

SHINNERS & MAHLER'S
FLORA OF NORTH CENTRAL TEXAS



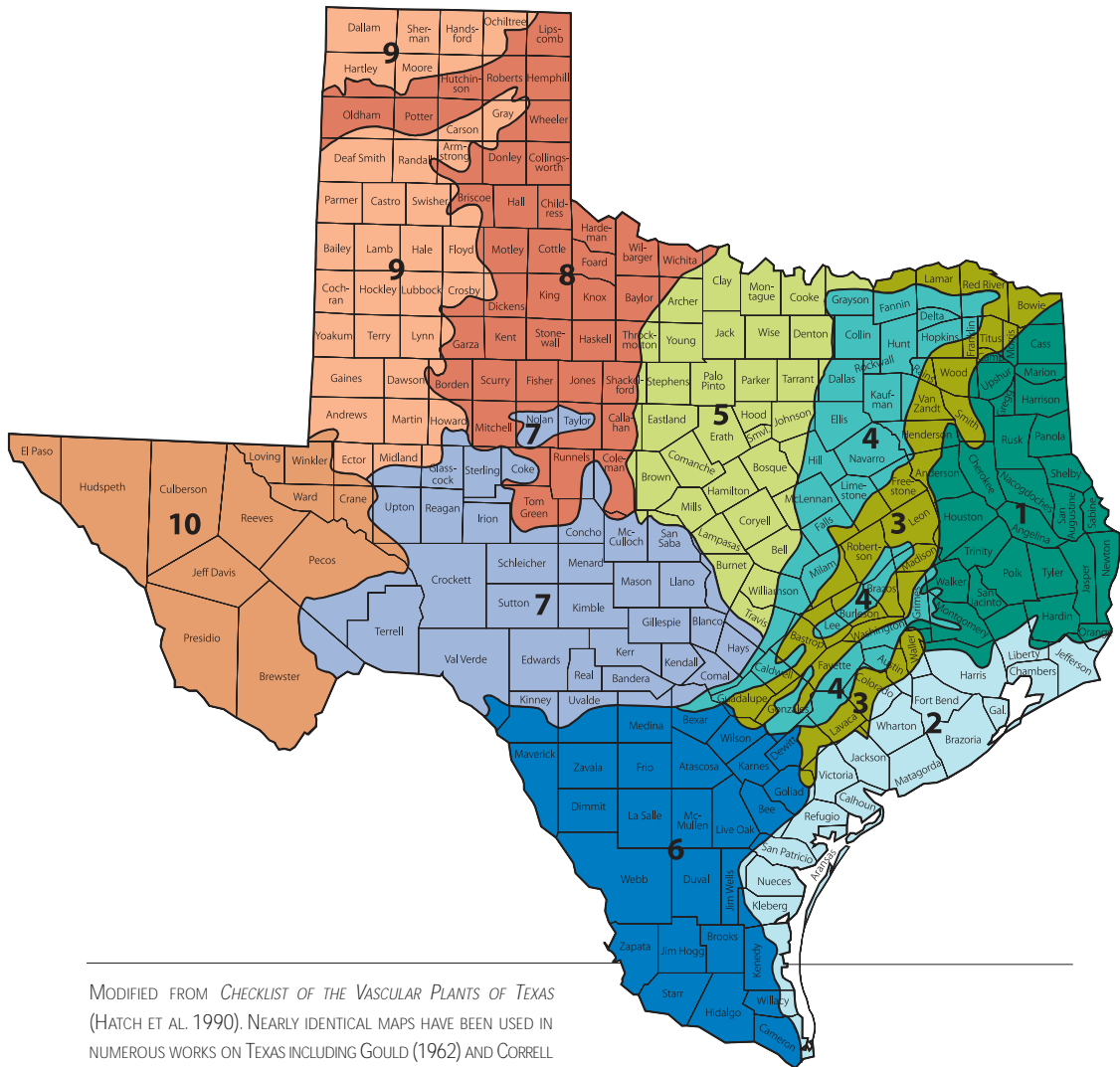
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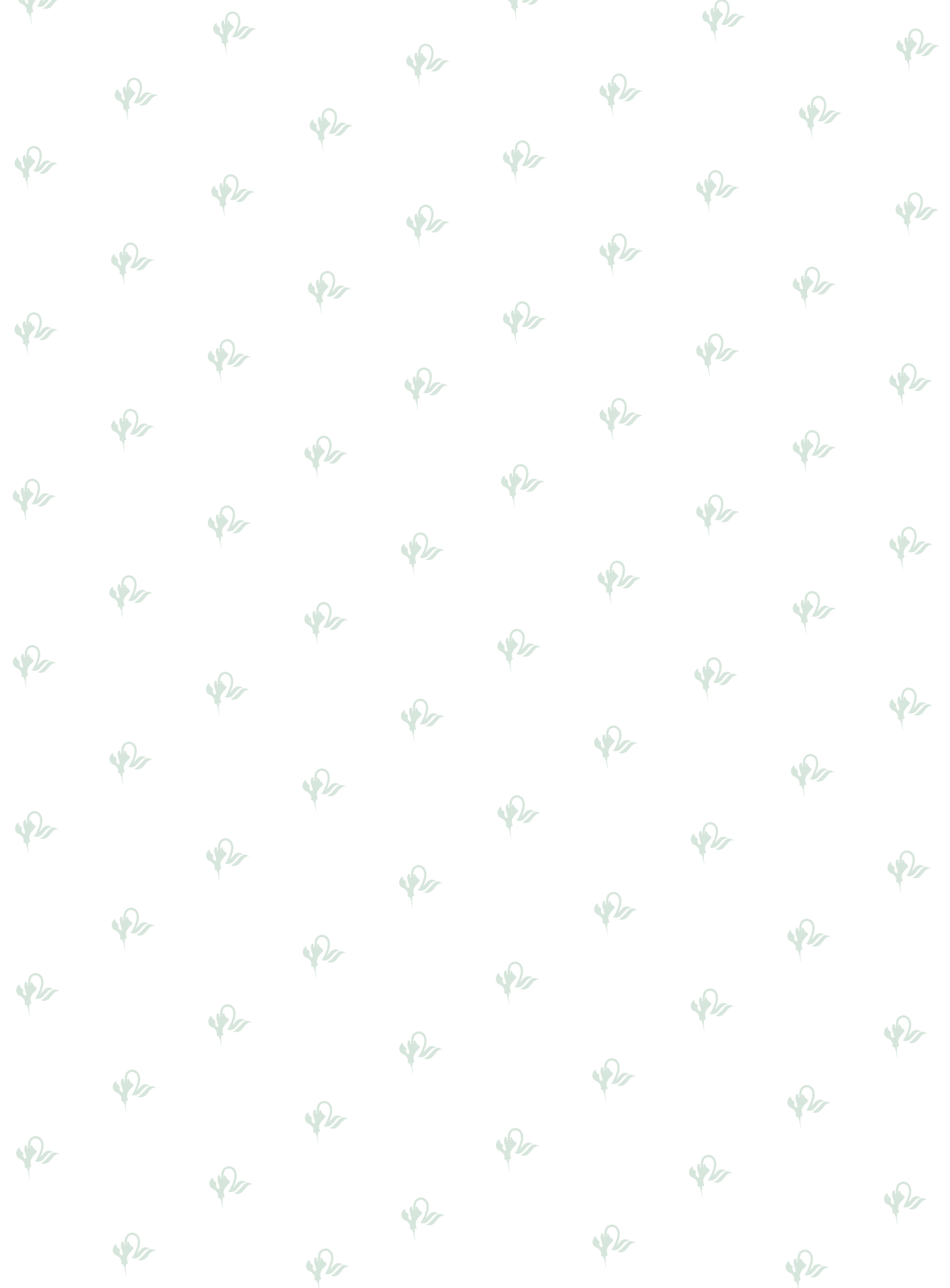


VEGETATIONAL AREAS OF TEXAS



MODIFIED FROM *CHECKLIST OF THE VASCULAR PLANTS OF TEXAS* (HATCH ET AL. 1990). NEARLY IDENTICAL MAPS HAVE BEEN USED IN NUMEROUS WORKS ON TEXAS INCLUDING GOULD (1962) AND CORRELL AND JOHNSTON (1970).

- 1 PINEYWOODS
- 2 GULF PRAIRIES AND MARSHES
- 3 POST OAK SAVANNAH
- 4 BLACKLAND PRAIRIES
- 5 CROSS TIMBERS AND PRAIRIES
- 6 SOUTH TEXAS PLAINS
- 7 EDWARDS PLATEAU
- 8 ROLLING PLAINS
- 9 HIGH PLAINS
- 10 TRANS-PECOS, MOUNTAINS AND BASINS





SHINNERS & MAHLER'S

ILLUSTRATED
FLORA OF
NORTH CENTRAL
TEXAS

Shimmers & Mahler's
ILLUSTRATED FLORA OF NORTH CENTRAL TEXAS

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Shinners & Mahler's
**ILLUSTRATED FLORA OF
NORTH CENTRAL TEXAS**



GEORGE M. DIGGS, JR. / BARNEY L. LIPSCOMB / ROBERT J. O'KENNON



CENTER FOR ENVIRONMENTAL STUDIES AND
DEPARTMENT OF BIOLOGY, AUSTIN COLLEGE
SHERMAN, TEXAS

Austin College
1849

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ILLUSTRATED FLORA OF NORTH CENTRAL TEXAS
IS THE FIRST PUBLICATION OF THE



**ILLUSTRATED TEXAS FLORAS
PROJECT**

A COLLABORATIVE PROJECT OF THE
AUSTIN COLLEGE CENTER FOR ENVIRONMENTAL STUDIES
AND THE
BOTANICAL RESEARCH INSTITUTE OF TEXAS
TO PRODUCE ILLUSTRATED FLORISTIC TREATMENTS
DESIGNED TO BE USEFUL TO BOTH BOTANICAL SPECIALISTS
AND A MORE GENERAL AUDIENCE.



“I CAN SIT ON THE PORCH
BEFORE MY DOOR AND SEE
MILES OF THE MOST 
BEAUTIFUL PRAIRIE INTER-
WOVEN WITH GROVES OF
TIMBER, SURPASSING, IN MY
IDEA, THE BEAUTIES OF THE
SEA. THINK OF SEEING A
TRACT  OF LAND ON A
SLIGHT INCLINE COVERED
WITH FLOWERS AND RICH
MEADOW GRASS FOR 12 TO
20 MILES....”

 JOHN BROOKE, EARLY SETTLER IN GRAYSON CO., TEXAS, 1849

To
Lloyd H. Shinnars
and
William F. Mahler
for their contributions to
Texas botany



Lloyd Herbert Shinnners



LLOYD HERBERT SHINNERS (1918–1971) was born in Bluesky (population 16), near Waterhole in the Peace River country of northwestern Alberta, Canada, on September 22, 1918. He was the child of homesteaders who had come from Wisconsin apparently under the National Policy [of Building Up Canada]. At the age of five, his family returned to Wisconsin where he attended public schools in Milwaukee and graduated from Lincoln High School as valedictorian of his class. He attended the University of Wisconsin-Milwaukee and later transferred to the University of Wisconsin-Madison from which he graduated Phi Beta Kappa in June, 1940. He also received his M.S. (1941) and Ph.D. (1943—Grasses of Wisconsin) degrees from the University of Wisconsin-Madison. Shinnners came to Southern Methodist University in Dallas in 1945, became the Director of the Herbarium in 1949, and was on the faculty there until his death in 1971. Not only did he almost single-handedly develop the herbarium which today forms the core of the Botanical Research Institute of Texas (BRIT) collection, but he also created one of the best botanical libraries in the United States, did extensive field work, and published a total of 276 articles and a 514-page flora (Flook 1973). Under his supervision the SMU herbarium grew from ca. 20,000 to 340,000 specimens. His contributions to botanical nomenclature are also particularly impressive, totaling 558 new scientific names and combinations (Flook 1973). Among his most lasting achievements are the *Spring Flora of the Dallas-Fort Worth Area Texas* (Shinnners 1958a) and the journal, *Sida, Contributions to Botany*, which he founded in 1962 (Mahler 1973b). His Spring Flora was the first completed, original, technical book on Texas plants prepared by a resident of the state. It was extensively used by high schools, colleges, and universities as a textbook for classes, and is still in use today. Shinnners was also one of the organizers in 1953 of the Southwestern Association of Naturalists and was the first editor of its journal, *Southwestern Naturalist*. He was a tireless worker and an individual of varied intellectual pursuits ranging from poetry to linguistics, music, and a proficiency in seven languages. He once wrote “I sometimes feel too that all my passionate desire to be a scientist, compose music and to write philosophy at one and the same time are in some measure owing to the land I live in.” His love of America was reflected in his gift to the Fondren Library at SMU of many books on American history. To quote Rowell (1972), he was “... a ‘scholar’ in the truest sense of the word.” For synopses of Shinnners’ life see Correll (1971), Mahler (1971b), and Rowell (1972); for a guide to his botanical contributions see Flook (1973). Details given here about Shinnners’ life are from Correll (1971), Mahler (1971), Rowell (1972), and particularly from an extensive unpublished biographical manuscript by Ruth Ginsburg (1998), a BRIT archivist who has organized all of Shinnners’ correspondence and other papers. —



William Fred "Bill" Mahler

WILLIAM F. "BILL" MAHLER grew up in Iowa Park, Texas, where he was born August 30, 1930. Upon graduation from W.F. George High School in 1947, he enrolled at Hardin College in Wichita Falls, Texas. After three years he enlisted in the U.S. Army instead of enrolling his last year in college and served from September 1950 to September 1953. After basic and advanced training in Headquarters Co., 8th Inf. Reg., 4th Inf. Div., he volunteered for airborne and ranger training. He served with the 14th Ranger Infantry Company (Airborne) at Fort Benning, Georgia, and Fort Carson, Colorado, until they were deactivated in 1951 (Black 1989; Taylor n.d.). In the meantime, the 4th Division had been sent

to Friedberg, Germany. He returned to his old company and spent nearly two years in Germany. In 1954, he returned to school and received his B.S. degree in 1955 in Agriculture from Midwestern State University (previously Hardin College) with a major in Soil and Plant Science and a minor in Animal Husbandry. Mahler and Lorene Lindesmith, from Addington, Oklahoma, met in his home town and were married in 1955.

In 1958 he went to Oklahoma State University (OSU) in Stillwater to pursue graduate work. Mahler received his M.S. degree in Botany/Plant Taxonomy from OSU in 1960, working under U.T. Waterfall. For the next six years he served as an assistant professor at Hardin-Simmons University (HSU) in Abilene, Texas, teaching botany and establishing the HSU herbarium. Subsequently he continued his graduate studies by attending the University of Tennessee at Knoxville where he received the Ph.D. in Botany/Plant Taxonomy in 1968. Upon graduation he joined the faculty of Southern Methodist University in Dallas, became editor and publisher of *Sida, Contributions to Botany* in 1971 following the death of L.H. Shinnars, and assumed leadership of the SMU herbarium in 1973. Mahler was publisher of *Sida, Botanical Miscellany* after he and Barney Lipscomb founded the journal in 1987. Under his guidance, the SMU herbarium grew by 72,000 specimens, eventually reaching about 400,000.

Mahler published *Shinnars' Manual of the North Central Texas Flora* (1984, 1988), well known for its clarity and ease of use. The manual, that included the summer and fall flora for North Central Texas, was an expanded version of Shinnars' (1958) *Spring Flora of the Dallas-Fort Worth Area Texas*. For his work, Mahler received the Donovan Stewart Correll Memorial Award for scientific writing on the native flora of Texas in 1991 from the Native Plant Society of Texas. Other notable publications included the *Keys to the Plants of Black Gap Wildlife Management Area, Brewster County, Texas* (1971), *Flora of Taylor County, Texas* (1973) and *The Mosses of Texas* (1980). Mahler's specialties include Fabaceae, *Baccharis* (Asteraceae), mosses, floristics, pollen morphology, and the study of endangered plant species. In 1988, Mahler was the first recipient of the Harold Beatty Award for his work with endangered plant species in Texas from the Texas Organization of Endangered Species. The Native Plant Society of Texas again honored Mahler in 1995 with the Charles Leonard Weddle Memorial Award in recognition of a lifetime of service and devotion to Texas native plants.

In 1987 SMU put its herbarium on permanent loan to a newly created organization, The Botanical Research Institute of Texas (BRIT). Mahler received early retirement from SMU (Associate Professor Emeritus) and served as the first Director of BRIT (1987-1992). Along with Andrea McFadden and long-time associate Barney Lipscomb, they were instrumental in its establishment as a free-standing research institution. Currently, Mahler is BRIT Director Emeritus and he and his wife are retired and living in Iowa Park, Texas. 🐾



SHINNERS & MAHLER'S

ILLUSTRATED FLORA OF NORTH CENTRAL TEXAS

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(Dodecatheon meadia)



ABSTRACT

Shinners & Mahler's Illustrated Flora of North Central Texas treats all native and naturalized vascular plant species known to occur in North Central Texas. The flora includes 2,223 species, about 46 percent of the species known for Texas, and 2,376 taxa (species, subspecies, and varieties). An introduction to the vegetation, geology, soils, climate, and presettlement and early settlement conditions is included as well as appendices on topics such as phylogeny and endemic species. The taxonomic treatments include family and generic synopses, keys and descriptions, derivations of scientific names, notes on toxic/poisonous and useful plants, and references to supporting literature. Line drawing illustrations are provided for all species with color photographs for 174. Three new combinations, *Gutierrezia amoena* (Shinners) Diggs, Lipscomb, & O'Kennon, *Manfreda virginica* (L.) Rose subsp. *lata* (Shinners) O'Kennon, Diggs, & Lipscomb, and *Mirabilis latifolia* (A. Gray) Diggs, Lipscomb, & O'Kennon, are made.

RESUMEN

Shinners & Mahler's Illustrated Flora of North Central Texas (La flora ilustrada del norte central de Texas, de Shinners & Mahler) trata todas las especies de plantas vasculares nativas y naturalizadas en la parte central del norte de Texas. La flora incluye 2,223 especies, aproximadamente el 46 por ciento de las especies conocidas en Texas y 2,376 taxa (especies, subespecies y variedades). Se incluye una introducción a la vegetación, geología, suelos, clima y condiciones de preasentamiento y asentamiento, así como apéndices sobre tópicos tales como filogenia y especies endémicas. Los tratamientos taxonomicos incluyen sinopsis de familias y géneros, claves y descripciones, etimología de los nombres científicos, notas sobre plantas tóxicas y útiles, y referencias bibliográficas. En cuanto a las ilustraciones se ofrecen dibujos de todas las especies y fotografías en color de 174. Se hacen tres nuevas combinaciones: *Gutierrezia amoena* (Shinners) Diggs, Lipscomb & O'Kennon, *Manfreda virginica* (L.) Rose subsp. *lata* (Shinners) O'Kennon, Diggs & Lipscomb y *Mirabilis latifolia* (A. Gray) Diggs, Lipscomb & O'Kennon.

SHINNERS & MAHLER'S ILLUSTRATED FLORA OF NORTH CENTRAL TEXAS



OVERVIEW OF THE BOOK

Shinners & Mahler's Illustrated Flora of North Central Texas is a floristic treatment of all native and naturalized vascular plant species known to occur in North Central Texas. The flora includes 2,223 species, about 46 percent of the species known for Texas, and a total of 2,376 taxa (species, subspecies, and varieties). Representatives of 168 families and 854 genera are included. It is a continuation in the tradition of Lloyd Shinners' *Spring Flora of the Dallas-Fort Worth Area Texas* (1958a) and William Mahler's *Shinners' Manual of the North Central Texas Flora* (1988). It differs from Mahler's (1988) work in the following ways: the total number of taxa is expanded from about 1,550 to 2,376; in addition to flowering plants, all ferns and similar plants (pteridophytes) and gymnosperms are included; it is fully illustrated; an introduction and appendices are provided; the taxonomic treatments have been expanded, including the addition of references to supporting literature; families, genera, and species are listed in alphabetical order within the major groups of plants; and a literature section with references pertinent to the plants of North Central Texas is provided.

A number of features have been incorporated to make the book more useful to non-specialists. Line drawings are provided for all species, making it the first fully illustrated flora for any region of Texas or the adjacent states. Color photographs are provided for 174 taxa. An introduction, covering general aspects of the vegetation, geology, soils, climate, and presettlement and early settlement conditions, has been included to provide background and context concerning North Central Texas. Further, the taxonomic treatments include brief synopses about each family and genus, derivations of generic names and specific epithets, characters helpful in family recognition in the field, notes on useful and toxic plants (ethnobotanical information), and references to supporting literature. Finally, appendices are provided on phylogeny (evolutionary relationships) at the family level, grass phylogeny, endemics, illustration sources, botanically related internet addresses, cladistics (a current controversy/approach in taxonomy), changes in scientific names, collecting herbarium specimens, conservation organizations, lepidopteran (butterfly and moth) host plant information, books for the study of native plants, suggested native ornamentals, sources for native plants, and state botanical symbols. When possible and practical, we have attempted to conform to the suggestions in Schmid's (1997) article on suggestions to make floras more user friendly.

GEOGRAPHIC AREA COVERED

North Central Texas is an area of roughly 40,000 square miles (103,700 square kilometers) or nearly the size of Kentucky. This 50 county region stretches from the Red River border with Oklahoma on the north, south nearly to Austin, east to Paris, and west nearly to Wichita Falls and Abilene. Vegetational areas included are the Blackland Prairie, the Grand Prairie, the East and West cross timbers, and the Red River Area (Fig. 1).

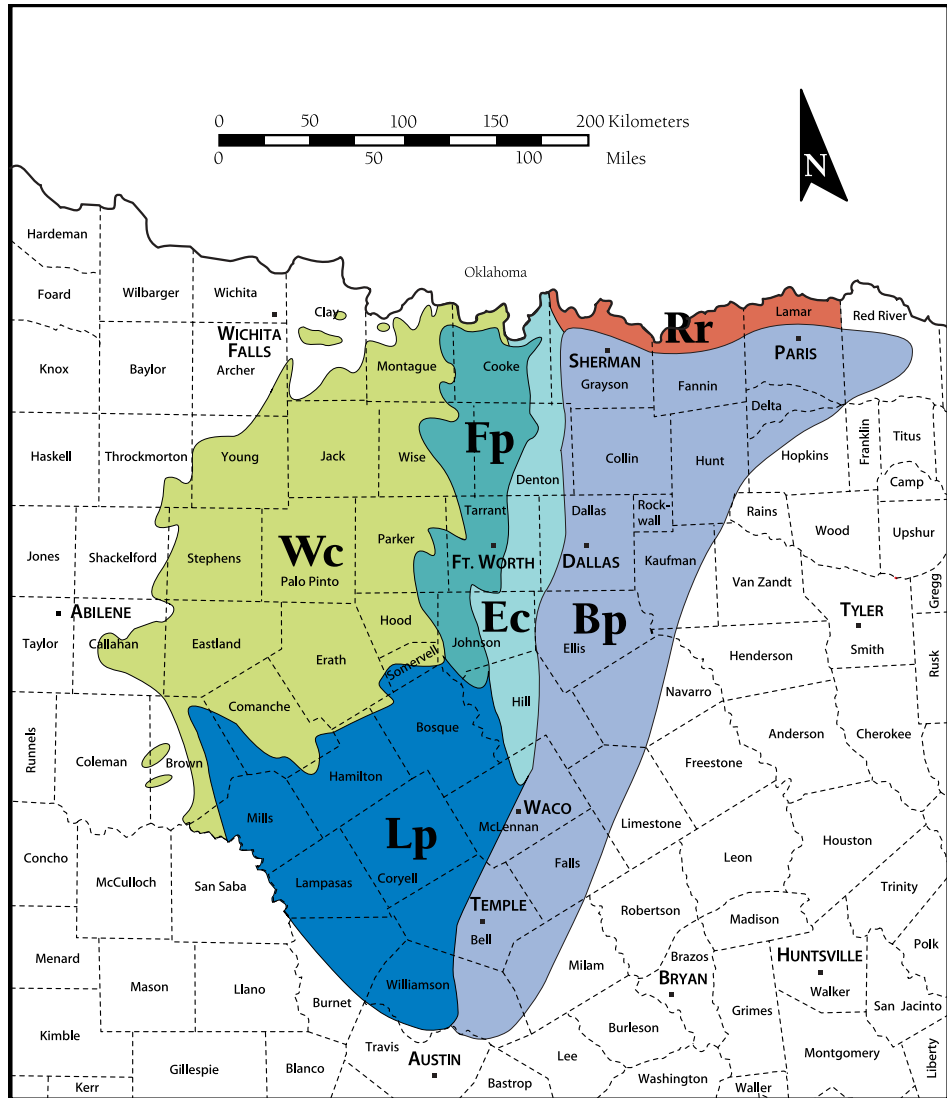
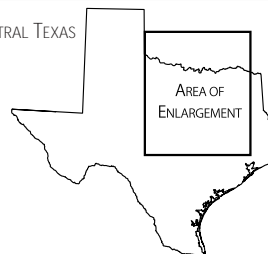


FIG. 1/VEGETATIONAL AREAS OF NORTH CENTRAL TEXAS



- Bp** BLACKLAND PRAIRIE
- Ec** EAST CROSS TIMBERS
- Fp** FORT WORTH PRAIRIE
- Lp** LAMPASAS CUT PLAIN
- Rr** RED RIVER AREA
- Wc** WEST CROSS TIMBERS

How does one define the limits of an area like North Central Texas for a floristic work such as this? On one level, the region can be defined geologically as encompassing all the Texas cross timbers and prairies occurring on soils derived from outcropping Cretaceous rocks. In a different manner, precipitation levels can be used (area of northern Texas with an average precipitation of 24 to 46 inches per year). In still another, the region is basically a broad ecotone between eastern deciduous forest and western grassland. However, for the purpose of this work, North Central Texas corresponds roughly with vegetational areas 4 (Blackland Prairie) and 5 (Cross Timbers and Prairies) of Correll and Johnston (1970) and Hatch et al. (1990) (Fig. 2) and is essentially the same as that treated by Mahler (1988) (Fig. 3). An alphabetical list of the counties wholly or partially included can be found in Fig. 3.

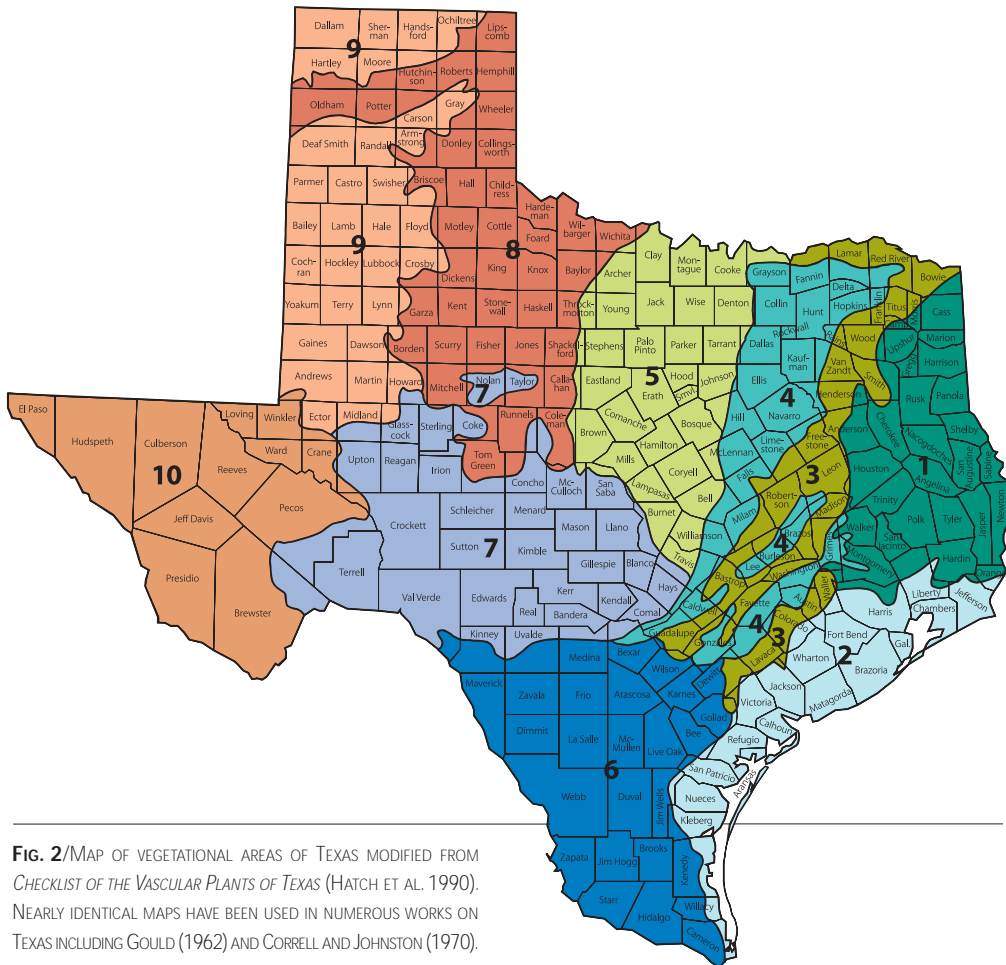
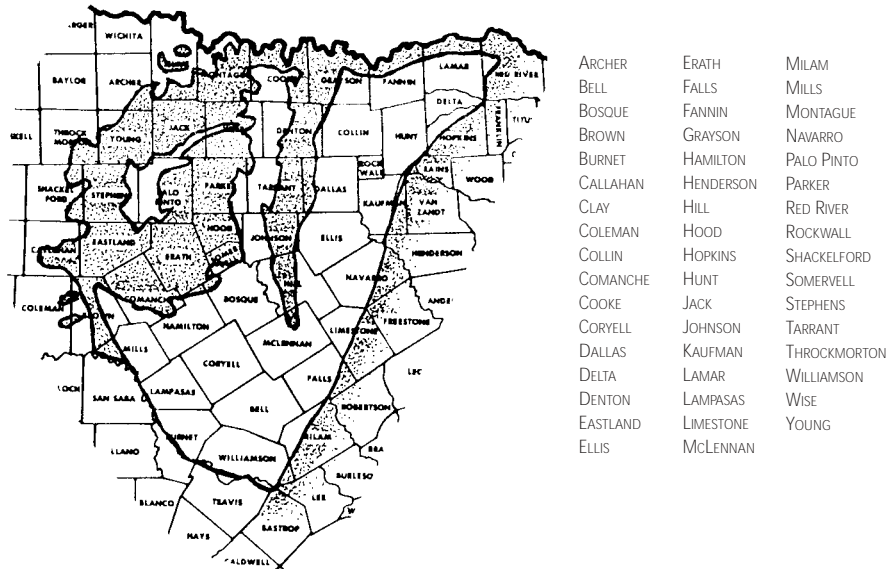


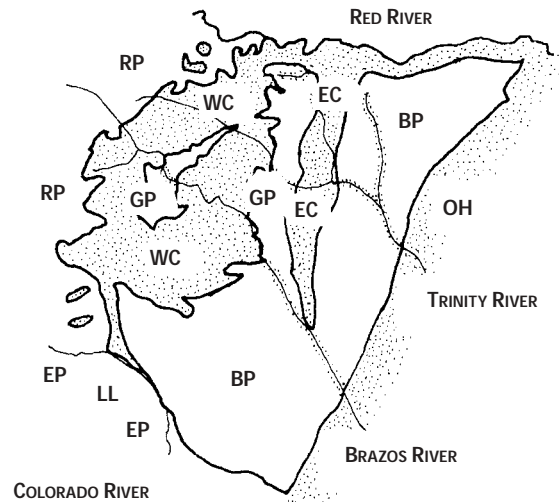
FIG. 2/Map of vegetational areas of Texas modified from *Checklist of the Vascular Plants of Texas* (Hatch et al. 1990). Nearly identical maps have been used in numerous works on Texas including Gould (1962) and Correll and Johnston (1970).

