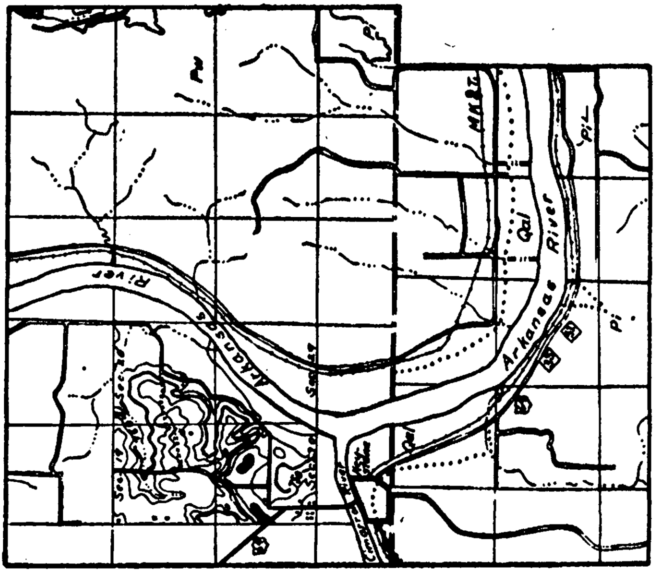

Fig. 1. Vicinity of Bear's Glen. Adapted from Areal Geology Map of Tulsa County by Malcolm Oakes, with Contours of 50 Feet Interval from U.S.G.S. Oklahoma Hominy Quadrangle.

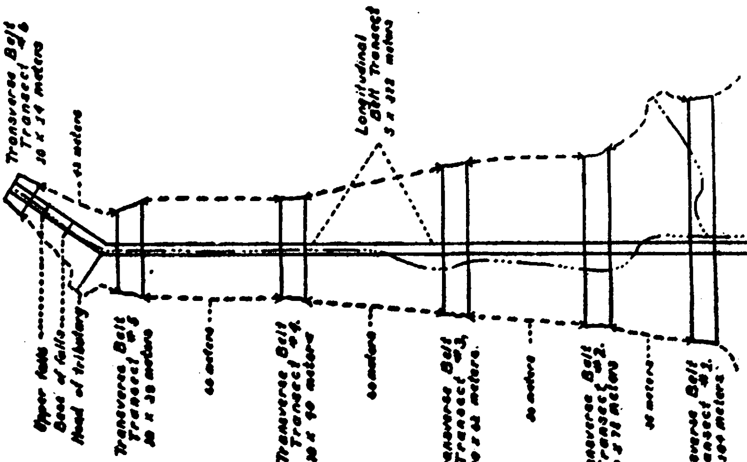

Fig 2 Location of Belt Transects

are presented in Fig. 3. Frequency of occurrence was tabulated by species. Density indices were computed for upland, slope, and bottomland, as well as for the six transverse transects.

The six transects across the ravine covered a total area of 3230 square meters. Since the area represented by the transects was 18,998 square meters, the six transverse chart transects afford statistical values of almost one-sixth of the total area. In the lengthwise transect, 1310 of the entire 1610 square meters covered portions of the ravine not touched by the transverse transects. Thus a grand total of 4540 of the 18,998 square meters was charted and studied statistically, which gives a figure of 4.18 or one-fourth of the area. Because of Penfound's study (1945) of quadrat size and number, the author consulted with him personally and is indebted for his assurance that the transects made in this study afford an ample proportion of the whole area of the ravine. For the upland, on the other hand, no definite proportion can be given because

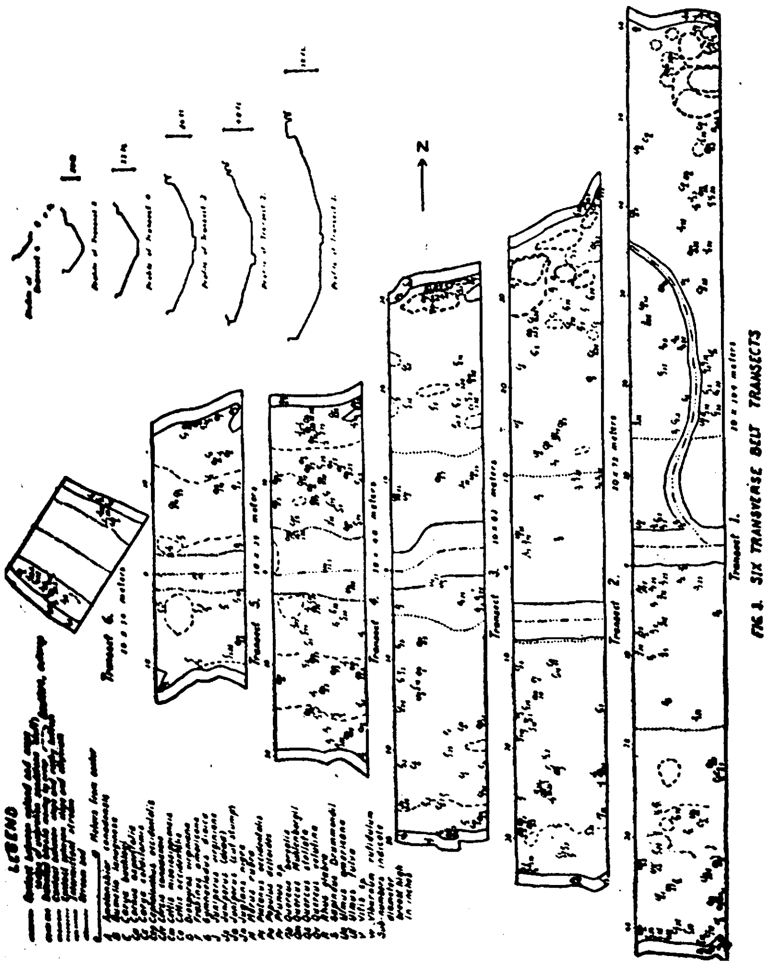

FIG. 3. SIX TRANSVERSE BELT TRANSECTS

of the large areas involved. The few list quadrats are intended only for comparison to the ravine and not as an adequate analysis of the upland vegetation.

The analyses of frequency and density were supplemented by a study of the diameter measurements of the trees in the six transverse belt transects. To this were added diameter measurements of all trees within the ravine with a D. B. H. of ten inches or more. This afforded a study of age classes 5 and 6 as described by Lutz (1930). From the diameter measurements a computation of basal areas was made. The diameter study and the basal-area analysis were used in comparing the vegetation of the different habitats found within and surrounding the ravine and in an attempt to interpret the successional relations.

COMPOSITION OF THE WOODY VEGETATION

Bruner (1931) designated the section of Oklahoma in which Bear's Glen is located as oak-hickory savannah and related this vegetation to the underlying sandstone. Luckhart and Barclay (1938) studied an oak-hickory community which was situated on sandstone of the Seminole formation of the Pennsylvanian, and was located near the southeastern limit of the city of Tulsa. Here the forest was shown by statistical study to be dominated by the hickory, *Carya buckleyi*, the post oak, *Quercus stellata*, and the blackjack oak, *Q. marilandica*. At Bear's Glen, the sandstone upland which surrounds the ravine on both sides and almost closes in on it at the head, supports these same three species as the important members of the oak-hickory woodland. The ravine, with its soil-covered and rocky slopes and with its lower floodplains and upper rocky gorge, offers a variety of habitats and presents a more varied vegetation than the upland.

The following list of plants, arranged according to families, includes all the woody plants which have been found to date in Bear's Glen. It represents a total of 45 species occurring in 35 genera and 22 families.

Pinaceae
- *Juniperus virginiana* L.

Liliaceae
- *Smilax rotundifolia* L.

Salicaceae
- *Salix nigra* Marsh.
- *Populus deltoides* Marsh.

Juglandaceae
- *Juglans nigra* L.
- *Carya buckleyi* Dur.
- *Carya cordiformis* (Wang.) K. Koch.

Fagaceae
- *Quercus stellata* Wang.
- *Quercus muhlenbergii* Engelm.
- *Quercus borealis* Michx. f.
- *Quercus marilandica* Muench.
- *Quercus velutina* Lam.

Urticaceae
- *Ulmus fulva* Michx.
- *Ulmus americana* L.
- *Celtis occidentalis* L.
- *Celtis mississippiensis* Bosc.
- *Morus rubra* L.

Aristolochiaceae
- *Aristolochia tomentosa* Sims.

Menispermaceae
- *Cocculus carolinus* (L.) DC.

Platanaceae
- *Platanus occidentalis* L.

Rosaceae
- *Rosa* sp.
- *Prunus* sp.
- *Amelanchier canadensis* (L.) Medic.
- *Rubus* sp.

Leguminosae
- *Gymnocladus dioica* (L.) Koch.
- *Gleditsia triacanthos* L.
- *Cercis canadensis* L.

Anacardiaceae
- *Rhus glabra* L.
- *Rhus copallina* L.
- *Rhus toxicodendron* L.
- *Rhus canadensis* Marsh.

Celastraceae
- *Evonymous atropurpureus* Jacq.
- *Celastrus scandens* L.

Sapindaceae
- *Sapindus drummondii* H. and A.

Vitaceae
- *Psedera quinquefolia* (L.) Greene
- *Vitis* sp.

Hypericaceae
- *Ascyrum stans* Michx.

Cornaceae
- *Cornus asperifolia* Michx.

Sapotaceae
- *Bumelia lanuginosa* (Michx.) Pers.

Ebenaceae
- *Diospyros virginiana* L.

Oleaceae
- *Fraxinus americana* L.

Rubiaceae
- *Cephalanthus occidentalis* L.

Caprifoliaceae
- *Symphoricarpos orbiculatus* Moench.
- *Sambucus canadensis* L.
- *Viburnum rufidulum* Raf.

From the foregoing list, the large number of genera (35) is notable with relation to the 45 species. With the exception of two species each for the genera *Ulmus*, *Celtis*, and *Carya* and four species each for the genera *Quercus* and *Rhus*, each genus is represented by just one species. That a similar relation existed in the Luckhart and Barclay (1938) study is indicated in Table I. In the latter location one slope led down to a small floodplain but no hillside was part of a ravine. The larger number of species at Bear's Glen and especially the number found only there is not surprising in view of the greater variation of habitat. The only woody plants found at the Seminole-sandstone station and not seen at Bear's Glen were *Carya pecan*, *Ulmus alata*, and *Crataegus* sp. Probably the most outstanding difference to the observer would be the abundance of red cedar, *Juniperus virginiana*, on the bluff around Bear's Glen and the lack of it at the other location.

TABLE I

Comparison of Bear's Glen and the Luckhart-and-Barclay Station

Woody vegetation	Bear's Glen (Wann sandstone)	Luckhart-Barclay Station (Seminole sandstone)
No. of species	45	31
No. of genera	35	21
No. of families	22	14
No. of species listed for one station only	15	3

STATISTICAL ANALYSIS OF TRANSVERSE BELT TRANSECTS

Species occurrence or frequency in the six transverse belt transects is summarized in Table II. In the combined 3230 square meters, 360 woody plants one inch D. B. H. or over were charted. The trees and shrubs are listed for this purpose as belonging to upland, slope, or bottomland. The listing of the species in the order of their frequency of occurrence indicates that the white ash, *Fraxinus americana*, is the most abundant tree over the area as a whole, followed by the red cedar, *Juniperus virginiana*, and the chinaberry, *Sapindus drummondii*. The variety of the woody vegetation of the ravine again becomes apparent, with many species making up small percentages of the transect trees.