- 1 PINEYWOODS
- 2 GULF PRAIRIES AND MARSHES
- 3 POST OAK SAVANNAH
- 4 BLACKLAND PRAIRIES
- 5 CROSS TIMBERS AND PRAIRIES
- 6 SOUTH TEXAS PLAINS
- 7 EDWARDS PLATEAU
- 8 ROLLING PLAINS
- 9 HIGH PLAINS
- 10 TRANS-PECOS, MOUNTAINS AND BASINS



VEGETATIONAL AREAS WITH COUNTIES

- RP RED PLAINS
- BP BLACKLAND PRAIRIE
- GP GRAND PRAIRIE
- EP EDWARDS PLATEAU
- EC EAST CROSS TIMBERS
- WC WEST CROSS TIMBERS
- OH OAK-HICKORY
- LL LLANO BASIN



VEGETATIONAL AREAS WITH MAJOR RIVERS

FIG. 3/VEGETATIONAL AREAS OF NORTH CENTRAL TEXAS MODIFIED FROM *SHINNERS' MANUAL OF THE NORTH CENTRAL TEXAS FLORA* (MAHLER 1988) INCLUDING A LIST OF COUNTIES WHOLLY OR PARTIALLY COVERED. THE GEOGRAPHIC AREA COVERED BY THE PRESENT WORK IS ESSENTIALLY THE SAME (EXCEPT THE RED RIVER AREA HAS BEEN ADDED); THE LIST OF COUNTIES TREATED BY MAHLER IS THEREFORE ALSO ACCURATE FOR THIS WORK.

The area includes the Blackland Prairie (excluding the San Antonio and Fayette prairies), the Grand Prairie—here divided into the Fort Worth Prairie and the Lampasas Cut Plain, and the East and West cross timbers (discrete belts of forest surrounded by prairie). Extensions of vegetational area 3 (Post Oak Savannah) and even components of vegetational area 1 (Pineywoods) also enter the area from the east along the major rivers (Fig. 4). In particular, the number of species treated was increased significantly in comparison with Mahler's 1988 work by the inclusion of

the Red River Area (Fig. 1). This is a vegetationally different, narrow strip of land near the Red River with sandy soils supporting numerous plants more typically found farther east. Similar range extensions exist farther south where eastern Texas plants extend west along the Trinity and Brazos rivers. Analogous situations also exist in the western and southwestern parts of North Central Texas where western Texas plants extend east to the West Cross Timbers and plants typical of the central Texas Edwards Plateau extend north well into the area, particularly in

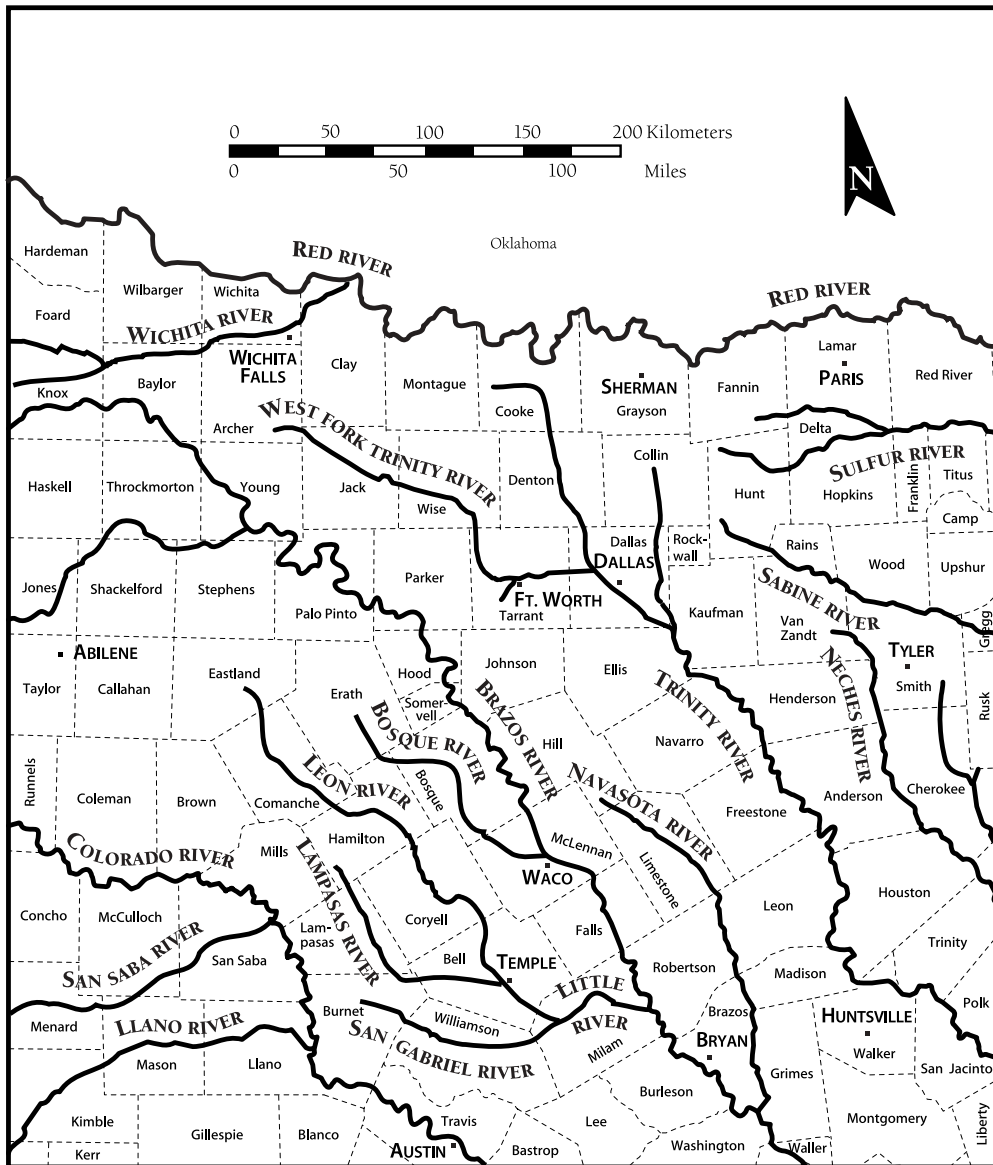
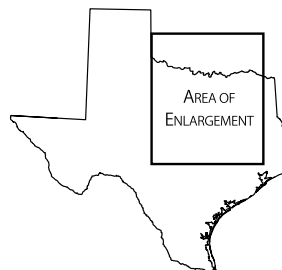


FIG. 4/MAJOR RIVERS OF NORTH CENTRAL TEXAS.



the rocky habitats associated with the Lampasas Cut Plain and the Palo Pinto Country. In virtually any geographic region, the microclimates and migration corridors provided by major rivers or specialized geology allow the occurrence of species not otherwise typical of that particular region. However, while these species may be neither abundant nor widespread, they are important biogeographically. Given their occurrence at the margins of their ranges, they may serve as ecological indicator species, possibly providing information in the future on important issues such as climate change or habitat alteration.

The vegetation map (Fig. 1) is a modification of that used by Mahler (1988) (Fig. 3) and is adapted from Dyksterhuis (1946, 1948) for the Fort Worth Prairie and West Cross Timbers. The eastern edge of the Blackland Prairie is defined by the boundary between the upland clay soils with grassland vegetation and the adjacent sandy soils of the Post Oak Savannah (also known as the Oak-hickory forest). The far northeastern corner of the study area goes east along the Red River as far as Lamar County; only the Blackland Prairie portion of central Red River County is included. To the west, the region extends to the western boundary of the West Cross Timbers; this vegetation type ends rather abruptly where the bedrock changes to Permian-age material underlying the Rolling or Red Plains. The topographically diverse southwestern part of North Central Texas is probably best referred to as the Lampasas Cut Plain. This area is geologically, and to a significant extent botanically, related to the Edwards Plateau and extends south and west to the Edwards Plateau and the Llano Basin. The least biologically meaningful boundary of North Central Texas is the southern one, corresponding roughly to the Williamson-Travis county border. The Blackland Prairie continues south past this line to the vicinity of San Antonio; that area is beyond the scope of the present study. Other sources for the vegetation map include Tharp (1926), Stanford (1971), Renfro et al. (1973), and county soil surveys (Soil Conservation Service). Plants of the adjacent Rolling Plains to the west, the Post Oak Savannah and Pineywoods to the east, and the Edwards Plateau to the southwest are included only if they enter the area under study, typically along river drainages.

INFORMATION HELPFUL IN USING THE FLORA

PLANTS TREATED

All known native and naturalized vascular plant species occurring in North Central Texas (Fig. 1) have been treated taxonomically. For the purposes of this work, a naturalized species is simply a non-native that is reproducing in the area without human assistance. For a species to be included, voucher specimens must have been seen, literature citations found, or in a several cases, plants observed in the field. If a taxon was included based on a literature citation, the citation is given in the text. A number of species were included based on citation of vegetational areas 4 (Blackland Prairie) or 5 (Cross Timbers and Prairies) by Hatch et al. (1990) and are indicated as such. In some instances, plants cited for vegetational area 4 were included only as notes since their distributions were well to the south (e.g., San Antonio Prairie) or east (e.g., Fayette Prairie) of North Central Texas. Such plants, with their scientific names in italics but not in bold, are listed as notes after all the alphabetically arranged species of a genus; they are not illustrated. If such plants are in a genus not treated in the flora, they are included in the family synopsis (e.g., *Ehretia anacua* in the Boraginaceae; *Campanula reverchonii* in the Campanulaceae). In a few instances, species were included based on field observations by individuals. These are listed as such in the treatments as “pers. obs.” (personal observation, which denotes observation by one of the authors) or “pers. comm.” (personal communication, which indicates an individual’s observation communicated to the authors; such individuals are listed in the literature cited with a one or two line biography). A few long-persistent (e.g., *Ficus carica*—common fig), but apparently non-reproducing taxa have been included because of the likelihood of them being encountered. Also, a few taxa in areas immediately adjacent to the boundaries of North Central Texas (e.g., in adjacent

parts of a partially treated county) have also been included to avoid confusion, improve clarity, or for general interest.

No attempt has been made to include the hundreds of non-native crop, landscape, and greenhouse plants cultivated in North Central Texas but not naturalized in the area. Information on cultivated plants can be found in such works as Bailey (1949), Shinnars (1958), Bailey and Bailey (1976), Huxley et al. (1992), Sperry (1991), Garrett (1994, 1996), and Brickell and Zuk (1997).

The North Central Texas flora has about 46 percent of the 4,834 species of native and naturalized vascular plants recognized as occurring in Texas by Hatch et al. (1990) and over 40 percent of the 5,524 taxa. Since non-naturalized, cultivated plants are not included in our flora, a direct comparison is not possible with the most recent checklist of Texas plants (Jones et al. 1997), which lists 6,871 taxa including cultivated plants.

ARRANGEMENT OF TAXA AND GENERAL METHODS

Families are listed alphabetically within divisions (Lycopodiophyta, Equisetophyta, Polypodiophyta, Pinophyta, Gnetophyta, and Magnoliophyta). The flowering plants (Magnoliophyta) make up the vast majority of North Central Texas species; within this group, class Dicotyledonae (dicots) is listed before class Monocotyledonae (monocots). For each family a taxonomic description, brief synopsis (indicated by the symbol ☛) including such information as number of genera and species, a short section on family recognition in the field, and references, if appropriate, are given. If the type genus (genus after which the family is named) of a family is not treated in the flora, a brief synopsis of the type genus and the derivation of its name are given at the end of the family synopsis. When only one genus of a family is represented in the flora, the family and generic descriptions are combined. Appendix 1 is a phylogenetic classification of all treated families modified from those of Cronquist (1981, 1988), Lellinger (1985), and Hickman et al. (1993).

Genera are listed alphabetically within families and species within genera. A taxonomic description, brief synopsis (indicated by the symbol ☛), derivation of the generic name, and references if appropriate are given for each genus. When only one species of a genus is represented in the flora, the generic and specific descriptions are combined. References for both families and genera are intended to provide an entry point into the more detailed taxonomic literature and should not be viewed as inclusive. Additional references can be found in Kent (1967), Hatch et al. (1990), Taylor and Taylor (1994), and Jones et al. (1997).

For each taxon treated at the rank of species, subspecies, or variety, all or most of the following are provided: 1) scientific name (**in bold type**) including authority followed by a comma to allow certainty over whether the name of the authority is abbreviated or not; 2) derivation of the specific or infraspecific epithet (in parentheses); 3) common name(s) if available (IN SMALL CAPITAL LETTERS); 4) taxonomic description; 5) habitat; 6) range; 7) phenology (period of flowering); 8) area of origin if not native to North Central Texas; 9) synonyms (in *italics* in brackets, []); 10) notes on toxic/poisonous nature (indicated by the symbol ☛) or other short notes of ethnobotanical or taxonomic interest; and 11) for taxa introduced to the United States, the symbol ☛. A line drawing illustration is provided for each species and in some cases for infraspecific taxa. The illustrations are grouped together on full pages and are as close to the description of a species as possible, typically within a few pages.

DESCRIPTIONS

Because of space limitations due to the inclusion of illustrations, descriptions are as brief as possible while still allowing accurate identification. Characters useful in identification or helpful in confirming the identity of a plant have been stressed. Information given in the keys is generally not repeated in the descriptions. When only one species of a genus is represented in the flora, the generic and specific descriptions are combined. Therefore, the species descriptions in such cases

are generally more ample than for other species. Characters described for a taxon at a higher rank (e.g., family) are not usually repeated for included taxa (e.g., genera). Descriptions were written for North Central Texas taxa and may not apply to taxa from other parts of the world; this is sometimes emphasized in the descriptions by the qualifier “ours” to denote species within the North Central Texas area.

KEYS

Keys are tools or shortcuts by which unknown plants can be identified. They provide a method whereby a choice between alternative statements about plant characteristics can be made, for instance:

1. Petals red; leaf blades pubescent on lower surface.
2. Petals < 1 cm long; leaf blades entire _____ **Species a**
2. Petals > 1 cm long; leaf blades toothed _____ **Species b**
1. Petals white; leaf blades glabrous on lower surface.
3. Plant a shrub; leaf blades with acute apex _____ **Species c**
3. Plant a tree; leaf blades with obtuse apex _____ **Species d**

The first choice (here lines beginning with the number 1) is followed by another choice indented under it (here lines beginning with the number 2) and so on until the identity of a plant is determined. In other words, after a choice has been made between the two alternatives of a pair (= couplet), the user goes to the more indented next couplet where another choice is presented. The keys provided in this work all have successive choices indented for ease of use and are strictly dichotomous; that is, the user must decide between only two choices at a time.

The keys have also been written to be as parallel as practical. In other words, when a character is given for one choice, it is also given for the other choice. However, in some cases, clarity, practicality, or the avoidance of ambiguity prevented absolute parallelism. Occasionally, a taxon, particularly a highly variable one, is keyed in more than one way to enhance ease of use and clarity. When possible, several characters are used for each choice in the keys; optimally both reproductive and vegetative characters are given. Sometimes, the plants falling under one alternative are variable and exhibit two character states; in order to emphasize this situation, the OR given between these two states is sometimes capitalized, for instance:

1. Leaves usually 30 cm or more long OR if shorter with a hard spiny tip.
1. Leaves 10–30 cm long, without a hard spiny tip.

While not preferred, such characters can still be helpful in identification.

Keys to genera and species were specifically written for the plants of North Central Texas and are not intended to be inclusive of plants occurring in other parts of the world. The General Key to All Families is modified from a key to families generously provided by the Oklahoma Flora Editorial Committee (Tyrl et al. 1994). While numerous couplets have been added to cover plants that occur in North Central Texas but not in Oklahoma, no couplets have been deleted from the Oklahoma family key. Therefore, some families/taxa occurring in Oklahoma are included that do not occur in North Central Texas. This was done so that the family key would be of maximum benefit to Oklahoma users as well as those in Texas. Such families are indicated in the *General Key to All Families* by a note in brackets, e.g., [Family in OK, not in nc TX]. In a number of instances, it is possible to key to the correct family even if a particular, easily confused dichotomy is misinterpreted. For such cases, explanatory notes are given in brackets in the key. The key to genera of Asteraceae is modified from one contributed by Constance Taylor (Taylor 1997).

In addition to the General Key to All Families, through which all families can be reached, several supplemental keys have been added for some groups. These include a key to ferns and similar plants (pteridophytes), a key to gymnosperms, a key to aquatic plants, a key to the families of monocots, and a key to woody vines.

SOURCES OF INFORMATION

In addition to original observations and measurements, materials for the keys and descriptions have been obtained from a variety of sources listed in the literature cited. Of particular assistance were the following works: *Manual of the Vascular Plants of Texas* (Correll & Johnston 1970); *Grasses of Texas* (Gould 1975b); *Flora of the Great Plains* (Great Plains Flora Association 1986); *Flora of North America North of Mexico*, Vol. 2, *Pteridophytes and Gymnosperms* (Flora of North America Editorial Committee 1993); *Flora of North America North of Mexico*, Vol. 3, *Magnoliophyta: Magnoliidae and Hamamelidae* (Flora of North America Editorial Committee 1993); *Manual of the Vascular Flora of the Carolinas* (Radford et al. 1968); and *Flora of Missouri* (Steyermark 1963). In addition to the references mentioned above, the *Checklist of the Vascular Plants of Texas* (Hatch et al. 1990) was extensively used to determine ranges and as a source of common names. Information for the family synopses was obtained from *The Plant Book* (Mabberley 1987, 1997); *Flowering Plants of the World* (Heywood 1993); *Guide to Flowering Plant Families* (Zomlefer 1994); *Vascular Plant Taxonomy* (Walters & Keil 1995); and *Contemporary Plant Systematics*, 2nd ed. (Woodland 1997); in the interest of space, citations are given only for material from other sources. Material for the brief FAMILY RECOGNITION IN THE FIELD section given for each family was obtained from Smith (1977), Davis and Cullen (1979), Baumgardt (1982), Jones and Luchsinger (1986), and Heywood (1993). Generic synopses were modified from Mabberley (1987, 1997); here also, citations are given only for material from other sources. Derivations of generic names and specific and infraspecific epithets (etymology) were obtained or modified from a variety of sources including *Plant Names Scientific and Popular* (Lyons 1900); *The Standard Cyclopedia of Horticulture* (Bailey 1922); *How Plants Get Their Names* (Bailey 1933); *Gray's Manual of Botany* (Fernald 1950a); *Composition of Scientific Words* (Brown 1956); *Dictionary of Word Roots and Combining Forms* (Borror 1960); *A Gardener's Book of Plant Names* (Smith 1963); *Flora of West Virginia* (Strausbaugh & Core 1978); *Dictionary of Plant Names* (Coombes 1985); *The New Royal Horticultural Society Dictionary of Gardening* (Huxley et al. 1992); *Botanical Latin* (Stern 1992); and *Plants and Their Names* (Hyam & Pankhurst 1995). References of particular importance for the Introduction to North Central Texas included Hill's (1901) classic *Geography and Geology of the Black and Grand Prairies, Texas*, works on the Blackland and Grand prairies by Hayward and Yelderman (1991) and Hayward et al. (1992), a volume on the Blackland Prairie edited by Sharpless and Yelderman (1993), and articles on the Fort Worth Prairie and West Cross Timbers by Dyksterhuis (1946, 1948).

NOMENCLATURE

Nomenclature, including authorities, in general follows *A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland* (Kartesz 1994) unless specifically indicated otherwise. An exception is that nomenclature for ferns, and similar plants, and gymnosperms follows the recent treatments in *Flora of North America* (Flora of North America Editorial Committee 1993). In a number of cases indicated in the treatments, nomenclature follows recent taxonomic works or the recently published *Vascular Plants of Texas* (Jones et al. 1997). While the decision over which source or sources to follow for nomenclature was not an easy one, in our minds the advantages of a standard source outweigh the advantages of other possible choices. Thus, only in instances where more recent works have been followed or where we believe biological reality or clarity is compromised by nomenclature do we differ from Kartesz. Unless other varieties or subspecies are specifically mentioned in the text, the type variety or subspecies is assumed.

Following the rules of the International Code of Botanical Nomenclature (Greuter et al. 1994), the scientific name of each species (or variety or subspecies) is followed by the authority, i.e., the author(s) who originally published that name. If the name is transferred to a different genus or rank, the name of the original author is placed in parentheses, followed by the name of the author(s) who made the transfer. For example, *Erythraea calycosa* Buckley was originally named by Samuel B. Buckley; later Merritt L. Fernald transferred the species to the genus



Centaurium with the correct citation becoming *Centaurium calycosum* (Buckley) Fernald. In some cases, the word “ex” is inserted between the names of authors (e.g., *Hydrolea ovata* Nutt. ex Choisy); this is used when an author such as Choisy publishes a new species (or variety or subspecies) based on a name attributed to but not validly published by another author (in this case Nuttall). Abbreviations for authorities of scientific names follow Brummitt and Powell (1992), which is now widely considered the standard for such abbreviations.


Nomenclatural change is inevitable as more is learned about various plant groups (see Appendix 7). These changes, especially when involving well known species, can be particularly irritating to both professional and amateur botanists as well as others needing to know correct scientific names. In order to avoid confusion regarding name changes, limited synonymy is provided. In particular, no longer recognized names used in Mahler (1988) and many from Correll and Johnston (1970) and Hatch et al. (1990) are listed as synonyms. Other synonyms are given to help clarify nomenclature or for general interest. However, no attempt was made to give complete synonymy. For detailed synonymy of Texas plants see Kartesz (1994) and Jones et al. (1997).

Common names are included in the treatments and in the index, enabling the identification of plants for which little other information is available. These names have been obtained from a variety of literature sources; none has been manufactured for this publication.

GEOGRAPHIC DISTRIBUTIONS

For taxa with limited known geographic distributions within North Central Texas, individual counties are cited. These citations represent specimens in the BRIT/SMU Herbarium (Botanical Research Institute of Texas) or in the private collections of G. Diggs and R. O’Kennon, that are being processed for deposit at BRIT; county records based on literature citations have also been included, as have records supplied by Jack Stanford of Howard Payne University—these are indicated by the herbarium abbreviation HPC, and Stanley Jones of the Botanical Research Center Herbarium—these are indicated by BRCH. A more general distribution within Texas usually follows the counties listed; examples include: e TX w to Blackland Prairie, West Cross Timbers s and w to w TX, and nearly throughout TX. When a taxon is well represented in North Central Texas, only the more general distribution within the state is given. Several taxa collected in the late 1800s and early 1900s by Reverchon, Ruth, and other early collectors have not been reported in the area since; these are mentioned as such. Plants of the eastern and southeastern parts of Texas penetrate into the Blackland Prairie up the Trinity and Brazos rivers, and some are becoming relatively scarce today in these bottomland extensions of their habitats. As mentioned earlier, plants of eastern Texas also enter the region along the northern edge of the Blackland Prairie in the Red River drainage. In both cases, these records have been mentioned.

Very few plants are endemic to North Central Texas; these are indicated by the symbol  in front of the scientific name. Many plants listed as endemic to Texas in Correll and Johnston (1970) have since been found in immediately adjacent areas. For information on endemics we are therefore following Bonnie Amos, Paula Hall, and Kelly McCoy (Amos et al. 1998) of Angelo State University who generously contributed their data on Texas endemics; such information is given in the descriptions following a plant’s Texas distribution. In order to make Texas endemics easily recognizable in the text, the symbol  is placed at the end of such species’ taxonomic treatments.

For naturalized plants whose place of origin is outside the continental United States, the symbol  is placed at the end of the species’ taxonomic treatment; plants for which this symbol is not given are native to the continental United States. A symbol to allow introduced species to be recognizable at a glance seemed a useful inclusion (Schmid 1997) and was an easy decision. However, the question of defining “introduced” was more difficult. For example, all species native outside North Central Texas could have been considered introduced; similarly, introduced species could have been defined as all species not native to Texas. Ultimately, we decided to use symbolic representation only for species native outside the United States. However, all species not native to North Central Texas have their area of origin indicated in the descriptions.

INFORMATION ON TOXIC/POISONOUS PLANTS

Notes on toxic/poisonous properties (indicated by the symbol ☠) are given in the synopses and at the end of the treatments of various taxa. This information has been obtained from a variety of cited sources. However, lack of information about toxicity does not indicate that a plant is safe and no plant material should be eaten unless one is sure of its safety. Indeed, most plants have not been tested for toxicity and all should be considered potentially dangerous unless known otherwise. Technically, a poison is a substance that in suitable quantities has properties harmful or fatal to an organism when it is brought into contact with or absorbed by the organism. Toxin, a more specific term, is any of various poisonous substances that are specific products of the metabolic activities of living organisms (Gove 1993). In referring to such material in plants, the terms have been used synonymously in the text.

In case of toxicity/poisoning by plant material or any other source, the **TEXAS POISON CENTER NETWORK** can be reached at **1-800-POISON-1 (1-800-764-7661)** or indirectly via the emergency number **9-1-1**. This is a state-wide 800 service available 24 hours a day.

INFORMATION ON ENDANGERED AND THREATENED TAXA

Taxa listed by the Texas Organization for Endangered Species (TOES 1993) are indicated by having (TOES 1993: Roman numeral) at the end of their treatment. The Roman numeral signifies the category as indicated by TOES:

CATEGORY I:

Endangered species—legally protected.

CATEGORY II:

Threatened species—legally protected.
Likely to become endangered

CATEGORY III:

Texas endangered—listed species.
Endangered in Texas portion of range

CATEGORY IV:

Texas Threatened—listed species.
Likely to become endangered in Texas portion of range

CATEGORY V:


Watch List—listed species.
Either with low population numbers or restricted range in Texas

Such species are also signified by having the symbol Δ placed at the end of their taxonomic treatments.

INFORMATION ON ILLUSTRATIONS AND PHOTOGRAPHS

The more than 2,300 line-drawing illustrations have been obtained from a variety of sources in the botanical literature dating back to the 1500s (Fuchs 1542). We thank the appropriate individuals or organizations for allowing their use. Three hundred twenty-six illustrations are published here for the first time. These include many drawings of Cyperaceae done by Brenda Mahler and Jessica Procter as part of B. Lipscomb's research on that family. A significant number of the never-before-published drawings were done decades ago by the late Eula Whitehouse, Pat Mueller, and unknown SMU students. These illustrations were made for Lloyd Shinnars, whose untimely death prevented publication of a flora for North Central Texas. The drawings were in the archives at BRIT. Finally, Linny Heagy has produced 226 original drawings for all those North Central Texas species either not previously illustrated or for which suitable illustrations could not be found.

Beneath each illustration is the scientific name of the plant represented. The name is followed by a code in parentheses indicating the source of the illustration. A list of illustration sources with codes is given in Appendix 4. Because all species are illustrated, reference to illustrations is not made in the text. Illustrations are as close to the taxonomic descriptions as possible and in general follow the taxonomic descriptions.

The 174 color photographs are arranged alphabetically by genus and are grouped together in plates. Following the common name of each species and the page number of its description, a three letter code in brackets is given to designate the photographer: [JAC] = J. Andrew Crosthwaite, [GMD] = George M. Diggs, Matthew A. Kosnik [MAK], and [RJO] = Robert J. O'Kennon. The symbol /80 at the end of a species description indicates a color photograph is provided on page 80.








INFORMATION ON THE GLOSSARY

The Glossary is modified from those of Shinnars (1958a) and Mahler (1988), with additional entries obtained or modified from a variety of sources including Lawrence (1951), Featherly (1954), Correll (1956), Gleason and Cronquist (1963, 1991), Radford et al. (1968), Correll and Johnston (1970), Gould (1975b), Lewis and Elvin-Lewis (1977), Benson (1979), Smutz and Hamilton (1979), Fuller and McClintock (1986), Jones and Luchsing (1986), Schofield (1986), Gandhi and Thomas (1989), Blackwell (1990), Isely (1990), Harris and Harris (1994), Spjut (1994), and Hickey and King (1997). The glossary is rather extensive and includes terms not otherwise found in the book. This was done so that when using this work in conjunction with other taxonomic treatments, the meaning of obscure terms can be readily found.

INFORMATION ON REFERENCES AND LITERATURE CITED

The Literature Cited section contains bibliographic citations for all sources cited including those listed immediately following family and generic synopses (e.g., REFERENCES: Wood 1958; Kral 1997). Originally, we had not intended to include such references. However, during preparation of the taxonomic treatments, we needed to refer repeatedly to the supporting literature; having references readily available in the developing manuscript proved helpful. We hope their inclusion will be useful to users of the treatments. While an attempt was made to be as thorough as possible, the magnitude of the botanical literature makes complete coverage impossible; the references given are intended to provide an entry point into the more detailed taxonomic literature and should not be viewed as inclusive. Abbreviations for periodicals follow *Botanico-Periodicum-Huntianum* (B-P-H) (Lawrence et al. 1968) and *Botanico-Periodicum-Huntianum/Supplementum* (B-P-H/S) (Bridson & Smith 1991). For each individual cited in the text as having personally communicated unpublished information to the authors (indicated by the abbreviation, pers. comm.), a short biographical entry is given in the Literature Cited section.

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS/SYMBOLS	MEANING
	endemic to North Central Texas
	endemic to Texas
	family or generic synopsis
	introduced species, subspecies, or variety
	endangered or threatened taxa; a TOES rating is also given for such taxa
	toxic/poisonous plant
	color photograph provided; page number follows symbol
<	less than
≤	less than or equal to
>	more than
≥	more than or equal to
±	more or less
+	or more (e.g., small tree 2–5+ m tall)
×	times or to indicate hybridization
auct.	auctorum = author
BAYLU	herbarium abbreviation for Baylor University Herbarium, Waco, TX.
B. P.	before present
BRCH	herbarium abbreviation for Botanical Research Center Herbarium, Bryan, TX
BRIT	herbarium abbreviation for Botanical Research Institute of Texas, Fort Worth
c	central
ca.	circa (about)
cm	centimeter
comb. no	Latin: <i>combinatio nova</i> , new combination of name and epithet
diam.	diameter
dm	decimeter
DUR	herbarium abbreviation for Southeastern Oklahoma State University, Durant, OK
e	east
e.g.	Latin: <i>exempli gratia</i> , for example
ex.	see preceding section on nomenclature for detailed explanation
f.	Latin: <i>filius</i> , son; e.g., L. f. indicates the younger Linnaeus
HPC	herbarium abbreviation for Howard Payne University, Brownwood, TX
i.e.	Latin: <i>id est</i> , that is
m	meter

ABBREVIATIONS/SYMBOLS	MEANING
MICH	herbarium abbreviation for the University of Michigan, Ann Arbor.
mm	millimeter
n	north
$n =$	haploid chromosome number
$2n =$	diploid chromosome number
nom. illeg.	nomen illegitimum (illegitimate name)
of authors, not	used to indicate a name was used in the sense of certain authors, but not in the sense of the author making the combination; technically written as: auct. non
p.p.	pro parte (in part)
pers. comm.	personal communication of information to the authors
pers. obs.	personal observation by one of the authors
s	south
sensu	in sense of; used to indicate that a name is used in the sense of one author, not another
sensu lato	in the broad sense, e.g., if a genus is broadly treated to include many species
sensu stricto	in the strict sense, e.g., if a genus is narrowly treated to include few species
SMU	herbarium abbreviation for Southern Methodist University Herbarium, now part of the Botanical Research Institute of Texas (BRIT), Fort Worth
s.n.	sine numero (without number)
spp.	species
subsp.	subspecies
TAES	herbarium abbreviation for S. M. Tracy Herbarium, Department of Rangeland Ecology & Management, Texas A&M University, College Station
TAMU	herbarium abbreviation for Biology Department Herbarium, Texas A&M University, College Station
TEX	herbarium abbreviation for University of Texas at Austin
TOES: (roman numeral)	Texas Organization for Endangered Species (category/status)
Univ.	university
VDB	herbarium abbreviation for Vanderbilt University Herbarium; currently housed at the Botanical Research Institute of Texas, Fort Worth
w	west
var.	variety

Ranges for measurements, e.g., (10–)12–23 mm long, should be interpreted as “typically 12 to 23 mm long, rarely as little as 10 mm long”

States are abbreviated using standard, two letter, United States Postal zip-code abbreviations (e.g., TX = Texas, OK = Oklahoma)

SUMMARY DATA ON THE FLORA

AND COMPARISON WITH OTHER FLORAS

SUMMARY OF THE FLORA OF NORTH CENTRAL TEXAS

	FERNS & SIMILAR PLANTS	GYMNOSPERMS	MONOCOTYLEDONS	DICOTYLEDONS	ANGIOSPERMS	TOTAL
Families	16	3	25	124	149	168
Genera	26	4	176	648	824	854
Species	47	10	567	1599	2166	2223
Additional Intraspecific taxa	2	0	40	111	151	153

COMPARISON WITH OTHER FLORAS

	NORTH CENTRAL TX	TX ¹	OK ²	KS ³	AR ⁴	TN ⁵	WV ⁶	NC&SC ⁷	CA ⁸
Families	168	180	172	139	154	167	143	180	173
Genera	854	1284	850	646	818	850	693	951	1222
Species	2223	4834	2549	1807	2356		2155	3360	5862
Native Species	1829								4739
Introduced Spp.	394								1023
Total Taxa	2376	5524	2844	2226	2469	2745			
Area (in 1000s of square miles)	40	269	70	82	53	42	24	86	164

NORTH CENTRAL TEXAS:

46 % of the species in Texas (in 15 % the land area)
 87 % as many species as Oklahoma (in 57 % the land area)
 82.3 % native species (17.7 % introduced from outside the United States)
 94 Texas endemics and 5 North Central Texas endemics
 Number of Genera and Species of Asteraceae
 (Largest North Central Texas family) 103 263
 Number of Genera and Species of Poaceae 86 249
 Number of Genera and Species of Fabaceae 56 176
 Number of Genera and Species of Cyperaceae 15 140
 Number of Species of *Carex*
 (Cyperaceae, largest North Central Texas genus) 56

¹Hatch et al. 1990; ²Taylor & Taylor 1994; ³McGregor 1976; ⁴Smith 1988; ⁵Wofford & Kral 1993;

⁶Strausbaugh & Core 1978; ⁷Radford et al. 1968; ⁸Hickman 1993

NEW COMBINATIONS MADE IN THIS BOOK

ASTERACEAE

✎ *Gutierrezia amoena* (Shinners) Diggs, Lipscomb, & O'Kennon

New combination on page 364, illustration on page 363

NYCTAGINACEAE

✎ *Mirabilis latifolia* (A. Gray) Diggs, Lipscomb, & O'Kennon

New combination on page 840, illustration on page 843

AGAVACEAE

✎ *Manfreda virginica* (L.) Rose subsp. *lata* (Shinners) O'Kennon, Diggs, & Lipscomb

New combination on page 1079; illustrations on pages 98 and 1081

ACKNOWLEDGMENTS

Contributions to an understanding of the flora of North Central Texas by the late Lloyd Shinnars and the very lively William (Bill) Mahler deserve special recognition; this volume is dedicated to them. For a synopsis of Shinnars' life see Mahler (1971b); for a guide to his botanical contributions see Flook (1973). This book is published as a volume of *Sida, Botanical Miscellany*, associated with the botanical journal *Sida, Contributions to Botany*, founded by Shinnars in 1962 (Mahler 1973b).

Three individuals were indispensable members of the team that produced this work. Special thanks to Linny Heagy, for designing and illustrating the cover and dust jacket, giving creative direction/art direction throughout the whole project, and creating 226 original botanical line drawings; Samuel Burkett, for scanning the more than 2,300 line drawings, laying out the illustration pages and visual glossary pages, coordinating copyright issues, and managing the project databases; and Amberly Zijewski, an Austin College student, for work on derivation of scientific names, authorities of scientific names, literature research, and assistance with layout of illustrations.

Several sections of the manuscript were generously contributed by other authors. Thanks to Stanley Jones of the Botanical Research Center Herbarium for contributing the treatment of the genus *Carex* (Cyperaceae), Connie Taylor of Southeastern Oklahoma State University for the key to genera of Asteraceae, and the Oklahoma Flora Editorial Committee (Ronald J. Tyrl, Susan C. Barber, Paul Buck, James R. Estes, Patricia Folley, Lawrence K. Magrath, Constance E.S. Taylor, and Rahmona A. Thompson—Tyrl et al. 1994) for allowing us to modify their key to families; we are especially indebted to our Oklahoma colleagues for the use of their fine key which represents many years of hard work. Thanks also to Bonnie Amos, Paula Hall, and Kelly McCoy (Amos et al. 1998) of Angelo State University who generously contributed data on plants endemic to Texas.

We are also particularly indebted to three other colleagues for major contributions: Jack Stanford of Howard Payne University reviewed the entire manuscript, made many helpful suggestions, and contributed plant distributional data on the southwestern part of North Central Texas; John Thieret of Northern Kentucky University reviewed large segments of the manuscript and provided valuable constructive criticism; and Ruth Andersson May of Dallas proofread the entire manuscript.

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The frontispiece and dust jacket were created by Linny Heagy. Color photographs are by Andrew Crosthwaite, George Diggs, Matthew Kosnik, and Robert O'Kennon; in the color photographs, following the name of each species, a three letter code in brackets is given to designate the photographer.

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AUTHORS' NOTE

In a work such as this, it is inevitable for omissions and errors, both large and small, to escape attention. Because of the possibility of future editions, we would appreciate corrections, suggestions, or additions from individuals using the book. Also, as part of the Illustrated Texas Floras Project (a collaborative project between BRIT and the Austin College Center for Environmental Studies), we are currently working on a companion volume, to be titled the *Illustrated Flora of East Texas*, projected to be published in the year 2004. Because there is substantial overlap between the plants of North Central and East Texas, corrections and suggestions on the present volume would be very helpful for the next work. Such information can be sent to:

George M. Diggs, Jr.	Barney L. Lipscomb	Robert J. O'Kennon
gdiggs@austinc.edu	barney@brit.org	okennon@brit.org

Also, we hope that this book will spur additional interest in, and collecting of, plants in the area. Plant specimens, particularly county, regional, or state records would be much appreciated and can be deposited at the:

BOTANICAL RESEARCH INSTITUTE OF TEXAS HERBARIUM (BRIT)
 509 PECAN STREET, FORT WORTH, TX 76102
 PHONE: 817/332-4441

Such specimens will be important scientific contributions, will have permanent protection, and will be important resources for the future.

In order to provide a service for fellow educators and scientists, figures 1, 2, 4, 37, and 44 are specifically released from copyright.

INTRODUCTION TO NORTH CENTRAL TEXAS

OVERVIEW

North Central Texas is an area of roughly 40,000 square miles, bound on the north by the Red River and extending south nearly to Austin. While small by Texas standards (260,000 square miles), it is about the size of Kentucky. It includes the Blackland Prairie, the Grand Prairie (Fort Worth Prairie and Lampasas Cut Plain), the East and West cross timbers, and the Red River Area (Fig. 1). The flora includes 2,223 species, about 46 percent of the species known for Texas (Hatch et al. 1990), and a total of 2,376 taxa (species, subspecies, and varieties). This biological diversity is the result of numerous factors, including the region's geologic and climatic variation and its location in the ecotone or transition zone between the eastern deciduous forests and the central North American grasslands. North Central Texas is a mixing ground for plants from the east and west, with different microhabitats even within the same county having radically different plant communities. For the past two centuries, humans have had, and are continuing to have, a tremendous impact on the plants and animals of the region. Presettlement and early settlement conditions were radically different from those found today; the current generation may be the last with the opportunity to preserve even small remnants of the once extensive natural ecosystems.

GENERAL GEOLOGY OF NORTH CENTRAL TEXAS

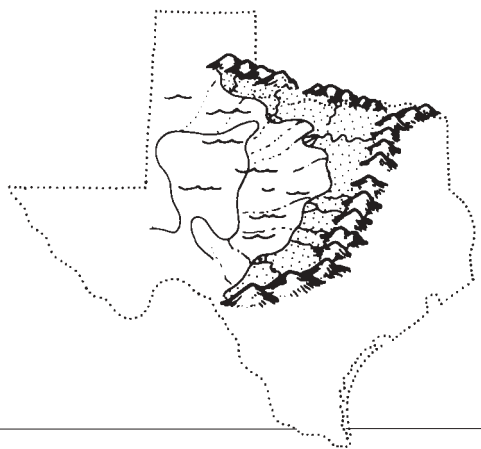


FIG. 5/ANCIENT OUACHITA MOUNTAINS (PART OF THE APPALACHIAN-OUACHITA-MARATHON MOUNTAIN SYSTEM). THIS BELT CUT NORTH-SOUTH ACROSS TEXAS IN A LINE ROUGHLY FROM SHERMAN TO DALLAS, WACO, AUSTIN, AND BEYOND. THIS RANGE ROSE APPROXIMATELY 300 MILLION YEARS AGO AS A RESULT OF A PLATE TECTONIC COLLISION (ADAPTED FROM SPEARING 1991 WITH PERMISSION OF MOUNTAIN PRESS PUBLISHING CO.; ©1991).

The geology of North Central Texas is much more interesting and complex than indicated by the gently rolling topography. If one begins about 300 million years ago, during the Pennsylvanian Period (320–286 million years ago), what is now North Central Texas was on the southern edge of a North American continent shaped very differently than it is today. As a result of plate tectonic movements, North America collided with Africa and South America to become part of the supercontinent Pangaea. The outcome of this collision was the uplift and formation of an extensive mountain system including the ancient Appalachians, Wichitas, and Ouachitas. The Ouachita Mountains formed in a line roughly following the western edge of the current Blackland Prairie and farther south, the Balcones Escarpment. They extended across much of Texas, in a line from near Sherman to Dallas to Austin and beyond (Fig. 5). The ancient Ouachita mountain belt also continued to the northeast; the eroded Ouachitas seen today in southeastern Oklahoma and southwestern Arkansas are remnants of this once much more extensive range. In western Texas, to the west of the ancient Ouachita Mountains, crustal areas sagged and low basins formed. Shallow inland seas invaded these low areas, and during the Pennsylvanian, and later the Permian, western Texas served as a collection basin for the sediments that eroded from the Ouachita Mountains to the east. These deep sediments are world-famous for their oil-bearing layers. They are also the source of the bright red, iron-rich (hematite) Permian layers that easily erode and give the modern Red River its name. Over tens of millions of years the Ouachita Mountains gradually eroded, until today all that is left over most of Texas are their roots, deeply buried under thousands of feet of sediments (Spearing 1991).

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During the Triassic (245–208 million years ago) and Jurassic (208–145 million years ago) periods and continuing into the Cretaceous Period (145–65 million years ago), Pangaea eventually split apart into separate continents. The North Central Texas region once again became very active geologically with the zone of weakness where the Ouachitas had originally formed serving as the site of continental rifting or breakup between North and South America. It was here, where the continents pulled apart, that huge shallow seas, eventually retreating to become the present-day Gulf of Mexico, began to form (Fig. 6). Into these seas, thick layers of sediment were deposited during much of the Cretaceous Period, the material coming in part from erosion of the Rocky Mountains rising to the west. The shallow seas repeatedly advanced and retreated over much of Texas. In fact, these seas extended to the Big Bend area and at times even connected all the way from the Gulf of Mexico north to the Arctic Ocean. As a result of the varying water depths and other conditions, a number of different layers of Cretaceous sediments were laid down across the state. Fossil-bearing limestones, so common in North Central Texas, were deposited in the shallow seas. Near the ancient coasts, where muds and sands were laid down, dinosaur tracks were sometimes preserved. Excellent examples of these can be seen in Dinosaur Valley State Park near Glen Rose in Somervell County, and others have been found in the Glen Rose Limestone in Comanche and Hamilton counties (Shuler 1935, 1937; Albritton 1942; Spearing 1991).

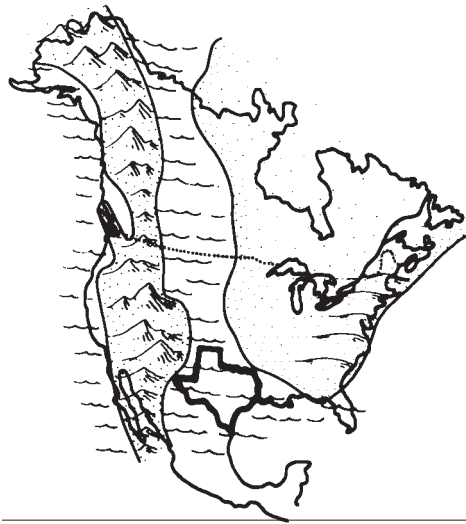


FIG. 6/FIGURE SHOWING AN EXAMPLE OF HOW TEXAS WAS COVERED BY AN INLAND SEA AT VARIOUS TIMES DURING THE CRETACEOUS. ONE RESULT IS THAT CRETACEOUS SEDIMENTS FORM MOST OF THE SURFACE ROCKS IN NORTH CENTRAL TEXAS (ADAPTED FROM SPEARING 1991 WITH PERMISSION OF MOUNTAIN PRESS PUBLISHING CO.; ©1991).

As a result of the depositional processes described above and subsequent erosion of overlying material, nearly all surface rocks of modern North Central Texas are Cretaceous in origin (Renfro et al. 1973; McGowen et al. 1991) (Fig. 7). An exception is the more recent, stream-deposited sediment along some of the drainages. As indicated above, all these Cretaceous layers were laid down near the margin of an ocean that can be thought of as a greatly expanded Gulf of Mexico. After the Cretaceous Period, as the Gulf retreated farther to the southeast, sediments continued to be deposited on eastern Texas during much of the Tertiary Period (65–2 million years ago). The youngest of these sediments are therefore found near the present-day Gulf Coast (Bullard 1931). During the Tertiary, the major geologic factor shaping North Central Texas was the removal of material by erosion (Sellards et al. 1932; Baker 1960), revealing layers that were once buried. This process can be clearly seen as one travels west across the region. The eastern Blackland Prairie at the eastern margin

of the area is developed on relatively young Upper (= Late) Cretaceous layers. Farther west, at higher elevations subject to greater erosion, more and more Cretaceous material was stripped away and progressively older rocks exposed. The only significant non-Cretaceous rocks found in North Central Texas are the older Pennsylvanian-age rocks uncovered by extensive erosion in the Palo Pinto Country in the extreme western portion of the region (Hill 1901; Sellards et al. 1932) (Figs. 7, 8). Here, all Cretaceous layers have been removed, and the much older, Pennsylvanian-age rocks are exposed at the surface.

As indicated above, North Central Texas was near the edge of the ocean during much of the Cretaceous, and as sea levels rose and fell, shallow seas repeatedly covered and then retreated from much of Texas (Sellards et al. 1932; Spearing 1991). Numerous layers of limestone, marl (chalky or limey clays), shale, and sand (Bullard 1931; Baker 1960) were deposited over the area, the type of layer depending on water depth, distance from shore, and other factors. According to Hill (1901),

22 INTRODUCTION/GENERAL GEOLOGY

- 1 PRECAMBRIAN OF THE LLANO REGION
- 2 OLDER PALEOZOICS OF THE LLANO REGION
- 2A MARATHON BASIN
- 3 MISSISSIPPIAN AND ORDOVICIAN OF THE LLANO BASIN
- 4 PENNSYLVANIAN OF THE PALO PINTO SECTION
- 5 PERMIAN OF THE OSAGE PLAIN
- 6 TRIASSIC AND JURASSIC OF THE CAP ROCK ESCARPMENT
- 7 LOWER CRETACEOUS OF THE EDWARDS PLATEAU, LAMPASAS CUT PLAIN, AND COMANCHE PLATEAU
- 8 UPPER CRETACEOUS OF THE BLACKLAND BELT
- 9 OLDER TERTIARY OF THE GULF COASTAL PLAIN
- 10 LATER TERTIARY OF THE GULF COASTAL PLAIN
- 11 PLEISTOCENE OF THE GULF COASTAL PLAIN
- 12 QUATERNARY OF THE PECOS VALLEY
- 13 LATE CENOZOIC ALLUVIUM OF THE HIGH PLAINS
- 14 TRANS-PECOS BASIN AND RANGES

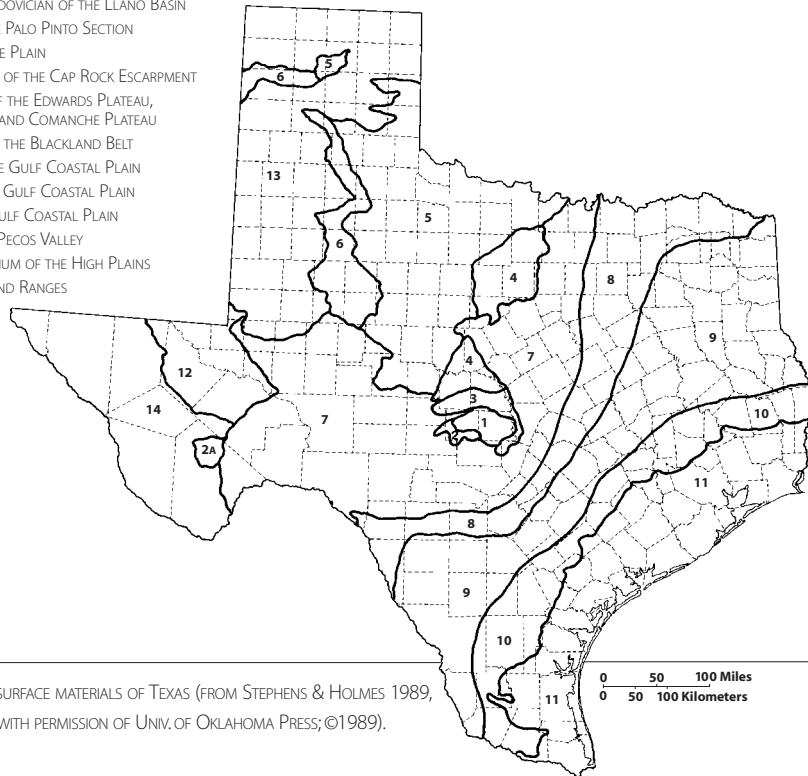


Fig. 7/GEOLOGIC AGE OF SURFACE MATERIALS OF TEXAS (FROM STEPHENS & HOLMES 1989, *HISTORICAL ATLAS OF TEXAS*, WITH PERMISSION OF UNIV. OF OKLAHOMA PRESS; ©1989).

- 1 GUADALUPE MTS.
- 2 DELAWARE AND APACHE MTS.
- 3 DAVIS MTS.
- 4 MARATHON BASIN
- 5 SANTIAGO, CHALK, AND CHRISTMAS MTS.
- 6 CHISOS MTS.
- 7 CHINATI MTS. AND SIERRA VIEJA
- 8 QUITMAN AND FINLAY MTS.
- 9 HUECO MTS.
- 10 FRANKLIN MTS.
- 11 HUECO BASIN
- 12 GLASS MTS.

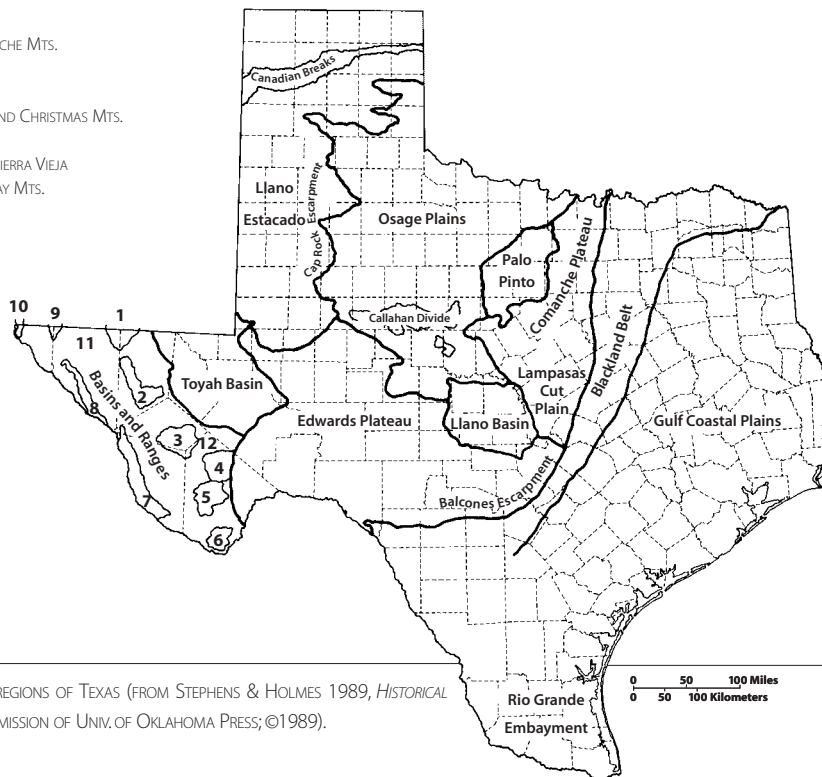


Fig. 8/PHYSIOGRAPHIC REGIONS OF TEXAS (FROM STEPHENS & HOLMES 1989, *HISTORICAL ATLAS OF TEXAS*, WITH PERMISSION OF UNIV. OF OKLAHOMA PRESS; ©1989).

In general the sands are near-shore deposits, such as are seen to-day on most ocean beaches. The finer sands were carried a little further seaward than the coarse material. The clays are the lighter débris of the land, which were laid down a little farther from the land border; and so on through the various gradations to the chalky limestones, which largely represent oceanic sediments deposited in relatively purer waters farthest away from the land. The limestones are not all chalky. Some are agglomerates of shells of animals which inhabited the sandy or muddy bottoms; others are old beach wash. The vast numbers of sea shells occurring upon the mountains and prairies of Texas have not been transported, as some people believe. Save that they have been subjected to general regional uplift whereby the sea bottom was converted into land, they are now in the exact locality where they lived and flourished, and the clays and limestones in which they were buried were once the muds of the old ocean bottom.

Because all these layers are ocean sediments, many have excellent fossils of marine organisms. Some of the most obvious include oyster-like bivalve mollusks, sharks teeth, a type of echinoderm known as heart urchins, and ammonites, the large, extinct, coiled-shell relatives of the octopus and squid. In fact, some North Central Texas rock layers are composed almost completely of fossilized animal remains and the area is well known among fossil hunters.

To the southwest of North Central Texas occurs a rugged area which includes granite and other Precambrian outcrops, variously known as the Burnet Country, Central Mineral Region, or Llano Basin; it has been exposed by the extensive erosion of overlying sediments. To the west of the West Cross Timbers, and thus like the Central Mineral Region outside of North Central Texas, lies the vast area known as the Rolling Plains, underlain by the famous Permian Red Beds. This region at least in part is sometimes referred to as the Red Plains. The strikingly colored, iron oxide-rich, erosional products of these Permian layers give the Red River (originating far to the west) its name. The salinity of the Red River (and thus of Lake Texoma) is also the result of erosion from salt-rich Permian-age evaporation flats through which the river passes on its course east from the Texas Panhandle (Spearing 1991).

SOILS OF NORTH CENTRAL TEXAS

Soils in North Central Texas vary dramatically, ranging from the characteristic black soil of the Blackland Prairie to the easily erodible sands underlying the West Cross Timbers.