The figures of Table II serve to show the fallacy of judging dominance in vegetation by frequency alone. On this basis, the white ash would be considered the dominant tree in the ravine, but the ash does not impress the observer as being one-third more important than any other tree, as the frequency figures would seem to indicate. These figures would make either the chestnut oak, *Quercus muhlenbergii*, or the northern red oak, *Q. borealis*, only half as important as the ash, but they are prominent on the slopes, and the American elm, *Ulmus americana*, with a still lower frequency rating, is represented by very large trees. A better picture of dominance is gained by a study of diameter averages and of basal areas and will be discussed under habitat comparisons.

This conclusion regarding frequency is in agreement with that of Penfound (1945) who regards frequency as the most artificial and least important measure of the prominence of a species.

The frequency totals of Table II are of value, however, in obtaining some general density comparisons. In every transect more species and more individuals are located on the slopes than on the upland and bottomland together. This difference could be expected to a degree since the greater part of the transects lies on slope areas, but if the transects had extended somewhat farther into the upland a similar difference would probably still occur, due to the greater density of the vegetation within the ravine. Statistical evidence of the greater density of woody vegetation within the ravine as compared with the

TABLE II

Statistical analysis of species occurring in six transverse transects[a]

Species	Transect 1			Transect 2			Transect 3			Transect 4			Transect 5			Transect 6			Species total
	U	S	B	U	S	B	U	S	B	U	S	B	U	S	B	U	S	B	
Fraxinus americana	1	11	1	1	17	—	—	14	—	—	9	—	—	10	1	—	1	—	66
Juniperus virginiana	5	4	—	1	—	—	2	3	—	—	13	—	—	4	—	5	8	—	45
Sapindus drumondii	—	7	21	—	1	8	—	—	—	—	—	—	—	—	—	—	—	—	37
Quercus borealis	—	4	—	—	9	—	—	3	—	—	15	—	1	1	—	—	1	—	34
Quercus muhlenbergii	—	14	—	—	3	—	—	7	1	—	7	—	—	2	—	—	—	—	34
Ulmus americana	—	7	1	—	1	1	—	3	5	—	—	2	—	—	—	—	—	—	20
Carya cordiformis	—	3	—	—	8	—	—	7	—	—	—	—	—	—	—	—	—	—	18
Quercus stellata	—	—	—	—	—	—	1	—	—	1	4	—	—	8	—	—	1	—	15
Vitis sp.	—	4	—	—	2	—	—	4	—	—	3	—	—	—	—	—	—	—	13
Gymnocladus dioica	—	8	—	—	—	—	—	1	3	—	—	—	—	—	—	—	—	—	12
Carya buckleyi	—	—	—	—	1	—	1	2	—	—	4	—	—	3	—	—	—	—	11
Amelanchier canadensis	—	—	—	—	4	—	—	—	—	—	3	—	—	1	—	—	—	—	8
Celtis occidentalis	—	5	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	7
Bumelia lanuginosa	—	2	—	—	3	—	—	—	—	—	—	—	—	1	—	—	—	—	6
Ulmus fulva	—	3	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Viburnum rufidulum	—	1	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Celtis mississippiensis	—	—	—	—	1	—	—	2	—	—	—	—	—	—	—	—	1	—	4
Prunus sp.	2	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	4
Cornus asperifolia	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Diospyros virginiana	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	2
Cephalanthus occidentalis	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	2
Cercis canadensis	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	2
Juglans nigra	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	2
Morus rubra	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Platanus occidentalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Populus deltoides	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Quercus velutina	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Rhus glabra	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Total No. spp.	3	14	4	3	16	2	3	12	5	1	10	4	1	9	2	1	6	0	
Spp. in transect		16			18			14			13			10			6		
Total No. individuals	8	76	24	3	59	9	4	48	11	1	60	5	1	31	2	5	13	0	360
Individuals in transect		108			71			63			66			34			18		360
Percentage in transect		30.00			19.72			17.50			18.33			9.44			5.00		

[a]U, upland; S, slopes; B, bottomland.

upland is seen in Table III, where the number of square meters studied by transect and quadrat methods is divided by the number of individuals to give the density index of the different areas. It will be noted that while both the bottomland and the upland vegetation are thus shown to be less dense, the slopes taken alone show the greatest density of woody growth.

TABLE III

Density indices of upland, slope, and bottomland

Area	No. of square meters	No. of individuals	Density index
Bottomland—in longitudinal transect	1610	52	30.96[a]
Bottomland—in transverse transects	865	50	17.30
Slopes and bottomland—in transverse transects	3110	335	9.28
Upland, slopes, and bottomland—in transverse transects	3230	358	9.02
Upland—in quadrats	1000	122	8.20
Slopes—in transverse transects	2245	285	7.90

[a]One tree or shrub of one inch D. B. H. or over to every 30.96 square meters.

Another comparison which can be made from the frequency totals of Table II is the reduction in numbers of individuals from 108 in Transect 1 to 32 in Transect 5 below the falls and to 18 in Transect 6 above the falls. This reduction is gradual throughout the length of the ravine except in Transect 4 (Fig. 3), where the large number of oaks raises the total. If the reduction were due only to the decrease in the size of the transects, it would seem that there should be no exception in Transect 4. The increasing amount of bare rock surface in proportion to soil, in passing from the opening to the head of the ravine, suggests a possible relation to the general reduction in number of species and individuals, but again, it seems as if there should be no exception in Transect 4. That the frequency picture is not reliable is indicated once more by obtaining density indices for the six transverse transects. Table IV shows that Transect 4 has the highest density of vegetation in the ravine, with one tree to every 6.06 square meters. Surprisingly, Transects 6 and 5 follow as second and third in density and Transect 2, which gives the appearance of having many trees, has the least dense vegetation. The ranking of Transect 6 might be due to the small size of the transect, but the greater density of the entire upper half of the ravine in comparison to the lower half must be important, as the younger unshaded habitat allows invasion by more individuals.