The “black waxy” soils of the Blackland Prairie are derived from Upper Cretaceous rocks, which are sometimes strikingly white in color (e.g., Austin Chalk); through the process of weathering there is a dramatic change in color (Fig. 9). In the words of Hill (1901),

The Black Prairie owes its name to the deep regolith of black calcareous clay soils which cover it. When wet these assume an excessively plastic and tenacious character, which is locally called “black waxy.” These soils are the residue of the underlying marls and chalks, or local surficial deposits derived from them, and hence are rich in lime. Complicated chemical changes, probably due to humic acid acting upon vegetable roots, are believed to cause the black color. The region is exceedingly productive, and nearly every foot of its area is susceptible to high cultivation. In fact, the prairies are the richest and largest body of agricultural land in Texas, constituting a practically continuous area of soil extending from Red River to the Comal. . . .

More specifically, the Blackland Prairie (also referred to as the Blacklands) has three dominant soil orders: Vertisols, Mollisols, and Alfisols (Fig. 10). The Vertisols develop mainly on the Eagle Ford shale and rocks of the Taylor Group and are characterized by abundant smectitic (= shrink-swell) clays (Hallmark 1993). Upon wetting and drying, these soils often undergo dramatic changes in volume, which can result in significant soil movements. Swelling and shrinking causes cracks up to 50 centimeters or more deep and as much as 10 centimeters wide at the surface (Hallmark 1993). Stories of golf balls or even baseballs or other objects disappearing in deep cracks are not uncommon from longtime residents of Blackland soil areas. The associated soil movements can have dramatic effects on human activities, resulting in uneven or cracked roadways,



Fig. 9/PHOTOGRAPH SHOWING STRIKING CONTRAST BETWEEN THE EXTREMELY DARK “BLACK WAXY” SOIL TYPICAL OF THE BLACKLAND PRAIRIE AND A PIECE OF THE NEARLY WHITE UNDERLYING AUSTIN CHALK BEDROCK FROM WHICH IT DEVELOPED. THE PHOTOGRAPH WAS TAKEN DURING TRENCHING ON THE AUSTIN COLLEGE CAMPUS (PHOTO BY GMD).

shifted buildings, and cracked foundations (Hallmark 1993). Only the most elaborately protected houses on many Vertisols are free from at least some cracks or other soil stability problems. These smectitic clay soils are also quite sticky and difficult to manage agriculturally, being easily compacted by farm machinery when wet and forming large clods when plowed dry. Because they can be effectively tilled only within a narrow moisture range, they gained the nickname “nooner soils”—too wet to plow before noon and too dry after noon (Hallmark 1993). The smectitic clays also result in both slickensides and gilgai, two phenomena often seen in Vertisols. Slickensides are planes of weakness in the soil caused by movements associated with shrinkage and swelling. These can result in rather large-scale slippage or failure of soil blocks, which can be problematic in construction (Hallmark 1993). According to Hallmark (1993), slickenside slippage, causing the collapse of the walls of construction trenches, results in Texas workers being crushed to death in trenches almost every year. Gilgai are the microhigh, microlow topography or relief features found on essentially all Vertisols (Diamond & Smeins 1993). On flat areas in the prairie landscape, gilgai typically form circular, almost tub-like depressions, called “hog wallows” by early settlers. These range from about three to six meters across and up to about one-half meter deep (Hayward & Yelderman 1991). On slopes, gilgai take the form of microridges and microvalleys up to about 20 centimeters deep (Miller & Smeins 1988; Diamond & Smeins 1993) (Fig. 11). Both gilgai and the great soil depth of this region are the result of the constant churning and overturn of the shrink-swell, clay-based soils. When these soils shrink during dry weather and large cracks form, loose pieces of soil fall deep into the cracks. Upon wetting, these pieces swell and exert lateral pressure. Material is pushed outward and eventually upward, resulting in depressions rimmed by slightly raised areas (Hayward & Yelderman 1991) (Fig. 12). Gilgai are thus formed and the soil is slowly but constantly churned; the name Vertisol (Latin: *verto*, turn upward, *sol*, soil) is derived from this continuous cycle of overturning of the soil (Steila 1993). On the native Blackland Prairie, soil erosion was low because of the dense tall grass community, and also because of the water-trapping capacity of gilgai. Temporary water storage in gilgai depressions of one-half acre foot of water per acre of flat prairie have been estimated. As much as six inches of rain could be temporarily trapped in these

structures before runoff began (Hayward & Yelderman 1991). This would have greatly reduced runoff and allowed significant infiltration, particularly important considering that clay soils are often rather impermeable. In fact, early accounts refer to clear runoff and clear streams on the Blacklands (Hayward & Yelderman 1991), in stark contrast to the current situation. However, because thousands of gilgai covered the prairies and created pools of standing water during wet weather, the prairies were at times virtually impassable (Hayward & Yelderman 1991). Under present agricultural conditions, with no plant cover during much of the year and with the suppression of gilgai formation by plowing, erosion rates in the Blacklands are high. Thompson (1993) noted that the Blacklands have one of the highest rates of soil loss on cropland of any major area in Texas. Estimates run from tens to hundreds of times higher than under the original native prairie vegetation (Hayward & Yelderman 1991). Richardson (1993) cited annual erosion figures of 15 tons per acre (t/a) for a cultivated Blackland area compared with only 0.2 t/a for a native grass meadow, a 70-fold increase. Even though gilgai were one of the most evident surface features on the original Blackland Prairie, because they are destroyed by plowing they are rarely observed today. Excellent examples of these "hog wallows," however, can still be seen at the Nature Conservancy's Clymer Meadow preserve in Hunt County as well as on scattered prairie remnants (Fig. 13).

Mollisols are found on the Fort Worth Prairie and the Lampasas Cut Plain on various limestone layers and on the Blackland Prairie on rocks of the Austin Group. All of these areas have high calcium carbonate levels and consolidated parent rocks. Because bedrock is usually just below the surface, rooting and soil water storage are restricted. Typically Mollisols are less useful for agriculture than are Vertisols and at present they tend to be used as pastures or homesites. Shrink-swell phenomena, while still occurring on Mollisols, are less problematic than on Vertisols (Diamond & Smeins 1993; Hallmark 1993). Laws (1962) and Brawand (1984) have studied the characteristics of soils formed from the Austin Chalk in the Dallas area.

Alfisols, which develop principally on bedrocks which are higher in sand and lower in calcium carbonate, are found mainly on the eastern and northern margins of the Blacklands (Hallmark 1993)

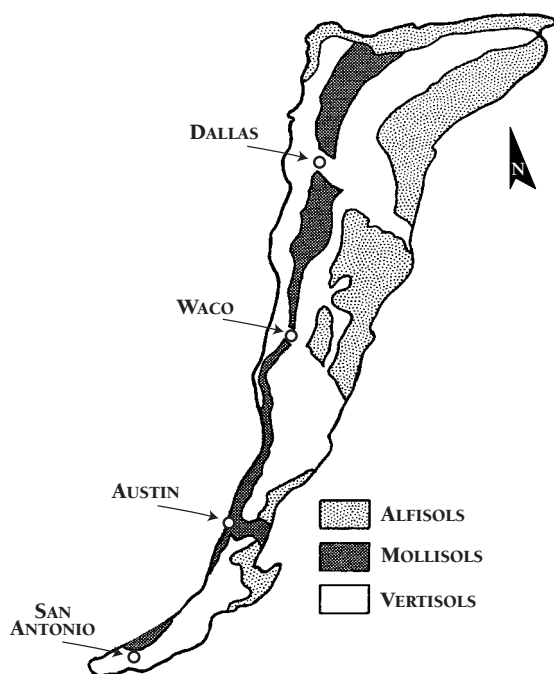


FIG. 10/DOMINANT SOIL ORDERS OF THE MAIN BELT OF BLACKLAND PRAIRIES IN NORTH CENTRAL TEXAS (FROM HALLMARK 1993, IN M.R. SHARPLESS AND J.C. YELDERMAN, EDS. THE TEXAS BLACKLAND PRAIRIE, LAND, HISTORY, AND CULTURE; WITH PERMISSION OF BAYLOR UNIV.; ©1993).

(Fig. 10). These soils are less fertile than either of the other two types (Hallmark 1993). Another microtopographical feature, mima mounds (also called pimple mounds or prairie mounds) (Fig. 11), were found on essentially all Alfisols within the Blackland Prairie region and can still be observed on certain unplowed prairie remnants (e.g., northern Grayson County (Fig. 14) and Tridens Prairie in Lamar County). These are circular, saucer-shaped hills roughly 1 to 14 meters in diameter and up to more than a meter tall. While numerous hypotheses have been proposed, the structures are of unknown and possibly multiple origins (Collins et al. 1975; Diamond & Smeins 1993). Both gilgai and mima mounds increase microhabitat diversity and thus cause vegetational differences over small distances. The overall biological diversity of the prairie is therefore increased (Miller & Smeins 1988; Diamond & Smeins 1993). Due to the different vegetation associated with the different microhabitats of both gilgai and mima mounds, these features are easily discernible in the field at certain seasons of the year (Figs. 13, 14).

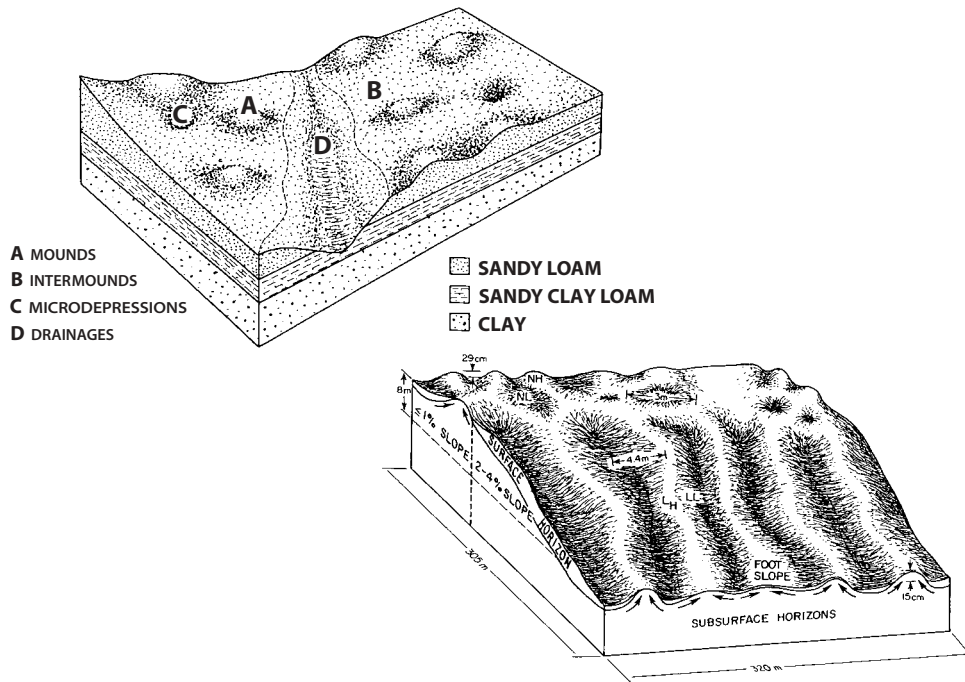


FIG. 11/DIAGRAMS OF MIMA MOUNDS AND GILGAI. TOP—MICROHABITAT VARIATION IN TEXAS TALLGRASS PRAIRIE SHOWING TYPICAL MIMA MOUNDS ON ALFISOL SOILS. **BOTTOM**—MICROHABITAT VARIATION IN TEXAS TALLGRASS PRAIRIE SHOWING TYPICAL GILGAI MICRORELIEF ON VERTISOL SOILS. NH=NORMAL HIGH; NL=NORMAL LOW; LH=LATERAL HIGH; LL=LATERAL LOW. (FROM DIAMOND & SMEINS 1993, IN M.R. SHARPLESS AND J.C. YELDERMAN, EDS. THE TEXAS BLACKLAND PRAIRIE, LAND, HISTORY, AND CULTURE; WITH PERMISSION OF BAYLOR UNIV.; ©1993).

"GILGAI" SHALLOW SURFACE BASINS

Loose pieces of soil fall into dry weather shrinkage cracks;
 when wet, these soil fragments expand and exert lateral pressure

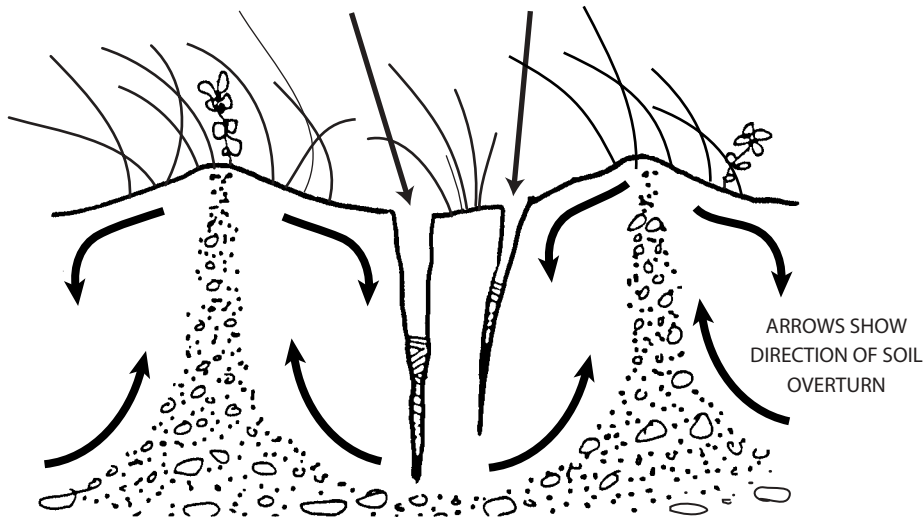


FIG. 12/DIAGRAM SHOWING GILGAI FORMATION (ADAPTED FROM HAYWARD & YELDERMAN 1991). THE TERM "GILGAI" DESCRIBES A PECULIAR FORM OF SURFACE CONFIGURATION, IN WHICH THE LANDSCAPE IS COVERED BY A VAST NUMBER OF SMALL DEPRESSIONS, TEN TO TWENTY FEET ACROSS, AND AS MUCH AS A FOOT-AND-A-HALF DEEP. IN WET SEASONS THESE FILLED WITH WATER, MAKING THE PRAIRIE ALMOST IMPASSABLE. THEY FORMED BECAUSE OF OVERTURN THROUGHOUT THE FULL DEPTH OF THE HIGHLY EXPANSIVE "BLACK WAXY" SOILS OF THE BLACKLANDS.



FIG. 13/PHOTOGRAPH OF GILGAI ON SLOPE (SHOWING MICROVALLEY AND MICRORIDGE EFFECT) ON VERTISOL IN NORTHERN GRAYSON COUNTY, TX (PHOTO BY GMD).



FIG. 14/PHOTOGRAPH OF MIMA MOUND ON ALFISOL IN NORTHERN GRAYSON COUNTY, TX (PHOTO BY GMD).

The soils of the East and West cross timbers are mainly developed on sandy Cretaceous Woodbine and Trinity strata. An exception are the soils in the western portion of the West Cross Timbers which are developed on gravelly and rocky Pennsylvanian strata. While somewhat variable (due to areas of clay in the Woodbine or Trinity Group sands and the complex nature of the Pennsylvanian strata), in general the soils of the cross timbers are rather loose, often deep sands. In fact, the sandy soils in some areas of the West Cross Timbers were so deep that early wagon travel was difficult because wagon wheels would sink in (Hill 1901). The loose nature of these soils also makes them extremely susceptible to erosion. Dyksterhuis (1948) discussed that tremendous gullies formed due to inappropriate cultivation and wind and water erosion, resulting in the subsequent abandonment of fields and even whole farms. However, it is because of these sandy soils, which are much more conducive to the growth of woody vegetation than the heavier clay soils typical of the Blackland and Grand prairies, that the cross timbers vegetation is found in this region.

CLIMATE OF NORTH CENTRAL TEXAS

North Central Texas is located in a zone of dramatic transition between regional climates. The striking vegetational change from the East Texas deciduous forests on the eastern margin of North Central Texas to the grasslands of the Great Plains just to the west is a vivid reflection of this climatic transition (Stahle & Cleaveland 1995). The climate of North Central Texas is often considered subtropical (Yelderman 1993; Norwine et al. 1995; Peterson 1995), but a wide range of extremes can be found. Like the rest of the state, the area can be referred to climatically as a "land of contrasts" (Bomar 1983). There is ample reason why locals say, "If you don't like the weather, just wait a few minutes." "Blue northerners," cold fronts swinging down from the north and accompanied by rapid drops in temperature of dozens of degrees, are not uncommon (Bomar 1983). Mean annual temperature varies from about 68° F (20° C) in the south (Williamson County) to about 64° F (18° C) in the north and west (Griffiths & Orton 1968) (Fig. 15), but temperatures of 0° F (-18° C) and 110° F (43° C) are not unknown for winter and summer respectively (Tharp 1926), with even more extreme readings observed on occasion. In the heat wave of 1980, temperatures climbed to 113° F (45° C) in Dallas-Fort Worth, and there were 69 days with a temperature of 100° F (38° C) or above (Bomar 1983). The highest reading, 119° F (48° C), was recorded for Weatherford in Parker County in 1980 (Bomar 1983). In the extreme cold spell of December 1983, temperatures were below freezing in Dallas-Fort Worth for 12 straight days (Bomar 1983). The coldest temperatures recorded in North Central Texas include minus 8° F (-13° C) (Dallas-Fort Worth) and minus 13° F (11° C) (Paris), both in the unusually cold winter of 1899 (Bomar 1983). Native vegetation has evolved with, and is adapted to, such recurrent extremes. A good example of the different effects of the climate on native versus non-native plants was the extensive damage to introduced landscape plants during the winter of 1983, while most native plants were not adversely affected. The mean length of the frost-free period in the area is given in Figure 16.

While native plants are in general adapted to local weather conditions, they can be damaged under exceptional circumstances. An example was the unseasonably late freeze on the night of 11-12 April 1997. Following a period of relatively warm weather, temperatures dropped substantially below freezing over a large part of North Central Texas. For example, a low of 22° F (-6° C) was recorded for a native habitat (Garnett Preserve) in Montague County (H. Garnett, pers. comm.). The result was substantial damage to the young foliage of many native species and in some cases nearly complete defoliation. Some of the species significantly damaged in Grayson County include *Berchemia scandens* (supple-jack), *Cercis canadensis* (redbud), *Diospyros virginiana* (common persimmon), *Fraxinus americana* (white ash), *Gleditsia triacanthos* (common honey-locust), *Morus rubra* (red mulberry), *Platanus occidentalis* (sycamore), *Quercus macrocarpa* (bur oak), *Quercus marilandica* (blackjack oak), *Quercus muhlenbergii* (chestnut oak), *Quercus shumardii* (Shumard's

red oak), *Quercus stellata* (post oak), and *Rhus glabra* (smooth sumac). Effects on post and blackjack oaks in areas of Cross Timbers vegetation at Hagerman National Wildlife Area (Grayson County) were serious enough that leaf damage was still obvious at a glance in late May. This event is a good example of a false spring weather anomaly. As discussed by Stahle (1990) and Stahle and Cleaveland (1995), a false spring episode includes late winter warmth followed by the movement of polar or arctic air into southern regions. The resulting intense subfreezing temperatures following a warm spell cause widespread damage to cultivated crops as well as native plant species which were advanced in their development by the unusually mild winter temperatures. Forty-four such false spring episodes have been documented in Texas between A.D. 1650 and 1980 (Stahle & Cleaveland 1995). This detailed information can be obtained because frost-damaged cambial tissues leave a permanent record in the annual growth rings of trees and these can be dated dendrochronologically (tree-ring dating) to the exact year of their formation. While there has been a notable decline in the frequency and intensity of false spring episodes in Texas in the last 100 years, the cause of this decrease is not clear (Stahle & Cleaveland 1995).

In terms of precipitation, there is a steep east-west gradient across North Central Texas. Mean annual precipitation ranges from about 46 inches in the northeastern corner of the area in Lamar County to about 24 inches in the westernmost portion of the West Cross Timbers (Dyksterhuis 1948; Griffiths & Orton 1968) (Fig. 17). In general, mean annual precipitation decreases about one inch for each 15 miles across Texas from east to west (Bomar 1983), in part as a result of the decreasing influence of moist air from the Gulf of Mexico. Thus there is a rainfall difference of more than 20 inches between the eastern and western boundaries of North Central Texas. This region, like much of the state, is prone to drought, while at other times it receives too much rain in a short time (Sharpless & Yelderman 1993). Severe storms and some of the largest rainfalls in the United States have occurred in this area. According to Hayward et al. (1992), all the point rainfall records for North America are held within a belt 50 miles east and west of a line from Dallas through Waco, Austin, and San Antonio. The town of Thrall, in Williamson County on the eastern edge of the Blacklands, had one of the largest recorded United States rainfalls on 9–10 September 1921, receiving 38.2 inches in 24 hours (Yelderman 1993). In 1978, Albany, in Shackelford County on the western edge of North Central Texas, received 29.05 inches in one day as a result of Hurricane Amelia. The yearly precipitation record for Texas, 109.38 inches, is also from this region. It occurred in 1873 at Clarksville in Red River County near the extreme northeastern tip of the Blackland Prairie (Bomar 1983).

In years past, the incredibly sticky “black waxy” soil of the Blackland Prairie was particularly problematic during wet weather. Personal accounts (e.g., Mosely in Yelderman 1993) described that under wet conditions the dirt roads were virtually impassable and families actually went hungry until the ground dried enough for people to get to town to obtain food. Drought, however, has been more of a problem, with the lack of water probably always being a limiting factor for humans in the area. The impermeable clay soils, the lack of dependable shallow water-bearing layers, and the scarcity and transitory nature of surface streams made the early Blacklands a particularly inhospitable environment for humans. This is exemplified by early accounts such as the one by D.P. Smythe (1852) who described a trip across the Blacklands:

The soil improves now at every step becoming more level, and uniformly of a dark rich color, but the water is very bad and scarce, drying up entirely during the heat of the summer. . . . During the forenoon of today we must have traveled some twenty miles without passing over a spot of thin soil; being chiefly the black stiff ‘hog wallow’ prairie, rolling just enough to drain itself, but entirely destitute of water during the summer. . . .

Josiah Gregg, another early explorer, indicated that in addition to droughts, the lack of springs or dependable water was “one of the greatest defects of this country” (Fulton 1941).

The concentration of rainfall in spring and fall, coupled with hot dry summers, makes the water problem even more acute (Yelderman 1993). The severe drought of the mid-1950s exemplifies water difficulties in the area. City water supplies were alarmingly low (e.g., Lake Dallas at 11%

of capacity), cattle and sheep ranchers were desperate, wells declined to record levels, and streams either barely flowed or dried up (Bomar 1983). At the time of settlement, while shallow wells were used in some areas, cisterns were the only source of water in others (Hayward & Yelderman 1991; Yelderman 1993). Currently, access to deep aquifers, such as the Trinity, and surface storage in large reservoirs (e.g., Lake Texoma, Lake Lewisville, Lake Ray Hubbard), provide water in this water-poor environment (Hayward & Yelderman 1991). However, Simpson (1993) has emphasized that, "Texas has been a water-deficit state since the dawn of recorded history" and that, "The problem will only be exaggerated as population growth expands." Currently, many cities and water-supply corporations in Texas are actively seeking access to more water, and some cities, such as San Antonio, have a serious water supply problem (Simpson 1993). The recurrent water difficulties seen locally are a reminder of the overall scarcity of water in the southwestern United States.

Major storms have also long been a problem in the region, as can be seen by Parker's (1856) account of the effects of a tornado in 1854 near Gainesville in Cooke County. He spoke vividly of trees broken off ten feet above the ground, an ox wagon carried a quarter of a mile, and a sheep blown into the top of a high tree. More recent destructive tornadoes (e.g., Waco 1953, Paris 1982—Bomar 1983, Jarrell in Williamson Co. 1997) and hail storms (e.g., grapefruit size hail in Fort Worth in May 1995) are present-day reminders of the ongoing power of extreme weather events.

From a longer term perspective, pollen, plant macrofossils, and other types of evidence demonstrate that the climate of Texas has changed substantially over the past 15,000 years. At 15,000 years BP, there was a more widespread forest mosaic over most of Texas with boreal species such as *Picea glauca* (white spruce) in specialized microhabitats (Stahle & Cleaveland 1995). Certain present-day plant distributions, such as the rare western occurrence of plants normally found predominantly in eastern Texas, may thus be relicts of these past climatic conditions. While long-term climate change is well-documented, attention has focused recently on the possibility

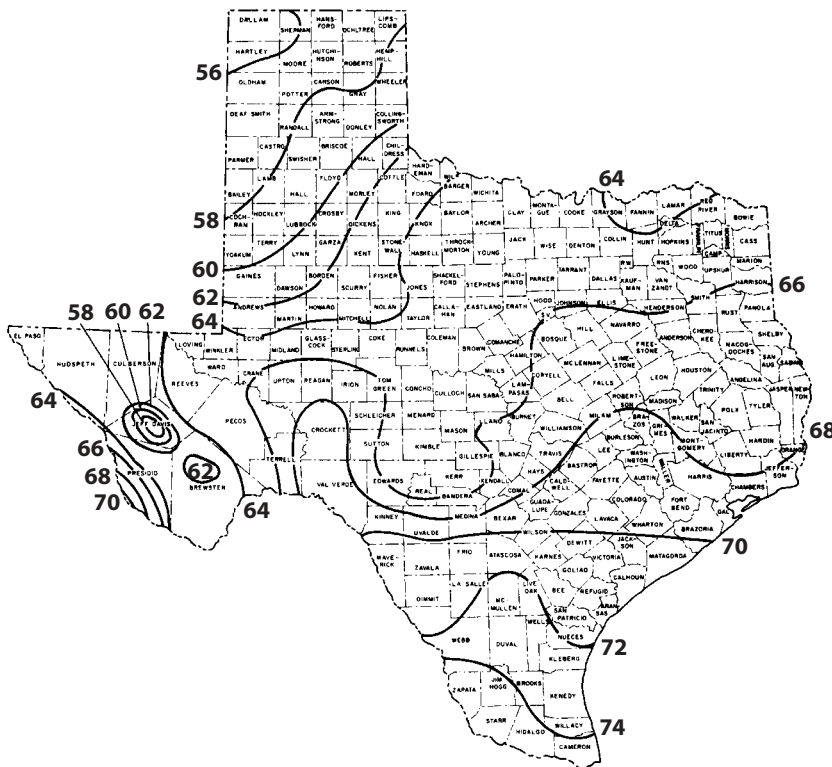


Fig. 15/MEAN ANNUAL TEMPERATURE (°F) FOR TEXAS (ADAPTED FROM GRIFFITHS & ORTON (1968) BY HATCH ET AL. (1990)).

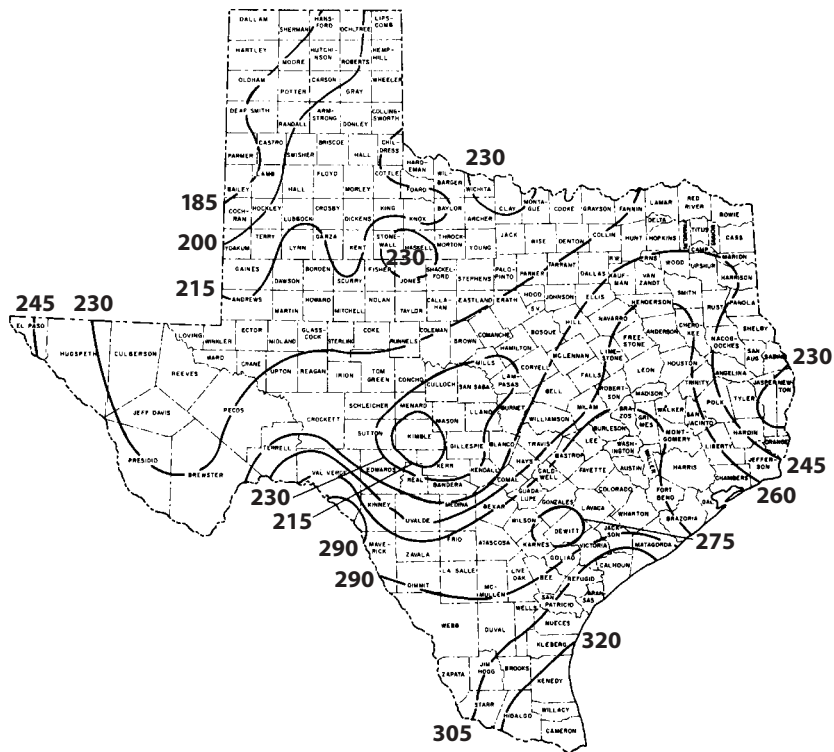


Fig. 16/MEAN LENGTH (IN DAYS) OF FROST-FREE PERIOD FOR TEXAS (ADAPTED FROM GRIFFITHS & ORTON (1968) BY HATCH ET AL. (1990)).

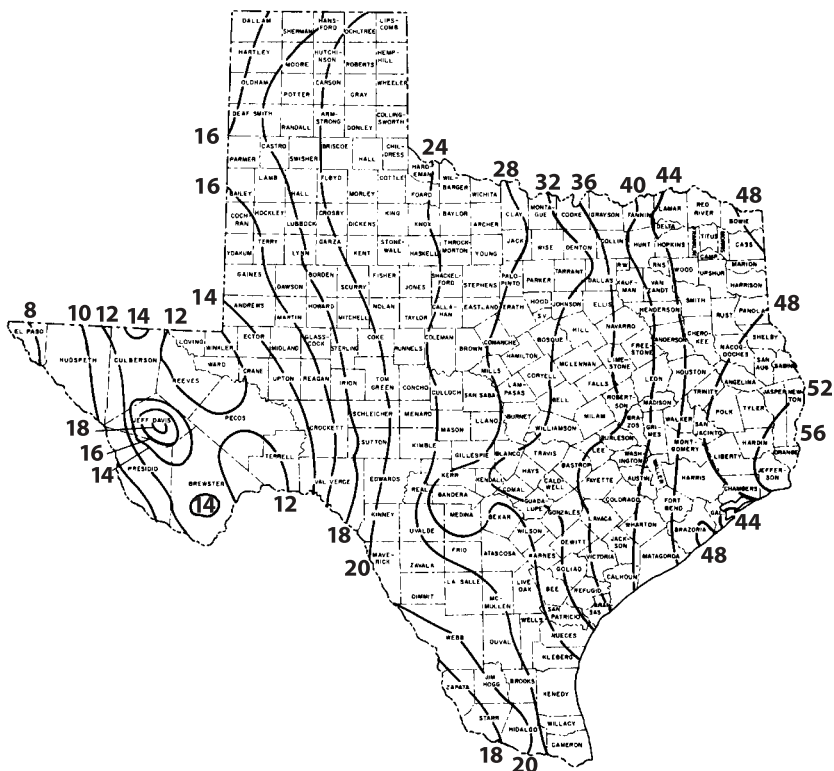


Fig. 17/MEAN ANNUAL TOTAL PRECIPITATION (IN INCHES) FOR TEXAS (ADAPTED FROM GRIFFITHS & ORTON (1968) BY HATCH ET AL. (1990)).

of future climate change in Texas due to human-induced modifications of the atmosphere (e.g., increased CO₂ concentrations) and the resulting increased greenhouse effect and global warming (e.g., Norwine et al. 1995). While considerable controversy exists over details, there is solid evidence that global atmospheric CO₂ concentrations have increased by about 30% since preindustrial times and that this trend can be attributed primarily to human activities (e.g., fossil fuel use, land-use changes, and agriculture) (Houghton et al. 1995). Further, consensus now exists that there is "... a discernible human influence on climate" (Houghton et al. 1995).

Plants can contribute to an understanding of climate change in several ways. First, dendrochronology, the study of tree rings, can provide information on past climate and thus a reference point for present and future studies (Stahle & Cleaveland 1992). Extensive tree-ring chronologies based on remnant old-growth *Taxodium disticum* (bald cypress) stands have provided accurate and well-verified climatic reconstructions for the past 1,000 years for some areas of the southeastern United States, including northwestern Louisiana (Stahle et al. 1988; Stahle & Cleaveland 1992). In North Central Texas, well-documented chronologies based on remnant populations of *Quercus stellata* (post oak) have yielded detailed information on climate for the past 300 years (Stahle & Hehr 1984; Stahle et al. 1985; Stahle & Cleaveland 1988; 1993; 1995).

Changes in phytogeography (plant distributions) can also indicate climate change. An example is the long-term McWilliams (1995) study of the distribution of *Tillandsia recurvata* (ball-moss). This species has expanded its geographical range in Texas over the last 80 years, with much of the expansion occurring since the 1940s. McWilliams demonstrated that even slight changes in temperature or moisture conditions can have significant implications for the survival of plants at the margins of their ranges. The eastward expansion into North Central Texas of species adapted to the drier western Rolling Plains and the northward shift of southerly species would both be expected based on climate models which predict increased temperature (and thus evapotranspiration) and decreased regional precipitation and soil moisture (Houghton et al. 1990; Packard & Cook 1995; Schmandt 1995).

THE BLACKLAND PRAIRIE

OCCURRENCE OF THE BLACKLAND PRAIRIE

The Blackland Prairie of Texas is a well-defined band stretching roughly three hundred miles from the Red River (Oklahoma border) south to near San Antonio (Chambers 1948; Sharpless & Yelderman 1993). It is widest at the north, extending from Grayson County east to near Clarksville in Red River County. It narrows to the south, tapering to a point near San Antonio (Fig. 18). The main belt of the Blackland Prairie totals about 4.3 million hectares or roughly six percent of the total land area of Texas (Collins et al. 1975), and is a region slightly larger than the state of Maryland. It coincides almost exactly with a belt of outcropping Upper Cretaceous marine chalks, marls, and shales (Hayward & Yelderman 1991) that upon weathering forms the characteristic black, calcareous, alkaline, heavy clay, "black waxy" soil. In this work we are including the main body of the Blackland Prairie from the Red River south to the Travis County-Williamson County line just north of Austin, but not the San Antonio Prairie or the outlying Fayette Prairie to the east. Topographically, the Blackland Prairie is a nearly level to gently rolling dissected plain (Hallmark 1993); elevations range from about 300 to 800 feet (92 to 244 meters) (Thomas 1962). Roughly speaking, the Blacklands are bounded on the north by the Red River, on the east by the Post Oak Savannah (also called the Oak-hickory) vegetational area, and on the west by the East Cross Timbers and the Lampasas Cut Plain. North of Sherman in Grayson County, the trend of the Blacklands undergoes a shift in direction, turning from north-south to east-west, before ending near Clarksville in Red River County. In this work we use the terms Blackland Prairie and Blacklands interchangeably.

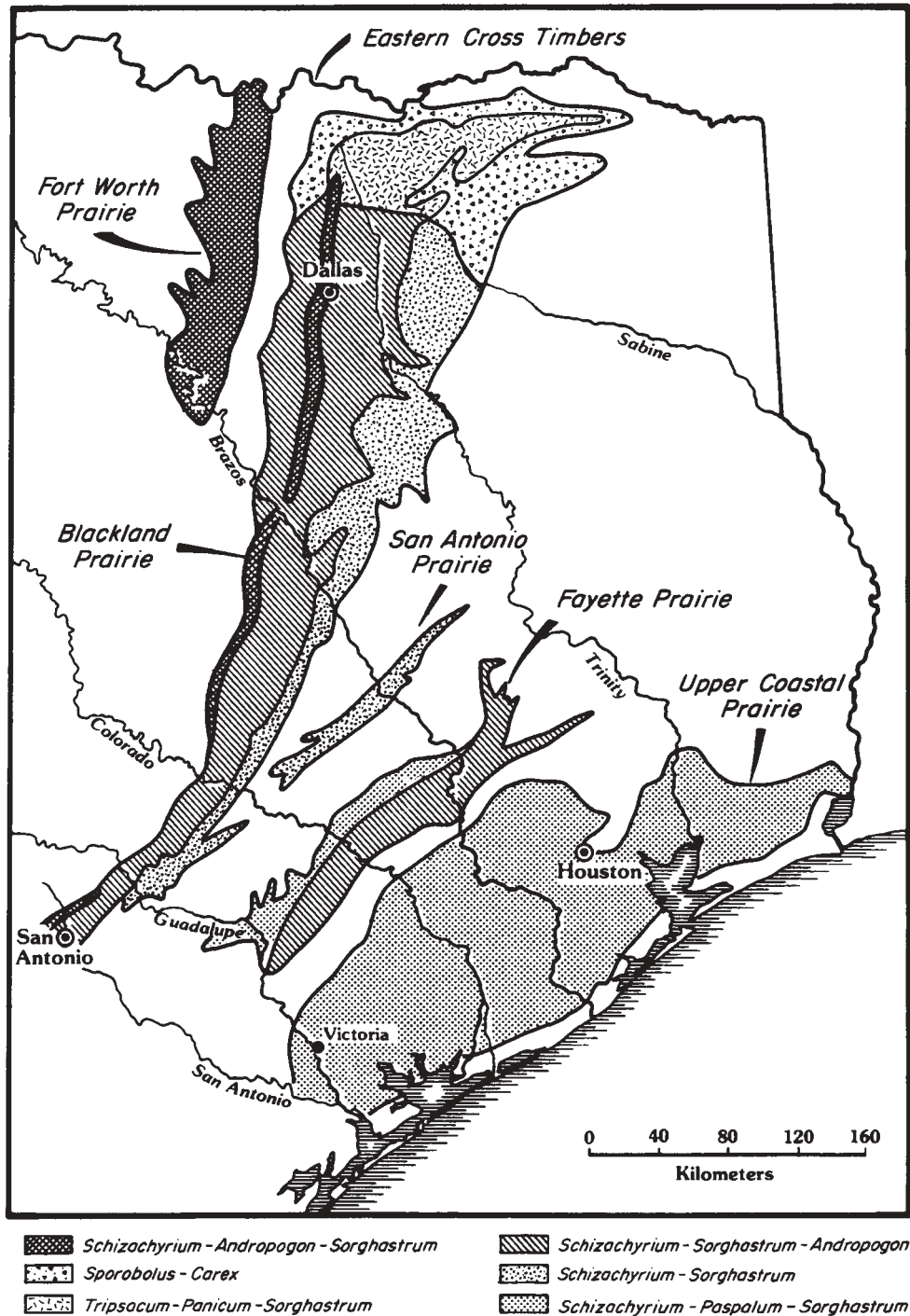


Fig. 18/ MAJOR PLANT COMMUNITY TYPES OF THE BLACKLAND PRAIRIE AND RELATED TALLGRASS REGIONS OF TEXAS (FROM DIAMOND & SMEINS 1993, IN M.R. SHARPLESS AND J.C. YELDERMAN, EDS. THE TEXAS BLACKLAND PRAIRIE, LAND, HISTORY, AND CULTURE; WITH PERMISSION OF BAYLOR UNIV.; ©1993).

PRESETTLEMENT AND EARLY SETTLEMENT CONDITIONS ON THE BLACKLAND PRAIRIE

Conditions on the presettlement Blackland Prairie were strikingly different from those found today. Probably the most conspicuous difference was the presence of vast expanses of tall grass prairie. In the words of Parker (1856), traveling with the 1854 Marcy expedition, "After leaving Preston [northern Grayson County], we entered upon the vast plains. . . ." Dr. John Brooke, who emigrated from England in 1848, stated on arriving at the edge of the Blackland Prairie, "It was the finest sight I ever saw; immense meadows 2 or 3 feet deep of fine grass & flowers. Such beautiful colours I never saw. . . ." (Brooke 1848). In describing the area where he settled near Dorchester in south central Grayson County, Brooke (1849) said,

I can sit on the porch before my door and can see miles of the most beautiful Prairie interwoven with groves of timber, surpassing, in my idea, the beauties of the sea. Think of seeing a tract of land on a slight incline covered with flowers and rich meadow grass for 12 to 20 miles. . . .

Hill (1901), speaking of the Blacklands in general, said,

The surfaces of the prairies are ordinarily clad with thick mantles of grass, liberally sprinkled with many-colored flowers, broken here and there by low growths of mesquite trees, or in exceptional places by 'mottes' or clumps of live oaks on uplands, pecan, bois d'arc, walnut and oaks in the stream bottoms; juniper and sumac where stony slopes exist, and post oak and black-jack in the sandy belts.

Smythe (1852) described the eastern edge of the Blackland Prairie as having

. . . a view of almost boundless Prairie stretching to the north, as far as the eye could reach. . . .

He further referred to it as

. . . a boundless plain scarcely broken by a single slope or valley, and nearly destitute of trees; (the mesquite appearing but seldom.) Several times during the forenoon not a single shrub or tree could be seen in any direction. . . . The grazing has reached its climax, it would be impossible for natural pasturage to excell [excel] this.

Kendall (1845) described the southern part of the Blackland Prairie as "beautiful rolling prairies, the land rich, and susceptible of cultivation." Roemer's (1849) descriptions of the same region included "open prairie," "extensive prairies" with mesquite trees and scattered oak groves, "undulating prairie extending . . . an immeasurable distance," and "gently rolling, almost treeless plain." Indeed, on the Blackland Prairie, trees were often rare except as riverine forests along streams or as occasional scattered groves or mottes "such as the one near Kentuckytown that gave Pilot Grove [in southeastern Grayson County] its name, the trees being a major landmark in a featureless terrain." (McLeRoy 1993). The riverine forests along Big Mineral Creek [Grayson County] were described by Parker (1856) as "a rich bottom, thickly grown up with large cotton wood, honey locust, overcup [bur oak], and other heavy timber, besides plenty of the bois d'arc." Roemer (1849) described a trading post he visited in Falls County as "on a hill covered with oak trees, two miles distant from the Brazos, above the broad forested bottom of Tohawacony Creek." He further described the wooded bottomland as having "high, dense trees."

Fire was probably an important factor in maintenance of the original prairie vegetation and had a major impact on community structure (Anderson 1990; Collins & Gibson 1990; Strickland & Fox 1993). Tall grass prairie fires, intensely hot, would have been stopped only by the lack of dry fuel or a change in topography. Even streambank vegetation was susceptible during dry years. The end result was that trees were rare even along some stream banks, and prairie margins probably extended somewhat beyond the limits of the soil types usually associated with prairie (Hayward & Yelderman 1991). Roemer (1849) wrote of a prairie fire as follows:

. . . we, ourselves, were entertained before going to sleep by the spectacle of a prairie fire. Like a sparkling diamond necklace, the strip of flame, a mile long, raced along over hill and dale, now moving slowly, now faster, now flickering brightly, now growing dim. We could the more enjoy this spectacle undisturbed, since the direction of the wind kept it from approaching us. My companion was of the opinion that Indians had without doubt started the fire, since they do this often to drive the game in a certain

direction, and also to expedite the growth of the grass by burning off the dry grass.

While lightning was an important source of naturally started fires, Native Americans were long present in the region and their use of fire is considered by some to be equally important in having maintained North American grasslands (Bragg 1995).

In summary, the original Blackland Prairie seems to have been predominantly tall grass prairie with trees along watercourses, sometimes scattered on the prairie or concentrated in certain areas (e.g., Pilot Grove) possibly as the result of locally favorable soil conditions or topography.

It is interesting to note that early (back to the 1830s) surveyor records of mesquite as the most common tree in presettlement upland prairies in Navarro County suggest "...the legendary spread of mesquite into North Texas by longhorn cattle may be an errant concept" (Jurney 1987). Roemer's (1849) mention of "extensive prairies covered with mesquite trees" also points to mesquite as a natural component of the vegetation. However, mesquite has increased in many areas and the observations mentioned above are not so early as to preclude mesquite having already been spread to some extent by land use changes.

While some question the degree to which mesquite was spread by longhorns, animals have had profound impacts on the vegetation since long before settlement. These range from the obvious effects of the bison or beaver to the more subtle but essential roles of pollination and seed dispersal. Present animal life is much different and some species reduced compared to presettlement days. In addition to relatively large present-day species such as the white-tailed deer, coyote, fox, and bobcat, a number of other large or interesting species occurred. According to Brooke (1848) writing of Grayson County, black bears were quite common ("I...have never tasted any meat I like better.") as were deer; panthers [mountain lions] and wolves were also present. In Brooke's (1848) words, "I have been out a-shooting Deer and Turkeys alone, and when going up the branches of the Rivers I often come across either bear or wolf..." Strecker (1926a) (based on early fur-trader records) indicated that next to the skins of deer, "those of the black bear were of the most value to the Indians of McLennan County." Strecker (1926a) also reported that gray wolves occurred as far east as McLennan County. He indicated that they

... may never have been very common permanent residents of McLennan County, but in late fall and winter, small packs followed the great herds of buffalo and deer from northwestern Texas and remained here for several months. It was probably only a minority that remained throughout the year. Old settlers refer to packs of from five to eight wolves which they considered small family groups.

Another predator, the ocelot, is thought to have ranged as far north as the Red River (Hall & Kelson 1959). Strecker (1924), for example, reported that ocelot occurred in the bottoms of the Brazos River near Waco in McLennan County. Even jaguar are believed to have ranged north to the Red River; the last jaguar record from North Central Texas was a large male killed in Mills County (Lampasas Cut Plain) in 1903 (Bailey 1905). Mountain lions probably occurred throughout North Central Texas (Schmidly 1983), with Strecker (1926a) indicating they were common in McLennan County in the middle of the 1800s. However, they were rare by the beginning of the 20th century (Bailey 1905) and since that time have been eliminated over most of the region (Schmidly 1983). The collared peccary or javelina, a small wild pig, was also originally present in the southern portion of the area, north to at least the Brazos River valley in McLennan County near Waco (Strecker 1926a; Schmidly 1983; Davis & Schmidly 1994). Other noteworthy large mammals that previously occurred in appropriate habitats of the Blackland Prairie as well as throughout the rest of North Central Texas include river otter, ringtail, and badger (Schmidly 1983; Davis & Schmidly 1994).

The occurrence of bison was documented by Judge John Simpson of Bonham (Fannin County). Simpson, describing a bison hunt in 1833, reported that hunters found "an immense herd" "on the prairie around Whitewright [Grayson County]" (McLeRoy 1993). Parker (1856), in his 1854 journal, stated, "But eight years since, herds roamed around the City of Austin, and were frequently seen in the streets; now there are but few to be found south of Red River." Roemer (1849) described bison on the southern Blackland Prairie as follows:

When on the following morning at daybreak we entered the prairie on which mesquite trees grew scatteringly, the first object that met our view was a buffalo herd, quietly grazing near us. . . . The whole prairie was covered with countless buffalo trails, crossing in all directions, reminding one of a European grazing ground.

On a different day, Roemer (1849) indicated,

They covered the grassy prairie separated into small groups and far distant on the horizon they were visible as black specks. The number of those clearly seen must have been not less than a thousand.

Pronghorn antelope were also native, occurring at least as far east as Fannin County (Hall & Kelson 1959). Smythe (1852) described a small herd on the eastern edge of the Blacklands, Roemer (1849) mentioned sighting pronghorn antelopes near where the Blackland Prairie and Lampasas Cut Plain come together, and Major G.B. Erath, a pioneer of Waco, indicated that antelope were common in what is now McLennan County in the early to middle 1800s (Schmidly 1983). Erath also reported that small herds penetrated as far east as Milam County on the eastern edge of the Blackland Prairie (Strecker 1926a).

While not native, wild horses, descended from those escaped from the Spanish, were by the early 1800s extremely common in Texas and were probably having a significant impact on the vegetation. Ikin (1841), speaking of Texas as a whole, indicated,

The wild horse which now roams every prairie, sometimes alone, sometimes in herds of more than a thousand, is not native, but the progeny of those which escaped from the early conquerors of Mexico. He is usually a small bony animal about fourteen hands high, with remarkably clean legs, and other signs indicative of good blood. When congregated in bodies of a thousand, these horses form the most imposing spectacle which the prairies present.

Strecker (1926a) also reported the wild horse as abundant throughout the Brazos Valley of McLennan County at the time of arrival of the first American settlers. He further indicated that early settlers sometimes shot the wild horses to prevent interference with their domesticated stock.

The bird, reptile, and fish faunas were also conspicuously different in significant ways from those today. Brooke (1848), writing about early Grayson County, mentioned both turkeys and prairie chickens, and Smythe (1852) spoke of hunting "Prairie Hens" in what is now Limestone County on the eastern edge of the Blackland Prairie. According to Pulich (1988), both greater and lesser prairie chickens were common in North Central Texas until the 1880s; these two species were locally extinct by the early 1900s. Oberholser (1974) mentioned a specimen record for the greater prairie chicken from Dallas County with a number of other North Central Texas records west of the Blackland Prairie in Clay, Cooke, Denton, and Navarro counties. There is a questionable record for the lesser prairie chicken from Dallas and also records for this species from Cooke and Young counties to the west of the Blacklands (Oberholser 1974). The extinct passenger pigeon is also well documented for the Blackland Prairie. These birds, known as "wild pigeons" by early settlers, were recorded from Collin, Fannin, and Henderson counties, with a number of records even farther west in the Grand Prairie, Lampasas Cut Plain, and West Cross Timbers (Oberholser 1974; Pulich 1988). This once very numerous species rapidly became extinct in North Central Texas, with 1896 being the last record in the area (Oberholser 1974; Pulich 1988). The ivory-billed, one of the world's largest woodpecker species, was also present in bottomland forests in the Blacklands. Oberholser (1974) listed records for Cooke, Dallas, Fannin, and Kaufman counties with sightings as late as the early 1900s (Pulich 1988). Another extinct species, the Carolina parakeet, was known from eastern Texas (Greenway 1958) and was probably also present in the riverine forests of the Blackland Prairie (Goodwin 1983), especially along the Red and Trinity rivers. Even more surprising, alligators were abundant in places, with Kendall (1845) describing them along the San Gabriel in the southern Blackland Prairie as "too plentiful for any useful purposes." This large reptile occurred in appropriate habitats throughout most of the Blackland Prairie, west to Grayson, Dallas, McLennan, and Williamson counties

(Brown 1950; Hibbard 1960; Dixon 1987), and are still known to occur in Dallas County. Kendall (1845) further indicated concerning the San Gabriel that “The stream abounds with trout, perch, and catfish, as do nearly all the watercourses in this section of Texas.”

During the Pleistocene, an even more extensive megafauna occurred in the area (Smeins 1988), as shown by the excavation of a mammoth from near Flowing Wells (Grayson County) by Dr. Daniel Schores and a student team from Austin College (D. Schores, pers. comm.). Further, fossils of at least three elephant species, including mammoth and mastodon, are known from the Dallas area (Shuler 1934). An even more impressive site containing a large (20+) mammoth herd was found near Waco in a Brazos River terrace dated around 28,000 years BP (Fox et al. 1992; C. Smith, pers. comm.). Several woody plants found in the Blackland Prairie region seem to have adaptations that are difficult to explain based on interactions with the present fauna. Bois d’arc (*Maclura pomifera*), honey-locust (*Gleditsia triacanthos*), and mesquite (*Prosopis glandulosa*) all have fruits that are adapted for dispersal by large animals (megafauna) and seem to fit Janzen and Martin’s (1982) hypothesis that large, now extinct animals were involved in the evolution of certain “anachronistic” plant characteristics we see today. Another such possible characteristic is the protective armature displayed by honey-locust. The long, stout, branched thorns, up to a foot or more long, would seem perfectly reasonable in Africa where there are abundant large herbivores, but rather out of place in northern Texas where currently no large native browsers exist.

In general, the animals of the Blacklands have faunal affinities with the eastern woodlands, the Great Plains, and the southwestern United States (Schmidly et al. 1993). A recent, now very abundant, southern addition to the fauna is the nine-banded armadillo. This species is originally native to South America, and as recently as the 1870s to 1880 was found only at the southern tip of Texas (Strecker 1926b; Phelan 1976). Since that time it has spread extensively and is now found hundreds of miles north of Texas (Hall & Kelson 1959). Armadillos were at least sporadic as far north as the Red River by the early 1930s, but did not become common there until the 1950s (H. McCarley, pers. comm.).

The earliest use of the Blackland Prairie by settlers was as grazing areas for herds of cattle or horses. According to Hayward and Yelderman (1991) “... the Blackland Prairie supported some of the earliest of large-scale ranching efforts in Texas, complete with pre-Civil War cattle drives to St. Louis and Chicago.” Brooke (1848) stated that, “... the cattle and horses feed on the prairies all winter; no need of laying up winter food.” Parker (1856) wrote of a herd of 1,200 wild cattle being driven north across the Red River at Preston (Grayson County).

While limited “sod plowing” occurred quite early (Smythe 1852), it wasn’t until the 1870s and 1880s, with the coming of the railroads and the development of special plows and favorable economic conditions, that extensive “breaking of the prairie” and exploitation of its agricultural potential finally occurred (Hayward & Yelderman 1991). Once farming on the Blacklands was possible, widespread cultivation of the rich soils, perhaps as rich as any in the nation (Hayward & Yelderman 1991), was inevitable and farming quickly replaced ranching. Cotton soon became an important crop and thus began the era referred to as the Cotton Kingdom. According to Sharpless and Yelderman (1993), for seventy years more cotton was grown on the Blackland Prairie than any other region of the world. Hill (1901) said, “In fact these calcareous soils ... of the Black Prairies are the most fertile of the whole trans-Mississippi region.” Others (e.g., Sharpless and Yelderman 1993) have said the soil is arguably the most fertile west of the Mississippi River. Within a very short time, most of the accessible and desirable land was put into cultivation, and according to Burleson (1993), by 1915 the human population on the Blacklands was greater than on any other United States area of comparable size west of the Mississippi. The result was the virtually complete destruction of native Blackland Prairie communities. With the exception of small or inaccessible areas and a relatively few hay meadows valued for their native grasses, almost nothing remains of the tall grass prairies that were once so abundant. Estimates of the destruction of this ecosystem range from 98% (Hatch et al. 1990) or 99% (Riskind & Collins 1975) to more than 99.9 % (Burleson 1993).

GEOLOGY OF THE BLACKLAND PRAIRIE

The Blackland Prairie is on an erosional landscape developed from easily erodible Cretaceous shales, marls, and limestones that dip gently to the east (Hayward & Yelderman 1991). It originally consisted of four somewhat different parallel north-south bands of vegetation: the Eagle Ford Prairie, the Whiterock Prairie, the Taylor Black Prairie, and the Eastern Transitional Prairie. These all correspond to underlying geologic layers (Hayward & Yelderman 1991).

The westernmost and geologically oldest portion of the Blackland Prairie, known as the Eagle Ford Prairie, is developed on the Eagle Ford Shale, Upper Cretaceous material deposited about 92 to 90 million years ago (Hayward & Yelderman 1991). This layer crops out just east of the Woodbine Sand, on which the East Cross Timbers are found. While variable, the Eagle Ford Shale is principally a dark bluish-gray to nearly black shaly clay (Bullard 1931) that weathers to form black vertisol soils supporting prairie vegetation.

Cropping out to the east of the Eagle Ford Shale is the slightly younger Austin Chalk, deposited about 90 to 85 million years ago. This layer, which supports the Whiterock Prairie, forms the elevated backbone or “axis” of the Blacklands (Hayward & Yelderman 1991). It is a strikingly white, very fine-grained limestone, called chalk, made primarily of millions of calcium carbonate cell walls of tiny marine algae. Similar deposits make up the famous white cliffs of Dover in southern England and are used commercially as writing chalk. The Austin Chalk is a relatively resistant hard layer (Dallas Petroleum Geologists 1941) compared to the surrounding shales, and because of this hardness, it forms a rather conspicuous escarpment from Sherman to Dallas and south to Austin. This topographic feature is sometimes referred to as the “white rock escarpment,” “white rock scarp,” (Hill 1901) or “white rock cuesta,” and although it never exceeds 200 feet in elevational difference from the surrounding terrain (usually much less), it is the most conspicuous topographic feature in the Texas Blacklands (Hill 1901; Montgomery 1993). It typically crops out as a west-facing bluff or escarpment overlooking a prairie formed on the less resistant Eagle Ford Shale (Bullard 1931). In striking contrast to the Grand Prairie with its numerous resistant layers, the Austin Chalk is the only resistant, escarpment-forming layer underlying the entire Blackland Prairie. As a result, most of the Blackland Prairie is gently rolling, in contrast to the sharper, more angular topography of the Grand Prairie (Hill 1901). Surprisingly, the extremely white Austin Chalk weathers to form a sticky black soil, typically thinner than, but similar to that derived from the Eagle Ford Shale (Bullard 1931) (Fig. 9). Where this soil is eroded away, as on stream banks, a distinctive flora can be found on the exposed chalky limestone (see description under vegetation). Despite their biological diversity, these exposed chalky areas are of little commercial value and are thus often destroyed by contouring or other types of “remediation.”

The layers that crop out to the east of the Austin Chalk are the Taylor marls and sandy marls, laid down about 79 to 72 million years ago. The Taylor Blacklands, the largest of the four Blackland Prairie belts, occurs on the soils derived from these rocks (Hill 1901; Hayward & Yelderman 1991). In fact, Taylor sediments underlie about two-thirds of the total Blackland Prairie (Hill 1901). The soils developed on Taylor rocks are the classic deep, rich, calcareous, “black waxy” soils that were formerly so valuable for cotton production.

Finally, the easternmost and youngest Cretaceous rocks supporting Blackland Prairie are those of the Navarro group, deposited about 72 to 68 million years ago (Hayward & Yelderman 1991). These deposits crop out from Red River County in the north, through Kaufman and Navarro counties, south to Williamson County on the southeastern margin of North Central Texas. They break down into a soil with a somewhat higher sand content than the Blackland soils farther west, and support the easternmost of the Blackland Prairies, the Eastern Transitional or Marginal Prairie (Hill 1901; Hayward & Yelderman 1991). While easier to till, these soils are poorer in nutrients and thus not as valuable for farming (Hayward & Yelderman 1991). Immediately to the east of the Navarro Group and east of North Central Texas, on younger sandy deposits of Tertiary-age, the Post Oak Savannah begins, marking the western edge of the eastern deciduous forest.