ANALYSIS OF VEGETATION BY HABITAT COMPARISON

Variation in the vegetation of a ravine should be considered from two standpoints. The change in physiography from the entrance to its head is

TABLE IV

Density indices of the transverse transects

Transect	No. of square meters	No. of individuals	Density index	Rank as to density
1	1040	108	9.63[a]	4th
2	730	71	10.28	6th
3	630	63	10.00	5th
4	400	66	6.06	1st
5	290	32	9.06	3rd
6	140	18	7.77	2nd

[a]One tree or shrub of one inch D. B. H. or over to every 9.63 square meters.

likely to be a basic factor in the development of plants throughout its length. Also the changes encountered from the rock ledge on one side of the ravine, down the adjacent slope, across the bottomland if there is one, and up the opposite slope, will offer other comparisons. These physiographic differences are evident in the proportions of bare rock and soil and in the variations of slope and exposure, and they are related to moisture and temperature. At Bear's Glen widely differing habitats have been produced both from the mouth to the head of the ravine and from side to side. A comparison of these habitats makes possible a better understanding of the vegetation associated with them.

The upland. The sandstone bluff represents a comparatively dry habitat which is characterized by exposure. As a ridge some fifty feet and more above the Arkansas floodplain to the east, it is subject to greater wind velocity and temperature changes than the ravine itself. It has not been possible to set up instruments for continuous records, but from psychrometer and anemometer readings at various times it is evident that the evaporating power of the air is greater on the upland than within the ravine. The sandstone rock is thinly soil-covered except for outcrops near the glen and for courses worn by the intermittent stream and its tributaries.

Since only a small portion of the transverse transects was upland and that at the very edges of the ravine, ten list quadrats were made, each ten meters square, five on each side of the upland bordering the ravine. Quadrats 1 and 10 were made on the upland near the mouth of the glen, that is, near the edge of the sandstone ridge. The quadrats were placed at random from there toward the upland bordering the head of the ravine, with numbers 1 to 5 on the north side and numbers 10 to 6 on the south side. The data from these quadrats is summarized in Table V.

It has already been stated that the woody vegetation of the upland is less dense in appearance than that of most of the ravine. This is due to the open nature of the oak-hickory savannah and it is verified by the occurrence of only 122 trees, one inch or more in diameter, in a total area of 1000 square meters. This gives a density figure of 8.2 (one tree to every 8.2 square meters). It would undoubtedly be much higher if it were not for the large numbers of small trees clustered so closely together that many of them will not survive.

It is not felt that 100 square meters is a sufficient measure of this large upland community, but it may serve somewhat as a basis for comparison to the ravine statistics. The variation from place to place is evident from the differences in the composition of the quadrats. The dominant tree is the post oak, *Quercus stellata,* from the standpoint of both frequency and size, since the large black oak, *Q. velutina,* is too scarce to be of significance. The quadrat averages do not indicate the very large size of many of the post oaks, since these figures are reduced by the many small trees also present. One old isolated tree not in the quadrats was 32 inches D. B. H. The blackjack oak, *Q. marilandica,* is well established in places; and the hickory, *Carya buckleyi,* usually a third dominant in oak-hickory communities, is present but large individuals are not abundant. This agrees with the importance ascribed to the post oak by Luckhart and Barclay (1938) as compared to the other two dominants. Bruner's (1931) statement that the post oak and blackjack oak in the same stand assume equal size would seem to be supported by the quadrat averages, but not by the individual large post oaks which often do not come within quadrats.

All species of woody vegetation which have been observed on the upland have also been found within the ravine. One upland tree, the black oak, *Quercus velutina,* was not found in any of the transects but was infrequently observed on the higher slopes near the middle of the ravine. The lack of abundance of this tree was remarked early in the study because it had been present at the Seminole-sandstone station mentioned above. The large black oaks on the south side of the upland indicate the more xeric nature of the upland as compared to the slopes of the ravine. The writer believes that there

TABLE V

Summary of ten 10-meter quadrats on the upland

Quad. No.		*Quercus stellata*	*Juniperus virginiana*	*Carya buckleyi*	*Quercus marilandica*	*Quercus velutina*	*Diospyros virginiana*	*Quercus borealis*	*Bumelia lanuginosa*	Total number
1	Number	7	1							8
	Av. B. D. H.	5.46	4.5							
2	Number	11	8							19
	Av. B. D. H.	4.43	2.34							
3	Number	4	3	1	3					11
	Av. B. D. H.	12.25	1.17	2.0	4.5					
4	Number	8	7		3					18
	Av. B. D. H.	4.38	1.0		3.5					
5	Number	6			3					9
	Av. B. D. H.	8.83			1.33					
6	Number	4	4						1	9
	Av. B. D. H.	2.75	4.88						2.25	
7	Number	4		9	2					15
	Av. B. D. H.	2.63		2.28	5.5					
8	Number			2		2	2	1		
	Av. B. D. H.			2.25		10.25	4.13	4.5		7
9	Number	14		5	1	1				21
	Av. B. D. H.	2.38		4.95	14.5	5.0				
10	Number	1		1	1	2				5
	Av. B. D. H.	5.0		3.0	1.5	7.88				
All	Number	59	24	18	12	5	2	1	1	122
	Av. D. B. H.	4.81	2.26	3.04	4.58	8.25	4.13	4.50	2.25	

has been some crossing between the red oak which is very abundant on the slopes and the black oak. The best means of identifying these two trees without acorns was found to be the winter buds. Sometimes terminal buds would be smaller but almost as hoary and angular as those of the black oak and would be associated with rounded lateral buds like those of the red oak. Since such trees from apparent crosses seemed to have the smooth upper bark of the red oak and grew on the slopes with red oaks of certain identification, they were classed as red oaks. Some of the red oaks charted for the south-facing rocky slopes of Transect 4 were of this type.