VEGETATION OF THE BLACKLAND PRAIRIE

According to Gould and Shaw (1983), the Blackland Prairie (and in fact all of North Central Texas) is part of the True Prairie grassland association, extending from Texas to southern Manitoba. This is one of the seven grassland associations of North America recognized in the classification system of Gould (1968a) and Gould and Shaw (1983) (Fig. 19). Based on location, climate, and vegetational characteristics, the tall grass prairies of the Texas Blacklands can be considered part of either the True Prairie or Coastal Prairie associations (Collins et al. 1975). They lie at the very southern end of the True Prairie association, but are also connected to the Texas Coastal Prairie. Rainfall values are intermediate and the Blackland Prairies have most of the vegetational dominants of both these areas. According to Collins et al. (1975), adequate data are not currently available for a clear determination. Many authorities, however, recognize the tall grass prairies of the Blacklands as an extension of the True Prairie with little bluestem (*Schizachyrium scoparium*) as a climax dominant (Allred & Mitchell 1955; Thomas 1962; Correll 1972; Gould & Shaw 1983; Simpson & Pease 1995).

Seven different specific grassland communities occurring on three main soil associations are recognized by Collins et al. (1975) as occurring in the Blackland Prairie. Diamond and Smeins (1993), however, recognized five major tall grass communities in the main body of the Blacklands (Fig. 18). Three of these types, the *Schizachyrium-Andropogon-Sorghastrum* (little bluestem-big bluestem-Indian grass), *Schizachyrium-Sorghastrum-Andropogon* (little bluestem-Indian grass-big bluestem) and *Schizachyrium-Sorghastrum* (little bluestem-Indian grass), are relatively similar, have little bluestem as the prevailing dominant, and occur over the majority of the Blacklands (Diamond & Smeins 1993). Associated species include *Bouteloua curtipendula* (side-oats grama), *Carex microdonta* (small-toothed caric sedge), *Sporobolus compositus* (tall dropseed), *Nassella leucotricha* (Texas winter grass), *Acacia angustissima* var. *hirta* (prairie acacia), *Bifora americana* (prairie-bishop), *Hedyotis nigricans* (prairie bluets), and *Hymenopappus scabiosaeus* (old-plainsman) (Diamond & Smeins 1985). The microtopographical features known as “hog wallows” or gilgai are often found on prairies of these types and provide important microhabitat variation based on differences in water, nutrient relations, and frequency of disturbance (Diamond & Smeins 1993). Vegetational differences associated with the microhighs and microlows are easily observed.

The other two Blackland communities are quite different vegetationally and are relatively limited in occurrence. The *Tripsacum-Panicum-Sorghastrum* (eastern gamma grass-switch grass-Indian grass) community is “. . . found over poorly drained Vertisols in uplands of the northern Blackland Prairie and in lowlands throughout the Texas tallgrass prairie region” (Diamond & Smeins 1993). Examples can be found in Grayson and Fannin counties. Additional common species include *Bouteloua curtipendula* (side-oats grama), *Carex microdonta* (small-toothed caric sedge), *Paspalum floridanum* (Florida paspalum), *Sporobolus compositus* (tall dropseed), *Acacia angustissima* var. *hirta* (prairie acacia), *Aster ericoides* (heath aster), *Bifora americana* (prairie-bishop), *Hedyotis nigricans* (prairie bluet), *Rudbeckia hirta* (black-eyed susan), and *Ruellia humilis* (prairie-petunia) (Diamond & Smeins 1985). The *Sporobolus-Carex* (silveanus dropseed-mead sedge) community, dominated by *Sporobolus silveanus* (Silveus’ dropseed) and *Carex meadii* (Mead’s caric sedge), is found in the northern Blackland Prairie on low pH Alfisols in areas of relatively high precipitation (Diamond & Smeins 1993). An example can be seen on the Nature Conservancy’s Tridens Prairie in Lamar County. Other common species found in this community type include *Panicum oligosanthos* (Scribner’s rosette grass), *Fimbristylis puberula*, *Coelorachis cylindrica* (Carolina joint-tail), *Panicum virgatum* (switch grass), *Paspalum floridanum* (Florida paspalum), *Sporobolus compositus* (tall dropseed), *Aster pratensis* (silky aster), *Linum medium* (Texas flax), and *Neptunia lutea* (yellow-puff) (Diamond & Smeins 1985). The microtopographical feature known as mima mounds is commonly associated with this community. Like gilgai, mima mounds provide microhabitat variation, increasing the overall biological diversity of the prairie ecosystem (Diamond & Smeins 1985).

Also worth mention is the special assemblage of herbaceous plants often seen on areas of very thin soil and especially on exposed outcrops of the Austin Chalk (Stanford 1995). Species seen in this type of setting in the northern Blackland Prairie (Grayson County) include *Baptisia australis* (wild blue-indigo), *Callirhoe pedata* (finger poppy-mallow), *Eriogonum longifolium* (long-leaf wild buckwheat), *Grindelia lanceolata* (gulf gumweed), *Ipomopsis rubra* (standing-cypress), *Linum pratense* (meadow flax), *Marshallia caespitosa* (Barbara's-buttons), *Oenothera macrocarpa* (Missouri primrose), *Paronychia jamesii* (James' nailwort), and *Thelesperma filifolium* (greenthread). At some seasons, these outcrops have the aspect of barren eroded rock; in the spring, however, they are covered with spectacular displays of color.

As can be seen above, there is considerable variation in the tall grass prairie communities of the Blacklands (Diamond & Smeins 1993), and disagreement about specific community types (Simpson & Pease 1995). However, common dominant grasses of this tall grass prairie ecosystem include *Schizachyrium scoparium* (little bluestem), *Andropogon gerardii* (big bluestem), *Sorghastrum nutans* (Indian grass), *Panicum virgatum* (switch grass), *Tripsacum dactyloides* (eastern gamma grass), *Sporobolus compositus* (tall dropseed), *Eriochloa sericea* (Texas cup grass), *Paspalum floridanum* (Florida paspalum), and *Tridens strictus* (long-spike tridens) (Collins et al. 1975). Despite similarities in general aspect and even the occurrence of certain species over broad areas, the particular community present and the dominants observed can vary considerably even over short distances, primarily on the basis of differences in soil. Localized patches of a community type well beyond its main zone of occurrence are common, based on soil or other factors. Therefore most of the Blackland Prairie is a complex mosaic of tall grass communities; an example of this can be seen in northern Grayson County where four of the community types discussed above can be seen within a few miles.

Although prairie predominated, some wooded areas were also natural components of the Blackland Prairie region at the time of settlement. Examples include bottomland forests and wooded ravines along the larger rivers and streams, mottes or clumps in protected areas or on certain soils, scarp woodlands on slopes at the contact zones with the Edwards Plateau and Lampasas Cut Plain, and scattered upland oak woodlands similar to the Cross Timbers (Gehlbach 1988; Nixon et al. 1990; Diamond & Smeins 1993). In areas such as Dallas, where the Austin Chalk forms a conspicuous escarpment or bluff, a characteristic woody vegetation is also found in the varied microhabitats associated with this topographic feature. Kennemer (1987) indicated that *Fraxinus texensis* (Texas ash), *Quercus sinuata* var. *breviloba* (shin oak), and *Ulmus crassifolia* (cedar elm) are dominant. Other noteworthy woody plants of the escarpment include *Cercis canadensis* var. *texensis* (Texas redbud), *Juniperus ashei* (Ashe juniper), *Morus microphylla* (Texas mulberry), and *Ungnadia speciosa* (Texas buckeye). Farther south, in Bell, Hill, and McLennan counties, the Austin Chalk scarp vegetation is similar. Depending on slope and moisture conditions, characteristic species include *Celtis laevigata* (sugarberry), *Diospyros texana* (Texas persimmon), *Forestiera pubescens* (elbow-bush), *Fraxinus texensis*, *Ilex decidua* (deciduous holly), *Juniperus ashei*, *Juniperus virginiana* (eastern red-cedar), *Ptelea trifoliata* (hoptree), *Quercus buckleyi* (Texas red oak), *Quercus fusiformis* (Plateau live oak), *Quercus sinuata* var. *breviloba*, and *Ulmus crassifolia* (Gehlbach 1988).

As indicated earlier, with the exception of preserves, small remnants, or native hay meadows, almost nothing remains of the original Blackland Prairie communities. According to Diamond et al. (1987), all of the tall grass community types of the Blackland Prairie are "...endangered or threatened, primarily due to conversion of these types to row crops." Three specific Blackland communities are considered "threatened natural communities" by the Texas Organization for Endangered Species (TOES 1992). Conversion of the Blackland Prairie for agriculture was the most important cause of the destruction of this ecosystem, with only marginal, often steeply sloped land not rapidly brought under cultivation. High prices for cotton and grains eventually resulted in the cultivation of even these marginal areas, "...with disastrous effects. Blackland soils on steep slopes, stripped of their protective grass, eroded rapidly. Gullying was everywhere,

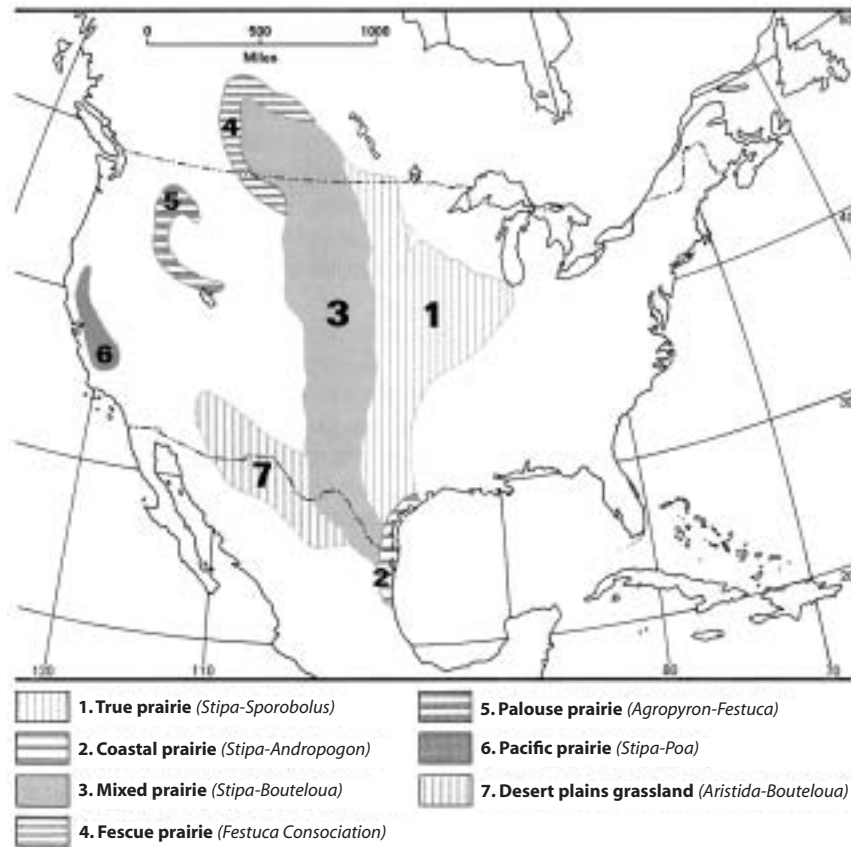


FIG. 19/GRASSLAND ASSOCIATIONS IN NORTH AMERICA (FROM GOULD 1968A; USED WITH PERMISSION OF LUCILE GOULD BRIDGES; ©1968). NOTE THAT ACCORDING TO GOULD (1968A) AND GOULD AND SHAW (1983), ALL OF NORTH CENTRAL TEXAS IS PART OF THE TRUE PRAIRIE ASSOCIATION.

and in a few years, over much of the marginal slope-lands, as much as three feet of soil had been eroded, exposing barren rock where once was prairie soil” (Hayward & Yelderman 1991). Today, extensive eroded areas and large sections that have been contoured to remedy erosion can be seen in many places throughout the Blacklands.

Existing prairie is still being lost due to a variety of causes. An example is the destruction of Stults Meadow in Dallas, studied in detail by Laws (1962) and Correll (1972). In addition to direct destruction of prairie through cultivation or other uses (e.g., urbanization), existing isolated small prairie remnants are currently being lost through invasion by woody vegetation and introduced species. Given the relatively high rainfall over most of the Blacklands, with the suppression of fire by humans, native trees and shrubs (e.g., *Juniperus virginiana*—eastern red-cedar, *Ulmus crassifolia*—cedar elm) as well as introduced species are able to invade and eventually take over areas that were formerly prairie.

Recurrent fire and grazing by bison were natural processes that maintained the Blackland ecosystem; the removal of these processes is a disturbance that causes changes in the vegetation (Smeins 1984; Smeins & Diamond 1986; Diamond & Smeins 1993). In this region, periodic disturbance is essential for the maintenance of prairie. However, even native hay meadows, which are routinely disturbed, are often markedly different from the original vegetation because of the substitution of mowing and particularly past herbicide use in place of fire and grazing. The results include a reduction in broad-leaved plants and an increased abundance of grasses (Diamond & Smeins 1993). While grazing was a natural component of the Blacklands and many

other Texas ecosystems, overstocking and thus overgrazing by domesticated animals has also caused a dramatic decline and even near elimination of numerous plants from many areas (Cory 1949). The cumulative effect of all these human-induced changes is that the Blackland Prairie communities have been largely destroyed. Large areas that were once tall grass prairie are now covered by crops or other introduced and now naturalized species such as *Bothriochloa ischaemum* (King Ranch bluestem), *Cynodon dactylon* (Bermuda grass), and *Sorghum halepense* (Johnson grass). Roadsides and pastures are particularly obvious examples; in many cases hardly any native grasses can be found. In these areas there has also been an accompanying dramatic reduction in native forb diversity.

In striking contrast to the terrestrial communities of the Blackland Prairie is the tremendous increase in aquatic habitats. Most native wetlands, including prairie “pothole-like” wetlands, have been lost. However, with the construction of numerous reservoirs, lakes, ponds, and tanks, there is vastly more habitat for aquatic vegetation than in presettlement days. With the exception of oxbow lakes along some of the larger streams, the only permanent surface water prior to human intervention was in rivers, streams, swampy or marshy areas, beaver ponds, and springs. Introduced, as well as native, aquatic plants are now widespread and in some cases so abundant as to be problematic weeds. Many aquatic plants probably have populations several orders of magnitude greater than in the relatively recent past. This same pattern holds not just for the Blackland Prairie, but for all vegetational areas within North Central Texas.

CROSS TIMBERS AND PRAIRIES

OCCURRENCE OF THE CROSS TIMBERS AND PRAIRIES

The Cross Timbers and Prairies (vegetational area 5 of Hatch et al. 1990), an area of about 26,000 square miles (about the size of West Virginia), occupies the region south of the Red River between the Blackland Prairie to the east, the Rolling Plains to the west, and the Llano Basin (Central Mineral Region) and Edwards Plateau to the southwest and south. Vegetationally it is quite diverse and includes the East and West cross timbers, the Fort Worth Prairie, and the Lampasas Cut Plain (Fig. 1). Notable physiographic features included are the Comanche Plateau, the Palo Pinto Country (sometimes referred to as the Palo Pinto Mountains), the mesa and butte country of the Lampasas Cut Plain, and the eastern portion of the Callahan Divide (Fig. 8).

The Cross Timbers, which stretch from Texas north through Oklahoma to Kansas (Marriott 1943; Dyksterhuis 1948; Kuchler 1974), are found in Texas from the Red River south for about 150 miles. They are actually two discrete belts of forest divided by the enclosed Grand Prairie (Dyksterhuis 1948). Surrounded by prairie on both sides (Blackland Prairie to the east, Rolling Plains to the west), they represent a final disjunct western extension of woody components of the eastern deciduous forest before the vegetation changes into the vast expanse of central U.S. grasslands known as the Great Plains. The two separate belts are the East Cross Timbers and the West Cross Timbers, sometimes referred to as the Lower Cross Timbers and Upper Cross Timbers respectively. According to Hill (1887), these names developed because the West or Upper Cross Timbers is at a greater altitude and in a more upstream position relative to the flow of rivers in the area. The East Cross Timbers is a narrow strip (roughly along the 97th meridian) extending from the Red River, in eastern Cooke and western Grayson counties, south to near Waco where it merges with the riverine forests of the Brazos River (Hayward & Yelder 1991). This southernmost portion of the East Cross Timbers, developed on the sandy terraces of the Brazos River, is sometimes referred to as the “false” East Cross Timbers to distinguish it from the upland or “true” East Cross Timbers farther north. The two areas are continuous but can be distinguished by topography—flat on the river terraces and gently rolling in the uplands (Hayward et al. 1992). The somewhat wider West Cross Timbers stretches west from the Grand Prairie to the beginning of the Rolling Plains and includes the rather rugged Palo Pinto Country (in Eastland, Jack, Palo Pinto, Stephens, and Young counties).

The Fort Worth Prairie portion of the Grand Prairie extends as a continuous body of open grasslands, roughly 10 to 30 miles wide, from near the Red River in the north, south about 110 miles to where it ends in the wooded area along the Brazos River near the Johnson County-Hill County line (Dyksterhuis 1946) (Fig. 1).

The Lampasas Cut Plain, the largest portion of the Grand Prairie, is highly dissected butte and mesa country with extensive lowlands, and can in some ways be considered a northern extension of the Texas Hill Country and Edwards Plateau. It has strong geologic and floristic links with the Edwards Plateau as discussed in the sections below on the geology of the Grand Prairie and the vegetation of the Lampasas Cut Plain. It is, in fact, considered a part of the Edwards Plateau by some authorities (e.g., Riskind & Diamond 1988). The Lampasas Cut Plain extends from the Fort Worth Prairie south and west to the Llano Basin (also called the Central Mineral Region or Burnet Country) and the Colorado River (Figs. 1, 8).

PRESETTLEMENT AND EARLY SETTLEMENT CONDITIONS IN THE CROSS TIMBERS

As has been noted by historical geographer Richard Francaviglia, the natural and cultural histories of the Cross Timbers are inseparable, for human populations have had an impact on the region for thousands of years—first through the Native Americans' use of fire, then in the 19th century through the European Americans' agricultural and grazing practices, and more recently in the form of urbanization, suburbanization, and conservation activities (Francaviglia, forthcoming). Francaviglia notes that the Texas Cross Timbers has become what geographers call a "vernacular region" in the late 20th century, but that the term was used as early as the 1820s to characterize its distinctive vegetation. The exact origin of the term Cross Timbers is not known, but Dyksterhuis (1948) stated that the name

... presumably alludes either to the fact that this forest extends north and south across, rather than along, the major streams all of which flow eastward; or to the fact that early westward travelers who had left the main body of the great eastern forest and entered upon open prairie found it necessary to cross yet another body of forest before entering upon the grasslands that extended to the Rocky Mountains.

The abrupt appearance of the East Cross Timbers was quite striking for westbound travelers who had just crossed the extensive open Blackland Prairie. This conspicuous change in the vegetation served as a landmark recognized by almost all early travelers, was a principal marker on early maps (e.g., Holley 1836; Ikin 1941; Gregg 1844; Kendall 1845), and was discussed in many immigrant guides and early explorer accounts (e.g., Marryat 1843; Roemer 1849; Parker 1856). Kennedy (1841), based on accounts of local residents, wrote of the Cross Timbers [not distinguishing East and West],

This belt of timber varies in width from five to fifty miles. Between the Trinity and Red Rivers it is generally from five to nine miles wide, and is so remarkably straight and regular, that it appears to be a work of art. When viewed from the adjoining prairies on the east or west, it appears in the distance as an immense wall of woods stretching from south to north in a straight line, the extremities of which are lost in the horizon.

Regarding their use as a landmark, he further stated,

As might naturally be supposed, the Cross Timber forms the great landmark of the western prairies; and the Indians and hunters, when describing their routes across the country, in their various expeditions, refer to the Cross Timber, as the navigators of Europe refer to the meridian of Greenwich. If they wish to furnish a sketch of the route taken in any expedition, they first draw a line representing the Cross Timber, and another representing the route taken, intersecting the former.

Together with the west-east rivers such as the Red and farther south, the Trinity, they formed a kind of navigational grid in an otherwise rather featureless landscape (Phelan 1976). Parker (1856) noted that "the long stretches of prairie, although undulating, present no object so prominent as the belt of timber which bounds them." He further described the East Cross Timbers as

... a very singular growth. The one we had now entered is called the Lower Cross Timbers, and is about six miles wide. ... The timber is a short, stunted oak, not growing in a continuous forest, but interspersed with open glades, plateaus, and vistas of prairie scenery, which give a very picturesque and pleasing variety.

Marcy (1853, 1866), based on extensive travel in the area, said,

At six different points where I have passed through it [Cross Timbers], I have found it characterized by the same peculiarities; the trees, consisting principally of post-oak and black-jack, standing at such intervals that wagons can without difficulty pass between them in any direction. The soil is thin, sandy, and poorly watered.

This statement agrees with numerous early settler accounts (Dyksterhuis 1948). Other early references, however, such as that by Kendall (1845) with the Texan Santa Fe Expedition in 1841, referred to the Cross Timbers in places as “almost impenetrable” and “full of deep and almost impassable gullies.” Kendall (1845) further stated,

The ground was covered with a heavy undergrowth of briers and thorn-bushes, impenetrable even by mules, and these, with the black jacks and post oaks which thickly studded the broken surface, had to be cut away, their removal only showing, in bolder relief, the rough and jagged surface of the soil which had given them existence and nourishment.

Some other early travelers also considered the Cross Timbers difficult to cross and an obstacle to travel because of the vegetation and topography (Dyksterhuis 1948). Gregg (1844), for example, wrote of them as follows:

Most of the timber appears to be kept small by the continual inroads of the ‘burning prairies;’ for, being killed almost annually, it is constantly replaced by scions of undergrowth; so that it becomes more and more dense every reproduction. In some places, however, the oaks are of considerable size, and able to withstand the conflagrations. The underwood is so matted in many places with grape-vines, green-briars, etc., as to form almost impenetrable ‘roughs’...

Another example is Smythe (1852), who referred to the “Lower Cross Timbers” as

... chiefly low scrubby Post Oak groves, extremely tangled and thick, with millions of green briers, ... making it truly a difficult task to make your way without serious damage to your skin, and clothes.

Marryat (1843) described the Cross Timbers in similar fashion:

During two or three days we followed the edge of the wood, every attempt to penetrate into the interior proving quite useless, so thick were the bushes and thorny briers.

The Cross Timbers vegetation at the time of contact by Europeans thus probably exhibited considerable variation. The boundaries in particular were probably variable and at least in places were not completely distinct. Parker (1856) described the area just west of the East Cross Timbers but east of what he referred to as the Grand Prairie (east of Gainesville in Cooke County) as follows:

... soon leaving the timber, we entered upon a broken country, consisting of ridges of sand and limestone, interspersed with small prairies and small strips of timber, principally black jack, until we emerged upon and crossed Elm Fork of the Trinity, where, on account of the intense heat, Captain Marcy determined to halt and encamp, thereafter, intending to march by moonlight, until we reached the Grand Prairie.

The variable nature of the Cross Timbers is also reflected in the following description from Kendall (1845):

The growth of timber is principally small, gnarled, post oaks and black jacks, and in many places the traveller will find an almost impenetrable undergrowth of brier and other thorny bushes. Here and there he will also find a small valley where timber is large and the land rich and fertile, and occasionally a small prairie intervenes; but the general face of the country is broken and hilly, and the soil thin.

In at least some areas the timber was extensive. An example is Jordan’s (1973) assertion that Forestburg, a small community in southeastern Montague County, boasted six sawmills by 1895.

The animal life of the Cross Timbers was probably similar to that described earlier for the Blackland Prairie. Because of the lower human population size and more native vegetation, slightly more animal life probably survives in the Cross Timbers. A recent (spring 1996) mountain lion sighting in Lake Mineral Wells State Park is an example.

GEOLOGY OF THE EAST CROSS TIMBERS

The narrow band of woody vegetation between the Blackland Prairie and the Grand Prairie, known as the East Cross Timbers, occurs largely on sandy soil derived from rocks of the Woodbine formation (Hill 1901), which were deposited about 96 to 92 million years ago (Hayward & Yelderman 1991). According to Hill (1901), the formation is "largely made up of ferruginous [iron containing], argillaceous sands, characterized by intense brownish discoloration in places, which are accompanied by bituminous laminated clays." Like the Trinity Group sands underlying the West Cross Timbers, the Woodbine sands are often unconsolidated and rather loose, but differ in having more iron and other minerals. The post oak-blackjack oak vegetation typical of the East Cross Timbers does well on the deep loose soils developed from these unconsolidated layers. In some instances, however, the iron minerals consolidate the sand layers into dark-brown siliceous iron ore (Hill 1901). These iron deposits are so abundant in places that they cap low, wooded, erosion-resistant hills and isolated knobs known as "iron-ore knobs." These are found from Hill County north through Johnson, Tarrant, Denton, and Cooke counties and east into Grayson County (Hill 1901) where the Woodbine formation swings east along the Preston Anticline (a buckle in the strata exposing deeper older layers). The bed of the Red River follows the outcrop of the Woodbine from Grayson County east along the northern boundary of North Central Texas all the way to Red River County in far northeastern Texas (Hill 1901). In general, the Woodbine formation forms a layer of loose brownish sand cropping out just west of the Eagle Ford Shale. Economically the Woodbine is important because its sands contain significant amounts of water and it serves as one of the main aquifers for some areas (Baker 1960).

GEOLOGY OF THE WEST CROSS TIMBERS

In general, west of the Fort Worth Prairie and north of the Lampasas Cut Plain lies an area of easily erodible sandy soils developed from the Trinity Group (Paluxy, Antlers, and Twin Mountain-Travis Peak sands), the oldest of the Cretaceous layers in North Central Texas (Hill 1901; Renfro et al. 1973). These sands, which represent shallow-water or near-shore sea deposits, are fine grained and so loose that they are "...readily cut with pick and spade." They are therefore locally known as "pack-sands" (Hill 1901). The West Cross Timbers has developed in part on the sandy soils derived from such strata. These permeable layers are also important as a source of ground water (Baker 1960), which is still used today by many North Central Texas communities. Because of the rather irregular pattern of outcropping and numerous remnant areas of these sands (Hill 1901), the West Cross Timbers is not an easily delineated region. Further, the sedimentary layers from which the soils of the West Cross Timbers formed are not homogeneous; instead these mainly sandy strata have substantial sections of clay and sandy clay. Therefore, numerous glade-like prairies formed on soils derived from these clayey outcrops can be found scattered through this mostly timbered region (Hayward et al. 1992). The area is further complicated by topographic extensions of the Lampasas Cut Plain that extend north into the West Cross Timbers in areas including Erath and Hood counties. Comanche Peak, a noted landmark in Hood County (Hill 1901), is a good example of such an extension.

North of the easternmost part of the Callahan Divide mesa country, and forming the northwestern portion of the West Cross Timbers, is an area known as the Palo Pinto Country (Fig. 8). This rather rugged region is underlain by the oldest rocks exposed in North Central Texas, deposited during the Pennsylvanian Period (Fig. 7) (the Pennsylvanian extends from 320 to 286 million years ago). According to Hill (1901) the Pennsylvanian (Carboniferous in his terminology) is

... largely made up of soft, impure shales alternating with harder, coarse, brown sandstone and conglomerates, produces ridge-like mountains and a broken belt of country ... composed of rough-scarped and flat-topped sandstone plains and hills of circumdenudation, surrounded by and overlooking wide clay valleys called 'flats.'

The area is deeply dissected and is essentially a cut plain marked by scarps, mesas, and canyons with flat areas of extensive beds of shale outcrop (Hill 1901). The same strata, and consequently landscapes of similar character, extend south of the Callahan Divide and form the Brownwood Country (parts of Brown, Coleman, and Mills counties) (Hill 1901; Renfro et al. 1973).

VEGETATION OF THE CROSS TIMBERS

The East and West cross timbers, with their woody overstory consisting primarily of post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*), owe their existence to the presence of sandy, slightly acidic soils derived from the Cretaceous Woodbine and Trinity strata (and in the westernmost area to gravelly and rocky Pennsylvanian strata). These soils allow more efficient water infiltration, permit easier penetration of tree roots, and provide more moisture to plants than do heavier clay soils (Allred & Mitchell 1955). The result is that the survival of trees is favored in these areas even though they receive less rainfall than the Blackland Prairie farther east. Hill (1887) first pointed out that the Cross Timbers were developed on sandy soils, and contrasted this vegetation with the adjacent treeless prairies growing on the tight calcareous clay soils developed from limestones.

The original vegetation of both the East and West cross timbers, as based on early accounts (discussed in the section on presettlement conditions), was almost certainly variable, ranging from quite open to dense thickets. However, based on these accounts and on an extensive vegetational study of the West Cross Timbers by Dyksterhuis (1948), presettlement vegetation can probably best be described as a savannah with an oak overstory, but dominated by *Schizachyrium scoparius* (little bluestem), with two other grasses, *Andropogon gerardii* (big bluestem), and *Sorghastrum nutans* (Indian grass), as lesser dominants. Weaver and Clements (1938) also regarded the Cross Timbers as "... chiefly oak savanna, in which the grasses are climax dominants." Dyksterhuis (1948) concluded that the current vegetation, even where not cleared for cultivation or pasture, is considerably modified from that present before settlement. He considered the existing understory vegetation a disclimax resulting mainly from overgrazing.

At present, in many Cross Timbers localities, younger trees are often branched to the ground, making movement through the vegetation extremely difficult and denying habitat for the originally dominant grasses; dense cedar brakes are particularly problematic in this regard. Fire suppression, apparently the chief cause of such changes, has thus probably been another major factor responsible for differences from the original vegetation.

Currently, where not completely destroyed, the vegetation ranges from open savannah to dense brush (Correll & Johnston 1970). In addition to the characteristic oaks, other woody species commonly found in the Cross Timbers today include *Ulmus crassifolia* (cedar elm), *Celtis* spp. (hackberry), *Carya illinoensis* (pecan), *Juniperus* spp. (juniper), and *Prosopis glandulosa* (mesquite). Additional common grasses include *Bouteloua hirsuta* (hairy grama), *Bouteloua curtipendula* (side-oats grama), *Sporobolus compositus* (tall dropseed), *Panicum virgatum* (switch grass), *Elymus canadensis* (Canada wild-rye), and *Nassella leucotrica* (Texas winter grass) (Dyksterhuis 1948; Correll & Johnston 1970). Past mismanagement and cultivation have caused many uplands to be covered primarily by scrub oak, mesquite, and juniper with mid- and short-grasses beneath (Hatch et al. 1990).

As the early accounts mentioned above indicate, even in presettlement days the Cross Timbers were probably not continuous unbroken areas of woodland. In the East Cross Timbers some clay is found in the Woodbine formation, and where this clay crops out small prairies are found (Hill 1901). The West Cross Timbers in particular represents a complex pattern of timbered areas interspersed with grasslands or with grassland inclusions (Dyksterhuis 1948).

Dyksterhuis (1948) distinguished two areas of woody vegetation within the West Cross Timbers, the “main belt” (developed on sandy Cretaceous strata), and the “fringe” (developed on rocky or gravelly Pennsylvanian strata in the topographically more rugged Palo Pinto Country). The two areas share the same woody species, but differ in other aspects of their vegetation. For instance, Dyksterhuis (1948) found that *Buchloe dactyloides* (buffalo grass), an important dominant of the drier western plains, was four times as abundant in the fringe as in the main belt. A variety of other plants are more common in one area than the other. Examples include *Bouteloua gracilis* (blue grama) being more frequent in the fringe, with *Bouteloua hirsuta* (hairy grama) more common in the main belt (Dyksterhuis 1948). In the fringe in particular, woody vegetation tends to occupy areas of rugged relief with grasses dominating areas of gentler relief (Dyksterhuis 1948).

Tharp (1926) considered the Cross Timbers to be part of the Oak-hickory Association, and as such, part of the eastern deciduous forest. Allred and Mitchell (1955), however, in their broad classification of Texas vegetation, considered the Cross Timbers and even the eastern Texas Post Oak belt to be Post Oak Savannas that are part of the True Prairie Association. They supported this contention by pointing out that the grasses of the True Prairie are important components in the vegetation of the savannas. Dyksterhuis (1948), as pointed out above, indicated that little bluestem was the primary dominant. Barbour and Christensen (1993) stated that in the southern part of the tall grass prairie-deciduous forest boundary [including Texas], the ecotone is an oak savanna 50–100 km wide. Clearly, whether classified as forest or grassland, the Cross Timbers are part of this ecotone. With their rather limited tree diversity and high grass diversity and dominance, they are intermediate vegetationally, as well as geographically, between the eastern deciduous forests and the western grasslands.

One of the most striking features of the Cross Timbers is that this vegetational area contains significant remnants of virgin forests (Stahle & Hehr 1984; Stahle et al. 1985). According to Stahle (1996a), “... literally thousands of ancient post oak-blackjack oak forests still enhance the landscapes and biodiversity of ... the Cross Timbers along the eastern margin of the southern Great Plains...” As a result, this is one of the largest relatively unaltered forest vegetation types in the eastern United States (Stahle & Hehr 1984). The small stature and often poor growth form of post and blackjack oaks made these species commercially unattractive and therefore less subject to systematic logging than other more productive forest types. Extensive dendrochronological (tree-ring) data from post oaks in the Cross Timbers indicate that old-growth remnants of post oak-blackjack forest can be found in numerous localities throughout the region. However, while extensive remnants remain, they are often degraded by various human activities such as heavy grazing or selective cutting and their authenticity is rarely noticed or protected (Stahle & Hehr 1984; Stahle 1996a). In comparison with areas in Oklahoma, the Cross Timbers of Texas are more degraded, in part because of the longer history of settlement (D. Stahle, pers. comm.). Examples of old-growth forests in North Central Texas are found in Comanche County (Leon River), Tarrant County (Fort Worth Nature Center), and Throckmorton County (Nichols Ranch) (Stahle et al. 1985; Stahle 1996a). Tree-ring chronologies extending from about 200 to 300 years have been obtained from these North Central Texas sites, with individual trees dating back to 1681. Such data are readily and harmlessly secured by using a Swedish increment borer to obtain a small diameter (<1 mm) core from the bark to the center of a tree; after careful polishing and under magnification, the annual growth rings can be counted (Stahle et al. 1985; 1996b). Because of the low availability of moisture, rocky or infertile soil, and other factors, the trees of these relict forests, while old, have a slow rate of growth and are of relatively small size, the canopy ranging from only about 6 to 15 meters high (Stahle et al. 1985). Such old-growth forests or ancient individual trees can often be located by environmental factors such as steep, rocky, infertile soils or by the appearance of the individual trees (Stahle & Chaney 1994). Twisted stems, dead tops and branches, canopies restricted to a few heavy limbs, branch stubs, fire and lightning scars, leaning stems, exposed roots or root collars, and hollow voids are all hints of significant age (Stahle 1996a, 1996b) (Fig. 20).

The centuries-long tree-ring chronologies obtained from these relict forests are a valuable source of information about past climate and are particularly important at a time when climate change is a topic of national and global concern. These forests also represent an irreplaceable resource and an unparalleled living record about the North Central Texas area prior to the time of European settlement. Further, because they are relatively unaltered, these remnants may represent areas of significant remaining biodiversity in an otherwise highly altered and reduced diversity environment. Finally, they provide a unique conservation opportunity to preserve some of the last remaining virgin North American forests.

PRESETTLEMENT AND EARLY SETTLEMENT CONDITIONS IN THE GRAND PRAIRIE (FORT WORTH PRAIRIE AND LAMPASAS CUT PLAIN)

Like the Blackland Prairie, the presettlement Grand Prairie was largely a vast grassland, with woody vegetation generally limited to areas along the larger watercourses, as scattered mottes on hilltops, or associated with mesas and buttes. Hill (1887) summarized the Grand Prairie as “a prairie region, utterly destitute of timber” and Kendall (1845) described the area as follows:

To the east, for miles, the prairie gently sloped, hardly presenting a bush to relieve the eye. In the distance, the green skirting of woods, which fringed either border of a large stream, softened down the view. . . . To the west . . . the immediate vicinity was even more desolate, but the fertile bottoms of the Brazos, with their luxuriant growth of timber, were still visible, and the Camanche [Comanche] Peak, rising high above the other hills, gave grandeur and sublimity to a scene which would otherwise have been far from monotonous.

Referring to another Grand Prairie locality, Kendall (1845) said, “As far as the eye could reach . . ., nothing could be seen but a succession of smooth, gently-undulating prairies.” In reference to the Brazos River valley where it cuts through the Lampasas Cut Plain, Kendall (1845) said,

The valley of the Brazos at this place abounded with every species of timber known in Texas; grapes, plums, and other fruit were found in profusion; honey could be obtained in almost every hollow tree; trout and other fish were plentiful in the small creeks in the neighborhood, and the woods and prairies about us not only afforded excellent grazing for our cattle and horses, but teemed with every species of game—elk, deer, bears, wild turkeys, and, at the proper season, buffalo and mustang.

Greer (1935), in describing the Grand Prairie in the period 1850–1890, wrote of an “...indescribably beautiful prairie where lush grass swept my mount’s sides. . . .” An early settler account (Hattie Richards Sparks in Pool 1964) of Bosque County describes it as follows:

It was a beautiful prairie country, with sage grass as tall as your head. . . . It was a common occurrence for prairie chickens to fly into the house. I shall never forget when one flew in during our noonday meal and lit in a bowl of soft butter. . . . Wolves were plentiful and I will always remember their howling around our house at night. It was a mournful sound in that open prairie country.

Hill (1887) described this region between the two bands of Cross Timbers as “utterly destitute of timber.” However, while Smythe (1852) mentioned “immense fields, with the greatest profusion of delicately painted flowers” and “grassy prairies only bounded by the horizon,” he also spoke of “prairie, with an occasional strip of woodland,” “beautiful groves of Live Oak . . . crowning every hill . . .,” and areas with “densely tangled cedar ravines.” The Grand Prairie vegetation thus showed considerable variability.

Based on the similarity of vegetation and climate, and on early traveler and settler reports, the original animal life was probably quite similar to that of the Blackland Prairie described earlier. From Kendall’s (1845) observations, bison were apparently particularly common:

... I have stood upon a high roll of the prairie, with neither tree nor bush to obstruct the vision in any direction, and seen these animals grazing upon the plain and darkening it at every point. . . . In the distance, as far as the eye could reach, they were seen quietly feeding upon the short prairie grass. . . .



Fig. 20/AN ANCIENT *QUERCUS STELLATA* FOREST DRAWN BY RICHARD P. GUYETTE; USED WITH PERMISSION. TWISTED STEMS, DEAD TOPS AND BRANCHES, CANOPIES RESTRICTED TO A FEW HEAVY LIMBS, BRANCH STUBS, FIRE AND LIGHTNING SCARS, LEANING STEMS, EXPOSED ROOTS OR ROOT COLLARS, AND HOLLOW VOIDS ARE ALL HINTS OF SIGNIFICANT AGE (STAHLE 1996A, 1996B). WHILE THE DRAWING IS FROM THE OZARK PLATEAU, SUCH TREES, SOME OF WHICH ARE MORE THAN 300 YEARS OLD, CAN BE FOUND IN NORTH CENTRAL TEXAS.

Kendall (1845) also described seeing many pronghorn antelope on the Upper Brazos. There is even a record of the American alligator as far west as Hamilton County in the central part of the Lampasas Cut Plain (Dixon 1987). Other noteworthy species recorded from the Grand Prairie, but not present there for many decades, include jaguar (Bailey 1905), greater prairie chicken, and passenger pigeon (Oberholser 1974).

In some areas animal populations were apparently reduced early on. Kendall (1845), speaking of another part of the Grand Prairie, said,

Occasionally a deer would jump suddenly from his noonday rest, and scamper off across the prairie, but other than this no game was seen. The few deer we saw were exceedingly wild, from the fact of there being so many Indians in the vicinity; while the buffalo had evidently all been driven to the south.

Native American influence had thus in some areas already modified the fauna, and probably the vegetation as well. Roemer (1849), for example, discussed a Caddo village near the Hill County-Bosque County line as having about one thousand horses and cultivated maize and watermelons.

As with the Blackland Prairie, fire was an important aspect of the presettlement Grand Prairie. Kendall (1845), for example, observed an extensive fire and commented,

All night the long and bright line of fire, which was sweeping across the prairie to our left, was plainly seen, and the next morning it was climbing the narrow chain of low hills which divided the prairie from the bottoms of the Brazos.

Settlement, basically the conversion of the prairie to ranching, swept across the Grand Prairie in the relatively short time span of 1850–1860. The importance of ranching and cattle to early Texas is also reflected in the fact that the famous Chisholm and Shawnee cattle trails crossed the Grand Prairie in the 1860s to the 1880s. The general availability of barbed wire in the 1870s and 1880s and subsequent droughts resulted in overstocking and severe overgrazing and thus had a significant detrimental effect on the vegetation (Dyksterhuis 1946). The result of these changes can be seen today in the wide variability of range quality in the area of Grand Prairie still devoted to grazing.

GEOLOGY OF THE GRAND PRAIRIE (FORT WORTH PRAIRIE AND LAMPASAS CUT PLAIN)

The following excellent description of the Grand Prairie is from Hill (1901):

Although often confounded with the Black Prairie, the Grand Prairie differs from it in many minor physical features. In general the surfaces are flat rather than undulating, and the valley slopes are angular (scarped or terraced) rather than rounded. The residual soils and regolith are shallow in comparison with those of the Black Prairie belts, and are of chocolate or brown colors instead of black, although in at least one belt (the Del Rio) the latter color prevails. Owing to the more shallow soil and the decreased rainfall many of the upland areas of the western part of the Grand Prairie are not so well adapted to agriculture, other than grazing, as are those of the Black Prairie, but the valley lands are very fertile and are extensively utilized.

The chief difference between the two regions is that the Grand Prairie is established upon firm, persistent bands of limestones, which are harder than the underlying clay substructure of the Black Prairie region, and which under erosion, result in more extensive stratum plains and more angular cliffs and slopes. These limestone sheets of the Grand Prairie belts also alternate with marls and chalky strata of varying degrees of induration and thickness, and at the base of the whole are unconsolidated sands. The rock sheets of the Grand Prairie are so much harder than those underlying the Black Prairie region and are so conspicuous features in the landscape that, in distinction, the Grand Prairie country has been appropriately called ‘the hard lime rock region’.

In general the surface of the Grand Prairie, especially north of the Brazos [Fort Worth Prairie], is composed of gently sloping, almost level, and usually treeless dip plains, broken only by the valleys of the transecting drainage. These prairies are more continuous and comparatively void of inequalities of erosion along the eastern portion of the area. In the western half, especially south of the Brazos [Lampasas Cut Plain], their surfaces are broken into cut plains, buttes, mesas, and flat-topped divides and are etched by deeply eroded valleys.

The overall character of the Fort Worth Prairie and Lampasas Cut Plain (Figs. 1, 8) is influenced by such factors as the hardness and slope of the underlying Lower Cretaceous rock layers (Hill 1901). Specific layers cropping out at the surface, from oldest to youngest, include the Twin Mountains-Travis Peak, Antlers, Glen Rose, Paluxy, Walnut, Comanche Peak, Edwards, Kiamichi, Duck Creek, Fort Worth, Denton, Weno, Pawpaw, Mainstreet, and Grayson (Sellards et al. 1932; Renfro et al. 1973). The oldest of these date from the early Cretaceous (which began 145 million years ago), while the youngest, the Grayson, dates from as recently as 98 million years ago (Hayward & Yelderman 1991). Many of these strata include resistant limestone which contributes to the character of what Hill (1901) called the “hard lime rock region.” In particular, the Fort Worth Prairie is mostly underlain by layers of firm limestone sloping gently eastward. As one moves from the west to the east, sequentially younger layers are encountered. In general the older western layers disappear under low west-facing escarpments produced by the strata of the next,

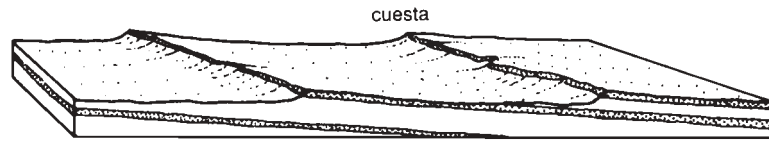


Fig. 21/DIAGRAM OF CUESTA TOPOGRAPHY (MODIFIED FROM SPEARING 1991; USED WITH PERMISSION OF MOUNTAIN PRESS PUBLISHING CO.; ©1991). A CUESTA IS A HILL OR RISE WITH A GENTLE SLOPE ON ONE SIDE AND A STEEP SLOPE, BLUFF, OR ESCARPMENT ON THE OTHER. IT RESULTS FROM AN INCLINED ROCK LAYER RESISTANT TO EROSION OUTCROPPING ADJACENT TO A LESS RESISTANT LAYER. THE STEEP SIDE IS THE END OF THE GENTLY DIPPING OR INCLINED RESISTANT LAYER. THE LESS RESISTANT ADJACENT LAYER ERODES MORE RAPIDLY EXPOSING THE END OF THE HARDER LAYER. IN NORTH CENTRAL TEXAS THE BLUFFS—OF AUSTIN CHALK IN THE BLACKLAND PRAIRIE OR OF VARIOUS LAYERS IN THE GRAND PRAIRIE—FACE WEST.

younger, overlying layer to the east (Hill 1901). It is the exposed ends of the younger layers that form the escarpments and produce the “cuesta” type of topography (Fig. 21) for which the Fort Worth Prairie is known. The Fort Worth Prairie occurs roughly from the Brazos River (northern Hill County) north through Johnson, Tarrant, Denton, and Cooke counties. The area is characterized in large part by gently sloping flat surfaces with thin soil over resistant limestone, extending for miles and “. . . making grass-covered uplands resembling the boundless views of the Great Plains proper” (Hill 1901). Fort Worth itself is built on one of these relatively hard, nearly flat layers, the Fort Worth Limestone.

To the south and southwest these rather flat plains grade into a more rugged, scarped, and dissected area with numerous low buttes and mesas known as the Lampasas Cut Plain (Hill 1901) (Fig. 22). Hill (1901) considered this region to be a modified northern extension of the Edwards Plateau. The term cut plain (or dissected plain) is defined by Hill (1901) as a plain that has been so dissected into remnants by erosion that the level of the original stratum is still recognizable in the summits of the dissected members. The Lampasas Cut Plain is a good example of this type of topography. The eastern portion of the Lampasas Cut Plain, sometimes referred to as the Washita Prairie, is a rolling landscape representing a remnant of the original surface, most of which eventually eroded away to form the highly dissected main portion of the Lampasas Cut Plain to the west (Hayward et al. 1992). This eastern undissected area, while somewhat different topographically, is thus clearly related to the rest of the Lampasas Cut Plain.

The landscape of the main portion of the Lampasas Cut Plain consists of broad grassland valleys that are separated by higher, narrow, often wooded, mesa-like divides (Hayward et al. 1992). These topographic features give the Lampasas Cut Plain a striking and distinctive appearance. The divides have been so eroded that in many places they remain only as flat-topped hills or buttes, often isolated or sometimes in chains. This type of topography can be seen in Bell, Bosque, Comanche, Coryell, Hamilton, Lampasas, Mills, and Williamson counties (Hill 1901); it owes its existence to the hard, white Edwards limestone, the same layer that forms the Edwards Plateau



Fig. 22/DRAWING OF SUMMITS OF THE LAMPASAS CUT PLAIN, LAMPASAS COUNTY (FROM HILL 1901).

(Hill 1901). In the Lampasas Cut Plain, however, much more of this layer has eroded away, the original surface remaining only as caps on the tops of the relatively few buttes and mesas. Figure 23 is a cross-sectional diagram of such an area. In fact, even though these uplands are the defining feature in the overall appearance of the region, less than ten percent of the area referred to as Lampasas Cut Plain is actually represented by these distinctive flat-topped features (Hayward et al. 1992). The majority of the area is made up of broad sloping valleys between the isolated upland fragments (Hill 1901). Most of the valley floors are formed from the Walnut Clay (Hayward et al. 1992) and the soils derived from this layer supported the original grassland vegetation typical of these valleys. On some of the valley floors, primarily in western portions of the Lampasas Cut Plain, the overlying material has been stripped away to expose the underlying Glen Rose Limestone; in these instances a rockier Glen Rose Prairie developed (Hayward et al. 1992). Often the slopes above the valleys are terraced or benched as the result of differential erosion of the various outcropping layers (Hill 1901).

In some places at the western edge of the Lampasas Cut Plain there is a conspicuous escarpment; this represents the edge of the Edwards limestone. To the south, this layer is less dissected and continues as the surface of that famous physiographic feature of central and western Texas, the Edwards Plateau. Also, some isolated fragments of Edwards limestone extend west through the West Cross Timbers into the Rolling Plains. These fragments cap scattered buttes and mesas in the region known as the Callahan Divide in counties including Brown, Callahan, Coleman, Comanche, and Eastland (Hill 1901) (Fig. 8). The erosion-resistant Edwards limestone, with its tendency to cap and protect more erosion-prone layers, has thus had a major effect on the appearance of large areas of Texas.

At the southern edge of the Lampasas Cut Plain near its boundary with the Blackland Prairie in Bell and Williamson counties, the subsurface geology is particularly important economically. The Edwards Aquifer, the main water source for 1.5 million people in central Texas, extends along the Balcones Fault Zone north to this region. The aquifer, which provides habitat for a number of threatened and endangered species, occurs in the porous Cretaceous layers overlying the Glen Rose Limestone. From the southern part of North Central Texas, the aquifer stretches south to the San Antonio area and west across the Edwards Plateau (Longley 1996). The maintenance of this aquifer is critical not only for the continued existence of a number of plants and animals, but also for the economy of central Texas.

VEGETATION OF THE FORT WORTH PRAIRIE

Based on early accounts as described in the section on presettlement conditions, and on a study of relict climax vegetation by Dyksterhuis (1946), a reasonable picture of the original vegetation of the Fort Worth Prairie can be gained. The most striking fact was the absence of trees. In Dyksterhuis' (1946) study of relict areas, *Schizachyrium scoparius* (little bluestem) was the overwhelming dominant, constituting nearly two-thirds of the total plant cover. Second in importance was *Bouteloua curtipendula* (side-oats grama), with other significant species including *Sorghastrum nutans* (Indian grass), *Sporobolus compositus* (tall dropseed), *Bouteloua hirsuta* (hairy grama), and *Andropogon gerardii* (big bluestem). Diamond and Smeins (1993) considered the Fort Worth Prairie to be part of the *Schizachyrium-Andropogon-Sorghastrum* (little bluestem-big bluestem-Indian grass) community, the same tall grass community type found on the shallow soils of the Austin Chalk outcrop in the Blackland Prairie. While the specific underlying strata differ, much of the Fort Worth Prairie, part of Hill's (1901) "hard lime rock region," is also developed on shallow limestone soils. *Nassella leucotricha* (Texas winter grass) and *Bothriochloa laguroides* subsp. *torreyana* (silver bluestem) [referred to by Dyksterhuis as *Andropogon saccharoides*], species that Dyksterhuis (1946) found to be most abundant in his broad study of the present-day grazing disclimax vegetation, were of almost negligible importance in the relatively undisturbed relicts. The major biotic influence on current vegetation is livestock grazing pressure (Dyksterhuis 1946). In comparison with the Blackland Prairie, much more of the original vegetation of the

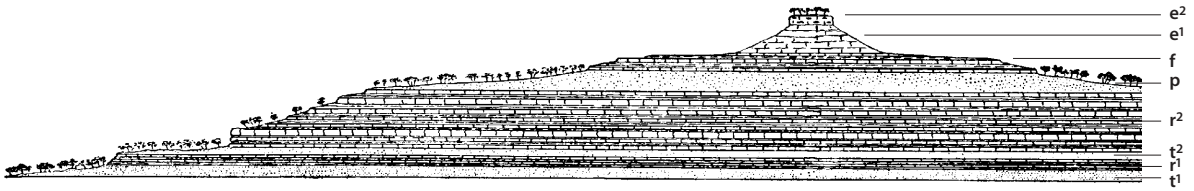


FIG. 23/DIAGRAM OF A DIVIDE OF THE LAMPASAS CUT PLAIN (FROM HILL 1901).

"Diagrammatic representation of a divide of the Lampasas Cut Plain, showing relation of agriculture, forestry, topography, and underground water to the geology. **e²**, Caprina limestone; summit divide of Lampasas Cut Plain; soilless except in large areas; growth of scrub oak, live oak, and post oak. **e¹**, Comanche Peak limestone; chalky, soilless slopes; growth of shin oak. **f**, Walnut formation, Walnut Prairie; rich, fertile land in many places. **p**, Paluxy sand; Eastern and Western Cross Timbers, forested with post oak and black-jack; fair cotton and good fruit land; water bearing. **r²**, Barren limestone slopes with growth of juniper, live oak, and sumac; occasional fertile soils from interbedded marly layers; water bearing. **t²**, Trinity sands; Western Cross timbers; same forest growth as p. **r¹**, small prairie spots; good soil. **t¹**, Trinity sands; Western Cross Timbers; same forest growth as p."

Fort Worth Prairie has survived, in large part due to the extensive areas of shallow untillable soils that are still used primarily for grazing. Fire suppression and the consequent invasion of woody species has also had an important impact on the vegetation of many areas of the Fort Worth Prairie.

VEGETATION OF THE LAMPASAS CUT PLAIN

The vegetation of the Lampasas Cut Plain is more variable than that of the other vegetational areas considered here because of its greater topographic diversity. Depending on the particular conditions present, the vegetation ranges from prairie similar to that found on the Fort Worth Prairie or even the Blackland Prairie, to post oak-blackjack oak woodland similar to the Cross Timbers, to vegetation resembling that of the Edwards Plateau. For example, the easternmost part of the Lampasas Cut Plain, sometimes referred to as the Washita Prairie, is a gently rolling landscape of prairie with scattered oaks on hilltops. This area is characterized in places by rather deep soils with tall grass prairie vegetation similar to the Blackland Prairie, and in other places by shallow soils over hard limestone, with vegetation more closely resembling that of the Fort Worth Prairie (Hayward et al. 1992). To the west, in the more typical butte and mesa country of the main part of the Lampasas Cut Plain, oaks, including *Quercus buckleyi* (Texas red oak), *Quercus fusiformis* (live oak), and *Quercus sinuata* var. *breviloba* (shin oak), may be found on the rocky Edwards limestone summits of the smaller divides. On the larger divides, areas of deeper soil remain and support westward extensions of the Washita Prairie (Hayward et al. 1992). On the chalky nearly soil-less slopes derived from the underlying Comanche Peak limestone, *Quercus sinuata* var. *breviloba* (shin oak), *Rhus* species (sumac), and *Juniperus* species (juniper) may be seen; these dry rocky areas have a distinctly desert-like microclimate (Hayward et al. 1992) and thus support plants with xerophytic adaptations. Below these slopes, on benches in valleys or on the summits of uplands lacking caprock, extensive areas of prairie can be found on the clay soils derived from the Walnut formation where it is exposed. The basal Trinity Group sands (Paluxy, Antlers, Twin Mountains-Travis Peak) underlying the Walnut formation develop Cross Timbers vegetation with *Quercus stellata* (post oak) and *Quercus marilandica* (blackjack oak) (Hill 1901). In parts of the western Lampasas Cut Plain, in areas where the overlying strata have been removed to expose the Glen Rose limestone (occurring between layers of the Trinity sands), short-grass prairie, oak-savannah, and woodlands with abundant junipers are found on the thin-soiled, rough, rocky, stair-stepped landscape (Hill 1901; Hayward et al. 1992).

The topographic diversity and deeply cut streams found in various parts of the Lampasas Cut Plain provide important microhabitat variation. In particular, the diverse microhabitats allow the northward extension of many species otherwise found primarily on the Edwards Plateau to the south and southwest. Plants traditionally considered Edwards Plateau endemics (e.g., Amos & Rowell 1988) but found in the Lampasas Cut Plain include *Acer grandidentatum* Nutt. var. *sinuosum* (Plateau big-tooth maple), *Agalinis edwardsiana* (Plateau gerardia), *Argythamnia aphoroides* (Hill Country wild mercury), *Astragalus wrightii* (Wright's milk-vetch), *Chamaesaracha edwardsiana* (Plateau false nightshade), *Clematis texensis* (scarlet clematis), *Garrya ovata* var. *lindheimeri* (Lindheimer's silktassel), *Matelea edwardsensis* (Plateau milkvine), *Muhlenbergia lindheimeri* (Lindheimer's muhly), *Nolina lindheimeriana* (devil's-shoestring), *Onosmodium helleri* (Heller's marbleseed), *Perityle lindheimeri* (Lindheimer's rock daisy), *Prunus serotina* var. *eximia* (escarpment blackcherry), *Styrax platanifolius* (sycamore-leaf styrax), *Pedimelum cypocalyx* (turnip-root scrufpea), *Tradescantia edwardsiana* (Plateau spiderwort), *Triodanis coloradoensis* (Colorado Venus'-looking-glass), *Verbesina lindheimeri* (Lindheimer's crownbeard), and *Yucca rupicola* (twisted-leaf yucca). When considering vegetation, soils, geologic layers, and general aspects of the landscape, some parts of the Lampasas Cut Plain (e.g., Fort Hood—Bell and Coryell cos; Meridian State Park—Bosque Co.; bluffs in southern Johnson Co. overlooking the Brazos River) are remarkably similar to the Edwards Plateau; in fact, it could be argued that the Lampasas Cut Plain is simply a northern extension of the Edwards Plateau. A number of plants widely known from the Edwards Plateau also occur not only in the Lampasas Cut Plain, but also in the topographically complex Palo Pinto Country to the north and northwest. Examples include a number of fern species unusual in North Central Texas such as *Astrolepis integerrima* (star-scaled cloak fern), *Cheilanthes eatonii* (Eaton's lip fern), *Cheilanthes feei* (slender lip fern), *Cheilanthes horridula* (rough lip fern), *Pellaea ovata* (cliff-brake), and *Pellaea wrightiana* (Wright's cliff-brake).

Currently in many places in the Lampasas Cut Plain, as well as in the Cross Timbers, junipers (*Juniperus* spp.) are a conspicuous component of the vegetation, often crowding out other native species. Because of the control of fire, overgrazing, and other human-caused changes, juniper has become much more common during the last century (Hayward et al. 1992). In fact, juniper is currently one of the most problematic species invading and eliminating native grassland. Fonteyn et al. (1988) emphasized fire suppression as causing a similar transformation from relatively open savannah to shrubland or woodland (in large part due to invasion by *Juniperus ashei*) on some parts of the Edwards plateau. Mesquite (*Prosopis glandulosa*), historically much less abundant than at present, shows the same pattern. Originally limited by fire, it has increased greatly in abundance as the result of fire suppression, overgrazing, and the plowing and other disturbances associated with agriculture (Hayward et al. 1992). In general, with the suppression of fire, woody vegetation is currently increasing at the expense of grassland throughout North Central Texas.