The slopes. The slopes of the ravine present a mesic habitat, varying in degree, in comparison with the upland. The substratum for plants changes from slopes of slight grade near the entrance, with good soil cover and only occasional large rocks, to steeper slopes in the middle portion and near the falls, with progressively less soil and more exposed rocks and boulders. Even in the latter location there is less exposure to drying winds than on the upland. During the spring the soil between the boulders is kept moist by seepage and by proximity to the water in the stream bed.

The woody plants of the slopes which are characteristic of the soil-covered areas below the middle of the ravine are bitternut hickory *(Carya cordiformis)*, American elm, *Ulmus americana*, slippery elm, *U. fulva*, black haw, *Viburnum rufidulum*, grape, *Vitis* sp. (occurring also in Transect 4), black walnut, *Juglans nigra*, and bush dogwood, *Cornus asperifolia*. Those which have become established on the rocky slopes of the upper portion but are not found in any great numbers on the soil-covered slopes are the post oak and the hickory, to which may be added the blackjack oak and the black oak which are not in any of the transverse transects.

Less obvious than the variation from entrance to head of the ravine, but of importance, is the difference between the slopes on the two sides. The south-facing slope tends to have less grade and to be longer than the north-facing slope. This is due to the more-rapid weathering of the rock ledge on the south-facing side with greater temperature fluctuations. The sandstone rock, some twelve feet thick near the entrance, is underlain by shale which wears away and allows great blocks of sandstone to tilt and finally move down the slope by creep. A few such detached blocks may be observed on the north-facing slope but happen not to have been in the transverse transects, whereas they are prominent features of the south-facing slope in the lower half of the ravine. They are shown in the profiles of Transects 1, 2, and 3 in Fig. 3. This displacement of blocks of sandstone, although gradual, is thought to have contributed to the overturning of three good-sized red cedars near the rim of the ravine, observed at times when no wind breakage was apparent. There are evidences of similar occurrences in the past. The shallow root systems of these trees and their tendency to grow on the surfaces of the large blocks of sandstone make them easier to dislodge than the oaks and other trees.

Temperature changes which are sufficiently different on the two slopes to cause variation in physiography can be expected to have an effect upon the development of vegetation. In walking through the glen, one is not aware of outstanding variations in the appearance of the woody plants of the two slopes. A difference in undergrowth appears, however, with a dense thicket of greenbrier, *Smilax rotundifolia*, on the south-facing slope and an almost complete lack of it on the opposite slope.

Table VI compares the woody vegetation of these opposite slopes, as well as the other habitats, by means of summations of the transverse transect data. The species are listed here in the order of their occurrence as follows: On the upland slopes but not bottomland; on upland, slopes, and bottomland; on the slopes alone; and finally chiefly on the bottomland. The D. B. H. figures are included, with averages for each species and each habitat. The combined transect segments of the north-facing slope have a total number of 146 woody plants, one inch or more in diameter, with the corresponding areas on the south-facing slope falling only five trees short of this. Frequency, again, therefore is insufficient to indicate the difference between the two slopes,

TABLE VI

Comparisons of woody vegetation in different habitats by transect summations

Species	Upland		N.-fac. slope		S.-fac. slope		Bottomland		Total average	
	No.	Average D. B. H.	No.	Average D. B. H.	No.	Average D. B. H.	No.	Average D. B. H.	No.	Average D. B.H.
Quercus stellata	2	5.25	2	7.75	11	3.93			15	4.62
Carya buckleyi	1	10.50	2	6.63	8	2.66			11	4.10
Juniperus virginiana	13	2.92	18	2.67	14	2.64			45	2.73
Quercus borealis	1	6.00	14	6.80	19	6.44			34	6.58
Quercus muhlenbergii			16	5.73	17	4.35	1	5.50	34	5.04
Prunus sp.	3	4.75					1	1.25	4	3.88
Fraxinus americana	2	8.38	43	2.92	19	3.89	2	4.75	66	3.42
Ulmus americana			5	6.75	6	9.08	9	10.28	20	9.04
Celtis mississippiensis			2	2.00	2	1.50			4	1.75
Celtis occidentalis			4	7.00	3	2.17			7	4.93
Amelanchier canadensis			8	1.75					8	1.75
Vitis sp.			9	1.42	4	1.50			13	1.44
Juglans nigra			1	6.25			1	11.00	2	8.63
Carya cordiformis			11	2.82	7	4.21			18	3.36
Ulmus fulva			2	7.25	3	7.67			5	7.50
Viburnum rufidulum			4	2.00	1	1.00			5	1.80
Cornus asperifolia			1	1.00	2	1.00			3	1.00
Morus rubra			1	3.25					1	
Cephalanthus occidentalis			1	1.00			1	1.50	2	1.25
Bumelia lanuginosa					6	3.83			6	3.83
Cercis canadensis			1	1.25	1	1.50			2	1.38
Quercus velutina					1	5.25			1	
Rhus glabra					1	1.00			1	
Gymnocladus dioica			1	1.50	8	1.66	3	2.17	12	1.77
Diospyros virginiana					1	2.00	1	1.00	2	1.50
Sapindus drummondii					7	5.21	30	2.16	37	2.74
Platanus occidentalis							1	13.00	1	
Populus deltoides							1	29.50	1	
Total of transect trees	22		146		141		51		360	
Av. D. B. H. for totals		4.36		3.76		4.11		3.02		

but a comparison of density is more helpful. For the 995 square meters charted on the north-facing slope by the transverse transects, a density index of 6.81 is obtained (one tree for every 6.81 square meters), whereas a similar index for the 1235 square meters on the south-facing slope is 8.75. This denser vegetation on the north-facing slope, denser than on either the south-facing slope or the upland, indicates a more mesophytic community.

It would appear from the transects that some trees such as shadbush, *Amelanchier canadensis*, and black walnut, *Juglans nigra*, might be limited to the north-facing slope, but they have been observed on the south-facing slope as well. Of possible significance is the second-largest diameter measurement on the slopes, 26 inches D. B. H., for a dead black walnut near the top of the north-facing slope about midway in the ravine. The tree may have died from old age since part of its trunk is still standing, 12 feet or more in height. It clearly shows the mesic conditions under which it grew on this north-facing slope.

The diameter measurements of Table VI provide further evidence of the greater degree of mesophytism of the community on the north facing-slope as compared with that on the south-facing slope. It is felt that the average of the individual species of the two slopes may be more important than the total D. B. H. averages of the two slopes, because the latter for the north-facing slope is undoubtedly reduced by the large number of small ash trees. In fact the only species which gave D. B. H. averages on the south-facing slope higher by more than one inch than on the north-facing slope were American elm, *Ulmus americana*, and bitternut hickory, *Carya cordiformis*. These are balanced by post oak, *Quercus stellata*, and hackberry, *Celtis occidentalis*, which had averages higher by more than one inch on the north-facing slope.

It was thought that Table VI would show the one or more trees which could be said to dominate the slopes. Since frequency alone has been shown to be undependable in indicating dominance, size in combination with frequency was considered. From these criteria it would seem that dominance is about equally divided between the northern red oak, *Quercus borealis*, and the chestnut oak, *Q. muhlenbergii*, with the same total number appearing in the transects. In each case there are more individuals on the south-facing slope but a larger average D. B. H. on the north-facing slope. The frequency of these two trees is surpassed only by the ash, but the average D. B. H. of the ash is very low, as considered previously. The average size of the two oaks is surpassed only by the American elm, especially on the south-facing slope, and by the post oaks on the north-facing slope but the number of the latter is too small to make them siginifcant and the number of elms on the two slopes is approximately one third the number of the oaks. It would seem from the transect data then, that the vegetation on the slopes should be called a northern red oak-chestnut oak community.

In order to check still further on dominance, the large trees of the entire glen were measured. Table VII gives the diameter averages of all trees 10 inches D. B. H. or over, and also, computed from these, the basal area averages. Lutz (1930) contended that his age classes 5 and 6, which include trees of 10 inches D. B. H. and over, are the true indication of dominance. Table VII shows at least a third more large red oaks than any other tree, and since this is a matter of selection, frequency is here thought to be of considerable importance. The second tree on the slopes from the standpoint of frequency of large trees is the American elm and it far outranks the red oak in average D. B. H., especially on the south-facing slope. Third, by way of frequency of large trees, is the chestnut oak, and it is interesting to note its larger D. B. H. average than the red oak on the south-facing slope.

A better check on dominance than diameter measurements should be the basal areas of the trees, especially when large trees alone are considered. It will be noted (see Table VIII) that even though the average diameter of the large elms exceeds that of the red oaks on the north-facing slope, the average basal area of the red oaks is slightly higher. The order of importance, as shown

TABLE VII

Diameter and basal-area averages for all large trees (10 inches D. B. H. or over)

Species	Upland			N.-facing slope			S.-facing slope			Bottomland			Totals		
	No.	Av'ge D. B. H.	Av'ge basal area	No.	Av'ge D. B. H.	Av'ge basal area	No.	Av'ge D. B. H.	Av'ge basal area	No.	Av'ge D. B. H.	Av'ge basal area	No.	Av'ge D. B. H.	Av'ge basal area
Q. stellata[a]				1	14.30	160.61	2	13.50	152.76				3	13.77	155.38
C. buckleyi	1	10.50	86.59	1	11.25	99.40							2	10.88	93.00
J. virginiana	6	12.79	135.29	2	14.00	163.56							8	13.09	142.36
Q. borealis	8	13.47	146.14	26	13.71	155.03	10	12.10	116.25				44	13.30	144.60
Q. muhlenbergii	3	14.50	171.55	5	12.80	135.63	6	14.46	180.89				14	13.87	162.72
Q. velutina				2	11.63	108.24							2	11.63	108.24
F. americana	4	11.69	113.42				2	11.38	103.11	4	11.50	104.50	10	11.55	107.80
U. americana	1	10.00	78.54	9	13.89	153.10	6	24.25	546.72	15	17.70	263.49	31	17.61	280.30
Celtis occidentalis				1	11.00	95.03	2	13.00	132.73				3	12.33	120.16
J. nigra							1	15.50	188.69	1	11.00	95.03	2	13.25	141.86
U. fulva							1	15.00	176.71				1		
B. lanuginosa							1	10.50	86.59				1		
S. drummondii							1	10.50	86.59				1		
P. occidentalis										2	12.88	260.41	2	12.88	260.41
P. deltoides										5	23.90	478.99	5	23.90	478.99
	23	12.84	135.40	47	13.47	148.63	32	15.02	213.88	27	17.32	263.74	129	14.55	186.55

[a]The abbreviated generic names, together with the same respective specific names, appear in full in Table VI.

by basal area alone, would be first, elm on the south-facing slope; second, chestnut oak on the south-facing slope; third, red oak on the north-facing slope; and fourth, elm on the north-facing slope. From the consideration of all the large trees in the glen, it would seem that the vegetation on the slopes would have to be called a chestnut oak-northern red oak-American elm community. The elm is named last, because although largest of all, these trees are more restricted to the lower parts of the slopes near the floodplain.

Table VII may also provide further evidence on the difference between the two slopes as tree habitats. In this case small individuals cannot reduce averages so the totals for the north- and south-facing slopes would seem significant. Almost a third more large trees were found on the north-facing slope and this should be a good indication of mesophytism. The higher average diameters and the higher average basal areas on the south-facing slope may indicate a greater growth of the established trees where light strikes more directly for a longer period of the day and the resulting periods of high temperature are longer, or it may indicate the earlier establishment of these trees on the south-facing slope. It is hoped that this study may be supplemented by a growth-ring analysis but it is doubtful whether an increment borer will reach to the centers of the large elms.

The bottomland. The bottom of the ravine presents a more hydric habitat than the slopes or the upland. It varies from the floodplain near the mouth of the ravine to the rocky stream bed and finally to the solid sandstone bedrock above the falls (Fig. 3). It also differs with the seasonal appearance of the intermittent stream or at least of seepage water if there is not sufficient water to flow as a stream through the lower floodplain.

The vegetation on the bottomland varies with the change from floodplain to rocky stream bed. Table VIII summarizes the 52 trees occurring within the longitudinal belt transect, 5 meters wide, laid out from the mouth of the ravine to the head (Fig. 2). Frequency alone indicates the importance of soapberry, *Sapindus drummondii,* and American elm, but size and frequency together show the dominance of elm and cottonwood, *Populus deltoides.* This same relationship is shown in the bottomland portions of transverse Transects 1 and 2 (Fig. 3). As the floodplain soil gives way, up the ravine, to a narrower rocky stream bed, persimmon, *Diospyros virginiana,* occurs frequently but the trees are small, whereas ash, *Fraxinus americana,* is less frequent but larger in size, and the tree which combines numbers and size is sycamore, *Platanus occidentalis.* In the last portion of the stream bed which is almost-unbroken sandstone bedrock, covered now very seldom by water, red cedar, *Juniperus virginiana,* seems to be the only tree which is able to establish itself, and that infrequently. In fact, this portion of the stream bed resembles upland more than it does bottomland, both in character and in vegetation. It would appear, then, that the vegetation of the lower bottomland or floodplain could be called a cottonwood-elm-soapberry community, that the rocky bottomland supports a sycamore-ash community, and the uppermost stream bed should be classed with the upland.

The importance of the cottonwood and the bottomland elm among the large trees of the entire glen may be seen in Table VII. The dominance of these two trees on bottomland is obvious but it must be rememberd that this applies to the lower part of the ravine where there is a floodplain. The sycamore of the rocky portion runs the basal-area figure of the bottomland elm a close second. Although the largest tree in the ravine is an American elm on the lower part of the south-facing slope (37.75 inches D. B. H.), the average of the five large cottonwoods near the mouth of the ravine is greater than the average of all the large elms. The average basal area of these cottonwoods is much larger than any other total average basal area, this figure being surpassed only by the average basal area of six large elms on the south-facing slope.

SUCCESSIONAL RELATIONSHIPS

Bear's Glen is a ravine cut into a sandstone ridge covered by oak-hickory woodland savannah. This is the climax vegetation of the sandstone hills region

TABLE VIII

Summary of longitudinal belt transect

Species		1-50 meters	50-100 meters	100-150 meters	150-200 meters	200-250 meters	250-300 meters	300-322 meters	Totals
Gleditsia	No.	1							1
triacanthos	Av. D. B. H.	4.50							
Celtis	No.	1							1
occidentalis	Av. D. B. H.	1.00							
Populus	No.	2							2
deltoides	Av. D. B. H.	22.25							
Sapindus	No.	4	2						6
drummondii	Av. D. B. H.	3.50	1.75						
Ulmus	No.	1	3	2	4				10
americana	Av. D. B. H.	4.50	15.75	13.63	6.19				
Fraxinus	No.			1	1	1	1		4
americana	Av. D. B. H.			6.00	13.00	4.50	5.00		
Bumelia	No.			1	1				2
lanuginosa	Av. D. B. H.			3.00	3.00				
Juglans	No.			1					1
nigra	Av. D. B. H.			11.00					
Quercus	No.			1			1		2
muhlenbergii	Av. D. B. H.			5.50			3.75		
Gymnocladus	No.			1					1
dioica	Av. D. B. H.			1.00					
Diospyros	No.			3	4	1	2		10
virginiana	Av. D. B. H.			2.33	3.25	3.00	2.50		
Platanus	No.				2	3	2		7
occidentalis	Av. D. B. H.				2.88	7.66	13.00		
Quercus	No.					1	1		2
borealis	Av. D. B. H.					6.00	3.00		
Juniperus	No.					1		2	3
virginiana	Av. D. B. H.					4.00		10.75	
Totals		9	5	10	12	7	7	2	52

of Oklahoma, being somewhat of an ecotone between the oak-hickory forest of eastern Oklahoma and the grassland of the greater part of Oklahoma. It is assumed that, given a sufficiently long time, the vegetation within the ravine will become oak-hickory woodland. Such maturity of vegetational development must be preceded by physiographic changes which have already broadened a narrow chasm and will eventually eliminate the ravine characteristics. Since these same physiographic changes are continually lengthening the ravine by cutting back into the sandstone ridge, the younger as well as the more mature stages are likely to be present for a long time to come.

Some evidence of the upper portions of the slopes working toward the oak-hickory community is seen in the occasional post oaks, blackjack oaks, and hickories invading the chestnut oak-red oak-elm community of the slopes.

It is natural that this invasion is at the upper portion of the slopes, while the elms are found on the lower portions where it is more mesic and less like the upland. It is thought that the woody succession on the upland and the exposed upper parts of the slopes may go through a shrub stage composed of such plants as sumac, *Rhus glabra*, and *Ascyrum stans*, which are found in these areas, to a tree stage composed of red cedar, *Juniperus virginiana*, and on to the oak-hickory community, or directly to the latter with an omission of the red cedar. There are many large cut stumps of the red cedar along the edge of the ravine, as well as much reproduction in places, indicating its prevalence in the past as well as in the future, but there is nothing to show that it is a necessary precedent to establishment of the oak-hickory community.

The lower portions of the slopes must necessarily take a longer time to become vegetated with post oaks, blackjack oaks, and Ozark hickories since the habitat is less like that of the sandstone ridge. As large sandstone blocks creep down the slopes, local habitats are established which are more like the substratum above than the broken rocks and soil surrounding them. Often red cedar and blackjack oak grow on these blocks when exposed in the upper half of the ravine. Excellent lichen and moss stages precede the establishment of other vegetation on the rock surfaces and could well be the subject of a separate study. Where soil has developed between the large blocks, elm, hackberry, and black walnut become established, the first two in great numbers. Ash trees, now so abundant on these slopes, may either have been coming in for a long time and not reaching the maturity of the elms or they may have come in more recently. It would seem to the author that an early stage of development on these lower soil-covered slopes is similar to a late floodplain stage dominated by elm, hackberry, and ash. Under the shade of these trees, especially the large elms, the red oaks and chestnut oaks have come in, so that the latter three together now dominate the slopes. The elms are larger and apparently older and they are certainly doomed to lose out as the habitat of the slopes becomes less mesic and the members of the oak-hickory community extend their invasion downward from above. It would seem that the isolated sandstone blocks with their local xeric habitats would become more mesic as they are shaded by the trees growing up around them, and their lichen and moss stages would give way to ferns and mesophytic herbs, and eventually they would be broken into smaller rocks. Such rocks have been observed under the cover of the dense growth of the mesophytic red oak-chestnut oak-elm community, on the more mature slopes near the mouth of the ravine. If they do not break down completely to soil by the time of the invasion of the oak-hickory community one could picture their return to the xeric habitat they once presented as isolated fragments separated from the upland.

The bottomland of the ravine should be the last to be invaded by the oaks and hickories from the ridge above. Here the woody stages of the succession are more clearly marked, beginning with such hydrophytic shrubs as buttonbush, *Cephalanthus occidentalis*, or omitting them and beginning with the sycamore, *Platanus occidentalis*, wherever the streambed is broken up into rocks and where considerable water is present at least for part of the year. The large sycamore just west of Transect 4 (Fig. 3) grows near a rock believed to have been described by Washington Irving (1832) as having a spring below it. There is at present water, at least seepage water, at this point much of the year. The sycamore stage might well have willow, *Salix nigra*, with it, but only one small specimen was observed in the glen. The sycamore stage, supplemented by persimmon and ash, is apparently prolonged until a floodplain soil is deposited on which cottonwood seeds can germinate. In Bear's Glen there is no intermediate stage of young cottonwoods. The intermittent stream must have stopped its flooding and soil building rather abruptly for the bottomland grades quite rapidly from an alluvial deposit four feet thick to rocky bottom with little soil. On the floodplain are the five very large cottonwoods mentioned previously which are apparently relics of a previous cottonwood stage and now can be only the old part of the cottonwood-elm-soapberry community. The soapberry is the young member of this developmental stage, and is reproducing widely near the mouth of the ravine. The establishment of this tree in such numbers (Fig. 3) in this and adjacent ravines is a point of interest to the author since no other specimens are known for some distance and this location is near the eastern limit of its range. The cottonwood-elm-soapberry stage is the most-mature community now present on the floodplain of the ravine. It is expected that it will eventually be invaded by the northern red and chestnut oaks with their accompanying species from the slopes, and eventually by the oak-hickory woodland.

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SUMMARY

A wooded ravine near Keystone, historically established as a one-night camp of Washington Irving's party in 1832, was statistically studied by means of belt transects. The ravine is cut into a sandstone ridge covered by oak-hickory savannah woodland, characteristic of the sandstone hills of Oklahoma. These trees grow in a comparatively xeric habitat and are openly spaced, with a density figure of 8.2. The dominants of the woodland were determined by quadrats to be post oak, *Quercus stellata*, blackjack oak, *Q. marilandica*, and hickory, *Carya buckleyi*.

Forty-five species of woody plants were identified in the ravine. The statistical data from six belt transects across the ravine and one transect running the length of the ravine, totalling one-fourth of the entire area, showed that frequency is not an indication of dominance, but that diameter measurements plus frequency can indicate dominance. Dominance was further established by diameter measurements and basal-area computations of all trees in the ravine ten inches or more in diameter. The slopes of the ravine are dominated by chestnut oak, *Quercus muhlenbergii*, northern red oak, *Q. borealis*, and on the lower parts by very large elm, *Ulmus americana*. The north-facing slope is more mesic as a habitat, as shown by fewer blocks of upland becoming detached and moving down the slope by creep. It supports a more mesophytic community as shown by a density figure of 6.81 for the north-facing slope as compared to 8.75 for the south-facing slope, by the woody species of the two slopes, and by a greater frequency of large trees on the north-facing slope. The south-facing slope has allowed greater growth of such trees as the elms, or they became established on that slope at an earlier date. The soil-covered slopes near the mouth of the ravine have some different species than the steeper rocky slopes near the head.

The bottomland of the ravine varies from rich floodplain near the mouth, on which a mature floodplain forest of old cottonwood, *Populus deltoides*, elm, and young soapberry, *Sapindus drummondii*, exists, to a rocky streambed with sycamore, *Platanus occidentalis*, elm, and persimmon, *Diospyros virginiana*, and finally to solid sandstone bedrock resembling the upland and supporting only a few red cedars, *Juniperus virginiana*.

The entire ravine should eventually become oak-hickory woodland, as physiographic changes eliminate the ravine characters. The succession toward the oak-hickory woodland is on xeric upland rock through woody shrubs and red cedar; on comparatively mesic slopes through elm, hackberry *(Celtis occidentalis)*, and ash *(Fraxinus americana)*, to a community of chestnut oak, northern red oak, and large elm, dominant now in the ravine; and on hydric bottomland through sycamore to cottonwood and to a community of old cottonwood, elm, and young soapberry now present near the mouth of the ravine.

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