RED RIVER AREA

AREA ADJACENT TO THE RED RIVER

The narrow band of vegetation found on the primarily sandy soils adjacent to the Red River in the northeastern portion of North Central Texas, specifically in the northern parts of Lamar, Fannin, and Grayson counties, is quite different from the vegetation of the rest of North Central Texas. At least part of this band, which we refer to as the Red River Area (Fig. 1), is often classified as part of vegetational area 3 (Post Oak Savannah) (Correll & Johnston 1970; Hatch et al. 1990). Such a classification is justified because a significant component of the vegetation more typically associated with eastern or southeastern Texas extends west along the Red River in microhabitats with special soil or moisture conditions. Even components of vegetational area 1 (Pineywoods), characteristic of extreme eastern Texas, can be found in this area. In northern Lamar County, the aspect of the vegetation is definitely similar to the eastern deciduous forest. Tall stands of *Quercus*

falcata (southern red oak), abundant *Liquidambar styraciflua* (sweetgum), *Pinus taeda* (loblolly pine), *Acer rubrum* (red maple), *Betula nigra* (river birch), *Carpinus caroliniana* (American hornbeam), *Crataegus marshallii* (parsley hawthorn), bottomland brakes of *Arundinaria gigantea* (giant cane), *Calyocarpum lyonii* (cupseed), *Osmunda cinnamomea* (cinnamon fern), *Trichospermum difforme* (climbing dogbane), and herbs such as *Lysimachia lanceolata* (lance-leaf loosestrife), *Monotropa hypopithys* (American pinesap), *Polygala sanguinea* (blood milkwort), *Porteranthus stipulatus* (Indian-physic), *Saccharum contortum* (bent-awn plume grass), *Sacciolepis striata* (American cupscale), *Saururus cernuus* (lizard's-tail), *Stachys tenuifolia* (slender-leaf betony), and *Veronicastrum virginicum* (culver's-physic), are just a few examples of eastern plants found in Lamar County. Even farther west in Fannin County, there are still isolated pockets of eastern Texas vegetation (e.g., Talbot property). Species reaching their known western limits there include *Quercus falcata* (southern red oak), *Quercus nigra* (water oak), *Quercus phellos* (willow oak), *Nyssa sylvatica* (black-gum), *Sassafras albidum* (sassafras), *Chasmanthium laxum* var. *sessiliflorum* (narrow-leaf wood-oats), *Cirsium horridulum* (bull thistle), *Erechtites hieracifolia* (American burnweed), *Impatiens capensis* (spotted touch-me-not), *Luzula bulbosa* (bulb woodrush), *Monotropa uniflora* (Indian-pipe), *Pedicularis canadensis* (common lousewort), *Pycnanthemum albescent* (white-leaf mountain-mint), *Sorghastrum elliottii* (slender Indian grass), and *Woodwardia areolata* (narrow-leaved chain fern). Grayson County, the next county to the west, does not have areas dominated by eastern Texas plants as do Lamar and Fannin counties, but there is a significant eastern Texas component to the vegetation. Numerous plant species reach their western limits in Grayson County including *Agrimonia rostellata* (woodland groovebur), *Asimina triloba* (pawpaw), *Desmodium glutinosum* (tick-clover), *Liatris aspera* (tall gayfeather), *Monarda lindheimeri* (Lindheimer's beebalm), *Podophyllum peltatum* (may-apple), *Polygonatum biflorum* (Solomon's-seal), *Quercus velutina* (black oak), *Thalictrum arkansanum* (meadowrue), *Triosteum angustifolium* (yellow-flowered horse-gentian), and *Vaccinium arboreum* (farkleberry). A few typically eastern plants extend even farther west into Cooke and Montague counties and beyond.

The area adjacent to the Red River in Grayson County is further complicated by the presence of the Preston Anticline, a post-Cretaceous (Bradfield 1957) fold in the sedimentary strata that brought deeper layers to the surface (Bullard 1931). In places the river valley is two hundred feet below the surrounding area and creeks have cut deep canyon-like valleys. The overall topography near the Red River is thus very rugged (Bullard 1931). Parker (1856) in an early account described the Texas shore of the Red River as "very bold, presenting a stratification of red clay and white sand, giving a striking and very peculiar appearance in the distance, like chalk cliffs." This different topography and the appearance at the surface of deeper strata otherwise only found far to the west in areas such as the Grand Prairie and West Cross Timbers (e.g., Goodland limestone, Duck Creek limestone, Trinity Group sands) makes the vegetational picture of the area more complex. Many microhabitats, and thus increased biological diversity, result from the cropping out of these deeper strata in the county. For example, in a number of places along the Red River (e.g., Eisenhower State Park, Preston Peninsula, Delaware Bend), the Goodland Limestone forms flat limestone outcrops at the top of rugged cliffs. These areas of very thin soil over flat rock and adjacent slopes and ravines have numerous interesting plant species found nowhere else in Grayson County including *Coryphantha missouriensis* (plains nipple cactus), *Minuartia michauxii* var. *texana* (rock sandwort), *Talinum calycinum* (rock-pink), *Dodecatheon meadia* (common shooting-star), and *Melica nitens* (tall melic).

The proximity of sandy and clayey soils, as well as some intermediate type soils, in the counties adjacent to the Red River, also allows species normally separated ecologically to occur together; this sometimes results in hybridization. An excellent example can be seen in Fannin and Grayson counties where three species of *Baptisia* (wild indigo) and all three possible hybrids are found in close proximity (Kosnik et al. 1996). These occur either in what early settlers locally called "mixed soil" or in the area of the Preston Anticline where radically different soil types are found over quite small distances.

The basic pattern of the Red River Area is thus one of the eastern Texas forests grading gradually into the much less diverse and more xeric woodlands usually referred to as the Cross Timbers. From an even broader perspective, as discussed in the overview, the whole North Central Texas region is in an ecotone or ecological transition zone between two extensive ecosystems, the eastern North American deciduous forest and the central North American grassland or prairie. In virtually any ecotone, significant areas of vegetational interdigitation are seen; rarely is there a clearcut boundary. One type of vegetation extends deep into another along streams, in-pockets are found in protected areas, and special soil conditions often result in a patchwork pattern of vegetation that at the strictly local level seems confusing. The East and West cross timbers, the enclosed Grand Prairie, and the Red River Area are all excellent examples of these phenomena.

ORIGIN OF THE NORTH CENTRAL TEXAS FLORA

The flora of North Central Texas, like that of any relatively large region, has a complex and varied origin. Ultimately, it is the result of the evolutionary and distributional history of each of the component species. However, several influences can be observed which together allow at least a broad understanding of how the present flora originated. North Central Texas contains components of four major floristic provinces as defined by Thorne (1993a): the Appalachian Province, the Atlantic and Gulf Coastal Plain Province, the North American Prairies Province, and the Sonoran Province. There are also considerable numbers of Texas endemics. In addition, the modern flora contains 17.7 percent introduced species, these coming from various parts of the world.

INFLUENCE OF THE EASTERN DECIDUOUS FOREST

Plants from the first two of these floristic provinces, the Appalachian Province and the Atlantic and Gulf Coastal Plain Province, represent the influence of the eastern deciduous forest. This component of the flora is particularly important in the Red River drainage in the northeastern part of North Central Texas, but eastern deciduous forest elements occur across all of North Central Texas, and even make up an important component of the flora of the Edwards Plateau to the south and west of the region studied here (Amos & Rowell 1988). The vast deciduous forest biome of eastern North America is composed of a number of plant communities, and the forests/savannahs of North Central Texas represent *Quercus-Carya* or *Quercus* communities on the relatively dry western fringe of the eastern deciduous forest (Thorne 1993a).

From the phytogeographical standpoint, eastern deciduous forest elements are one of the most fascinating components of the North Central Texas flora. In the geologic past, dispersal between the Eurasian and North American continents was possible, and the combined area is considered a single "Holarctic" biogeographic region. The fossil record shows that many plants had distributions across the Northern Hemisphere—temperate forests, for example, occurred very broadly and reached their maximum extension in the mid-Tertiary (the Tertiary extended from 65 to 5 million years ago). This flora has been referred to as the Arcto-Tertiary flora or the Tertiario-mesophytic flora. Geohistorical events from the mid-Tertiary to the present have included alterations in the shapes of the northern land masses, fluctuations in sea levels, mountain building, and profound changes in the climate. As a result, there have been great changes in both the composition and the disposition of the flora.

A number of species of the once widespread Arcto-Tertiary flora have survived in one or more of four widely separated Tertiary relict areas—1) eastern Asia; 2) eastern North America; 3) southeastern Europe; and 4) western North America (Li 1952b; Little 1970; Wood 1970; Graham 1972a, 1972b; Boufford & Spongberg 1983; Hamilton 1983; Hsü 1983; Wu 1983; Ying 1983; Cox & Moore 1993; Graham 1993). Examples of North Central Texas genera found in all four of these areas include *Aesculus*, *Cercis*, *Erythronium*, *Juglans*, *Ostrya*, *Philadelphus*, and *Platanus* (Wood 1970). Wood (1970) and Thorne (1993a) emphasized the strong floristic relationships between the eastern United States and western North America, and indicated that about 65% of the genera



Fig. 24/WORLDWIDE DISTRIBUTION MAP OF *CARYA* (JUGLANDACEAE) SHOWING ITS DISJUNCT OCCURRENCE IN EASTERN ASIA AND EASTERN NORTH AMERICA (FROM WU 1983).

of southern Appalachian seed plants also occur in western North America. Examples of North Texas genera with such western North American connections include *Ceanothus*, *Oxypolis*, *Pycnanthemum*, and *Trichostema* (Wood 1970).

A significant number of species, however, have survived in only two very distant Tertiary relict areas, eastern Asia and eastern North America, and this striking distribution pattern has long been of interest to botanists (e.g., Gray 1846, 1859) and continues to be so today (e.g., Li & Adair 1994, 1997). The genus *Carya* is such an example (Fig. 24); other North Central Texas examples include *Campsis*, *Menispermum*, *Penthorum*, *Phryma*, *Sassafras*, *Saururus*, *Triadenum*, *Triosteum*, and *Veronicastrum* (Li 1952b; Little 1970; Boufford & Spongberg 1983; Hamilton 1983; Hsü 1983; Wu 1983; Ying 1983; Cox & Moore 1993; Graham 1993). In the words of Graham (1993), "It is well known that the broad-leaved deciduous forests of eastern North America and eastern Asia are floristically related. . . . It results from the maximum extension of the temperate deciduous forest in the mid-Tertiary and its disruption in western North America during the Pliocene and in western Europe during the Quaternary." This is one of the most ancient components of the North Central Texas flora. By at least the early Tertiary period (Eocene epoch—54.9–38 million years ago) deciduous vegetation was present across the middle of the North American continent (familiar genera include *Acer*, *Celtis*, *Liquidambar*, *Populus*, and *Rhus*) (Graham 1993). Dilcher (1998) indicated that different routes between the Old and New worlds have been open at different times in the past and that the shared vegetational elements between Asia and the United States are possibly derived from multiple introductions.

A related floristic relationship is the similarity seen between some forests in the mountains of Mexico and those in the eastern United States. Numerous North Central Texas genera (e.g., *Carpinus*, *Crataegus*, *Cornus*, *Liquidambar*, *Myrica*, *Nyssa*, *Pedicularis*, *Quercus*, *Smilax*, and *Vaccinium*) and even species (e.g., *Liquidambar styraciflua*) occur broadly across the eastern United States as far west as Texas and then reappear in the Mexican highlands and in some cases even in Guatemala (Miranda & Sharp 1950; Martin & Harrell 1957; Thorne 1993a). This relationship represents a middle to late Miocene (Miocene epoch—24.6–5.1 million years ago) extension of deciduous forest and associated fauna (particularly amphibians) into Mexico during a period of climatic cooling. Subsequently, during the Pliocene (Pliocene epoch—5.1–2 million years ago) and later times as the climate warmed and dried, these deciduous forests became disjunct, surviving in Mexico only in isolated pockets of appropriate microclimate in the highlands (Miranda & Sharp 1950; Graham 1993).

Geohistorical events in Tertiary and post-Tertiary times brought tropical elements into the present eastern deciduous forests, including North Central Texas. According to Graham (1993), "In the southeastern U.S., tropical forests reached their maximum northern expansion (to about 50°–60°N) in the Eocene [Eocene epoch—54.9–38 million years ago] with Annonaceae, Lauraceae, and Menispermaceae known from western Kentucky and Tennessee." A few North Central Texas species such as *Asimina triloba* may be a reflection of such an influence.

INFLUENCE OF THE NORTH AMERICAN PRAIRIES PROVINCE

The second major floristic component of North Central Texas is derived from the North American Prairies Province. Grassland vegetation historically covered much of the area currently referred to as North Central Texas, but human activities, particularly the conversion to cropland and the suppression of fire, have greatly reduced the amount of grassland. Allred and Mitchell (1955) viewed virtually all of North Central Texas to be prairie. In their broad classification of Texas vegetation, they considered the Cross Timbers and even the eastern Texas Post Oak belt to be Post Oak Savannas that are part of the True Prairie Association. They supported this contention by pointing out that the grasses of the True Prairie are important components in the vegetation of the Post Oak Savannas. Barbour and Christensen (1993) stated that in the southern part of the tall grass prairie-deciduous forest boundary (including Texas), the ecotone is an oak savanna 50–100 km wide. Since there are clearly components of both prairie and deciduous forest, viewing the region as an ecotone seems the most reasonable approach.

Axelrod (1985) argued that North American grasslands are geologically recent and that the rise of extensive grasslands probably dates to the Miocene-Pliocene transition (about 7–5 million years ago), the driest part of the Tertiary. Fossil evidence shows the Great Plains were largely forested from the middle Miocene into the early Pliocene. As the climate dried at the end of the Miocene, forests were more restricted and grasslands were able to spread rapidly. According to Graham (1993), the widespread late Miocene-Pliocene appearance of prairie vegetation in the middle of the North American continent was part of the first major disruption of the vast temperate deciduous forest (the above-noted Arcto-Tertiary flora) that had extended across north temperate latitudes since the late Eocene. During the Pleistocene (the Pleistocene epoch began 2 million years ago), again based on fossil evidence, there was great fluctuation in grassland versus forest vegetation associated with glaciation. From 15,000 to 12,000 years B.P. (before present), areas now covered with grassland vegetation (e.g., Texas panhandle) supported forest. The widespread central North American grasslands (including those of North Central Texas) present at the time of European settlement, probably date to post-glacial times only 12,000 to 10,000 years B.P. (Axelrod 1985). Axelrod (1985) supported his view of the grassland as a young biome with the following evidence: 1) there are few endemic taxa, with most of the grassland species being present in adjacent forests; 2) populations of trees scattered over the region are readily interpreted as relicts of a once more widely distributed forest; and 3) fossil evidence of forests in the recent past occurs over much of the present grasslands. According to Axelrod (1985), "That grasslands spread following the last glacial is apparent from data provided by bogs at Boriack, Gause and Soefje, central Texas (Bryant, 1977). During late glacial time, central Texas was covered with an open deciduous forest with some conifers and an understory of mixed grasses and shrubs. With retreating glaciers, warmer and/or drier climates developed over central Texas. Forests were restricted, leaving parkland vegetation dominated by grasses, shrubs, and herbs, but including trees in protected sites. During post-glacial time many mesic trees disappeared from the pollen record. It was the continual increase in non-arboreal taxa, and especially grasses, throughout post-glacial time that led to the establishment of the present post oak-grassland vegetation of central Texas (Bryant, 1977)." Thorne (1993a) also considered the grasslands of the Prairies Province to be "... mostly recent and adventive. ..."

INFLUENCE OF THE NORTH AMERICAN SONORAN PROVINCE

A third floristic component of North Central Texas is derived from the Sonoran Province (southwestern United States and northwestern Mexico). According to Thorne (1993a), this province is part of the broader Madrean Region which has an exceedingly diverse and distinctive flora that is mostly locally derived and rich in endemics. He further indicated that the xerophytic flora of the Sonoran Province is subtropical and largely Madro-Tertiary in origin. In North Central Texas such Sonoran elements (e.g., *Aloysia* (Verbenaceae), *Colubrina*, *Condalia* (Rhamnaceae), *Garrya* (Garryaceae), *Karwinskia* (Rhamnaceae), and *Nolina* (Agavaceae)) are found mostly in the drier southern and southwestern parts of the region, but others (e.g., some *Acacia* (Fabaceae), *Opuntia* (Cactaceae), and *Yucca* (Agavaceae) species) occur more broadly. *Cylindropuntias* and *Yucca* species, for example, are the commonest tall plants in some parts of the Sonoran Province (Thorne 1993a) and a strong connection is seen to North Central Texas which has four species of *cylindropuntias* and seven species of *Yucca* (two of these are endemic to North Central Texas). Thorne indicated that the plants of the Sonoran Province "... seem to have originated as the arid areas of North America expanded through the Tertiary—for the past 65 million years, and especially in the last 15 million years." Families in the North Central Texas flora that he emphasized as examples of this diversification include Agavaceae, Cactaceae, Menispermaceae, Nyctaginaceae, Rafflesiaceae, and Sapotaceae. While some desert species are quite old, this emphasis on the last 15 million years seems to mesh with the prevailing opinion that the modern North American deserts and their floras are relatively recent geologically (Axelrod 1950, 1979; Barbour & Christensen 1993).

Thorne (1993a) indicated that there are other minor components of the North American flora which have very different origins. North Central Texas genera such as *Menodora* (Oleaceae), *Prosopis* (Fabaceae), and *Nicotiana* (Solanaceae) seem to have strong links with South America, while *Thamnosma* (Rutaceae) and *Selinocarpus* (Nyctaginaceae) are related to African taxa.

ENDEMICS

North Central Texas itself has only five endemic taxa (*Yucca necopina*, *Y. pallida* (Agavaceae), *Evonymus atropurpurea* var. *cheatumii* (Celastraceae), *Croton alabamensis* var. *texensis* (Euphorbiaceae), *Dalea reverchonii* (Fabaceae)) presumably because of the lack of geographic and climatic isolation and the ecotonal nature of the area. However, 94 Texas endemics range into North Central Texas (see Appendix 3), with many endemics that were once thought to be restricted to the Edwards Plateau now known from the Lampasas Cut Plain in the southern part of North Central Texas (Amos & Rowell 1988). The explanation for the endemism seen in the Edwards Plateau and adjacent areas, while unclear, may be the result of the climatic history of the last two million years. During the Quaternary period (beginning 2 million years ago) there was significant climatic variability and at least 20 glacial-interglacial cycles. Widespread changes in vegetation were associated with these climatic fluctuations (Delcourt & Delcourt 1993); for example, during the last full-glacial interval (20,000–15,000 years B.P.), across the unglaciated parts of southwestern North America, there was a cool, moist "pluvial" climate (Delcourt & Delcourt 1993) with forest species presumably expanding their ranges. Indeed, Bryant's data (1977) showed an open deciduous forest in central Texas during the last full-glacial interval. The climate moderated from 15,000–10,000 years B.P., with interglacial conditions (i.e., warmer and drier) for the last 10,000 years (Delcourt & Delcourt 1993). The Edwards Plateau and Lampasas Cut Plain endemics are typically found in moist areas such as canyons along wooded streams and have presumably survived in the favorable microclimatic pockets as the overall climate of the area has warmed and/or dried. Many of these species have affinities with eastern taxa and may be relicts of a more widespread flora that became restricted as the result of climatic or geologic changes (Palmer 1920; Amos & Rowell 1988).

INTRODUCED SPECIES

Finally, the 394 species introduced from outside the United States since the time of Columbus make up 17.7 % of the North Central Texas flora (the percentage would be slightly higher if species that have invaded Texas from elsewhere in the United States were included). These introduced taxa are variously referred to as alien, exotic, or foreign species. They are also sometimes called “weeds,” but that word can have different meanings (Randall 1997). From the sociological standpoint a weed is a plant growing where it is not wanted or a “plant-out-of-place” (Stuckey & Barkley 1993); if defined in this way, introduced species are indeed often weeds. Biologically, weeds (sometimes termed colonizing or invasive plants) are species that “have the genetic endowment to inhabit and thrive in places of continual disturbance, most especially in areas that are repeatedly affected by the activities of humankind” (Stuckey & Barkley 1993). Again, many introduced plants fall within this definition of weedy species.

While introduced species include some of our most beautiful ornamentals (e.g., *Iris*, *Narcissus*, and *Wisteria* species), some are also extremely invasive taxa capable of becoming serious agricultural pests or of destroying native habitats. Luken and Thieret (1997) examined the assessment and management of plant invasions and gave a selected list of species interfering with resource management goals in North America. Particularly problematic are those that aggressively invade native ecosystems, reproduce extensively, and occupy the habitat of indigenous species. In some cases, single invasive species can come to dominate communities and occur in near monocultures, completely changing the species composition, structure, and aspect of an ecosystem. After habitat destruction, invasion by exotics may be the most serious threat facing native plants in North Central Texas and it is a common but underestimated problem in many ecosystems around the world (Cronk & Fuller 1995; Bryson 1996; Westbrooks & Epler 1996). It is also a potentially lasting and pervasive threat (Coblentz 1990). According to Cronk and Fuller (1995), “It is a lasting threat because when exploitation or pollution stops, ecosystems often begin to recover. However, when the introduction of alien organisms stops the existing aliens do not disappear; in contrast they sometimes continue to spread and consolidate, and so may be called a more pervasive threat.” Invasive exotics are an example of the phenomenon of ecological release—an introduced species is released from the ecological constraints of its native area (e.g., diseases, parasites, pests, predators, nutrient deficiencies, etc.) and is consequently able to undergo explosive population growth. There are numerous examples in North Central Texas, some of the most serious including *Bothriochloa ischaemum* var. *songarica*, King Ranch bluestem, *Festuca arundinacea*, tall fescue, *Hydrilla verticillata*, hydrilla, *Lespedeza cuneata*, sericea lespedeza or Chinese bush-clover, *Ligustrum sinense*, Chinese privet, *Lonicera japonica*, Japanese honeysuckle, *Pueraria montana* var. *lobata*, kudzu, and *Sorghum halapense*, Johnston grass. For example, kudzu, an aggressive vine, can completely cover native forests (e.g., in the southeastern United States) and, unfortunately, it is well-established in a number of North Central Texas counties (Grayson, Lamar, and Tarrant). *Festuca arundinacea* is capable of invading intact native tall grass prairies and is considered by some (e.g., Fred Smiens, pers. comm.) to be the most serious invasive threat to tall grass Blackland Prairie remnants (such as the Nature Conservancy’s Clymer Meadow in Hunt County).

Some exotic species are currently spreading in North Central Texas. For example, the offensive *Carduus nutans* subsp. *macrocephalus*, musk-thistle or nodding-thistle, is each year becoming more abundant in the northern part of North Central Texas (e.g., Grayson Co.). A possibly even more serious threat, *Scabiosa atropurpurea*, pincushions or sweet scabious, is currently taking over roadsides and adjacent areas in the northern part of North Central Texas (e.g., Collin Co.) and has the potential of becoming one of the most destructive invasive exotics in the area. From the aquatic standpoint, *Hydrilla verticillata* is a serious pest which can completely dominate aquatic habitats eliminating native species, clogging waterways, and severely curtailing recreational use (Steward et al. 1984; Flack & Furlow 1996). It is rapidly spreading at present in North Central Texas (M. Smart, pers. comm.), probably from lake to lake by boats or boat trailers and also intentionally by fishermen (L. Hartman, pers. comm.) to “improve” the habitat. This activity

is both illegal and ill-advised since it ultimately degrades the fishery. In fact, because of their potential as problematic invaders, five aquatic species that occur in North Central Texas, *Alternanthera philoxeroides*, alligator-weed (Amaranthaceae), *Eichhornia crassipes*, common water-hyacinth (Pontederiaceae), *Hydrilla verticillata* (Hydrocharitaceae), *Myriophyllum spicatum*, Eurasian water-milfoil (Haloragaceae), and *Pistia stratiotes*, water-lettuce (Araceae), are considered “harmful or potentially harmful exotic plants” and it is illegal to release, import, sell, purchase, propagate, or possess them in the state (Harvey 1998).

These alien taxa are from nearly all parts of the world (e.g., *Bromus catharticus*, rescue grass, from South America; *Chenopodium pumilo*, ridged goosefoot, from Australia; *Eragrostis curvula*, weeping love grass, from Africa; *Bothriochloa ischaemum* var. *songarica*, King Ranch bluestem, from Asia; *Stellaria media*, common chickweed, from Europe) and have gotten to North Central Texas in assorted ways. However, most introduced weeds in eastern North America, including many in North Central Texas, are from central and western Europe. It is thought that many weedy colonizing species evolved in Europe over thousands of years as humans disturbed and modified the environment for agricultural purposes; these same species do well in the disturbed habitats of the eastern United States (Stuckey & Barkley 1993). Numerous such European species entered North America at seaport cities along the Atlantic coast and spread westward across the continent (Stuckey & Barkley 1993). An excellent example of this phenomenon can be seen with *Chaenorrhinum minus*, dwarf snapdragon, which was first observed growing in North America in New Jersey in 1874 (Martindale 1876) and has since spread to over 30 states and nine Canadian provinces (Widrechner 1983). In some cases, seeds were introduced with soil, sand, or rocks being used as ballast in seagoing ships; Mühlenbach (1979) discussed the role of maritime commerce in dispersal. Other currently problematic taxa were intentionally introduced as ornamentals (e.g., *Ligustrum* species, privets), as windbreaks (e.g., *Tamarix* species, saltcedars), or in misguided attempts at habitat improvement, erosion control, soil stabilization, etc. In yet other cases, exotics are thought to have been accidentally introduced with crop seeds (e.g., *Myagrum perfoliatum*), hay (e.g., *Carduus nutans* subsp. *macrocephalus*), cotton or wool, or are associated with livestock yards (e.g., *Onopordum acanthium*, Scotch-thistle). Still others are transported by trains (e.g., *Chaenorrhinum minus*—Widrechner 1983); Mühlenbach (1979) discussed the importance of railroads as a means of dispersal. A particularly unusual dispersal mechanism is suspected for *Soliva pterosperma*, lawn burweed or stickers, which is thought to have been introduced into North Central Texas at a soccer field by the spinulose achenes sticking in athletic shoes.

The percentage of exotics in the North Central Texas flora—17.7% as stated above—is approximately what would be expected based on data from other parts of the United States. Elias (1977) estimated the level of exotics at 22% in the northeastern United States and more recently Stuckey and Barkley (1993) indicated that in northeastern states the percentage of foreign species ranged from 20% to over 30%. Their data, compiled from a number of sources, showed that there are higher percentages of foreign species in those states that have been occupied the longest by non-native inhabitants and in those that have been most extensively involved in agriculture. Some northern and western states, with less human influence and disturbance, have figures below 20%. While rather recently colonized by European settlers, North Central Texas, particularly the Blackland Prairie portion, has been extensively cultivated and numerous exotic species have arrived and become naturalized. Comparable percentages of foreign species are seen in the floras of California (17.5%) (Rejmánek & Randall 1994), Colorado (16%), Iowa (22.3%), Kansas (17.4%), and North Dakota (15%) (Stuckey & Barkley 1993).

Several introduced species have only recently been reported in North Central Texas, including *Chaenorrhinum minus*, dwarf snapdragon (Diggs et al. 1997), *Cerastium pumilum*, dwarf mouse-ear chickweed, and *Stellaria pallida*, lesser chickweed (Rabeler & Reznicek 1997). As this book was nearing completion, another European species, *Agrostemma githago*, corn-cockle, was discovered in the area (O’Kennon s.n., Parker Co.) as were two exotics new to Texas, *Cerastium brachypetalum*

(*Rabeller 1333*, Red River Co.), gray chickweed, and *Plantago coronopus* (*O'Kennon 14221*, Tarrant Co.), buck-horn plantago (*O'Kennon et al. 1998*). Additional exotics can be expected to become part of the North Central Texas flora in the future, many with serious negative consequences to the remnant native flora.

CONSERVATION IN NORTH CENTRAL TEXAS

Human activities have profoundly altered the biological picture of North Central Texas. Only small remnants of the original habitats have survived to the present day. However, numerous conservation efforts are currently underway in the region. Addresses and telephone numbers of the organizations mentioned below are provided in Appendix 9.

Substantial areas of land are controlled by the federal government including Hagerman National Wildlife Refuge (an 11,000-acre tract in Grayson County), Balcones Canyonlands National Wildlife Refuge in Burnet, Travis, and Williamson counties, protected areas in Fort Hood in Bell and Coryell counties, U.S. Army Corps of Engineers land around numerous impoundments, and the Caddo and Lyndon B. Johnson National Grasslands in Fannin and Wise counties. The Texas Department of Parks and Wildlife is also protecting, and in some cases attempting restoration on, numerous tracts in state parks and state wildlife management areas throughout North Central Texas. Examples of state land include Bonham State Park in Fannin County, Cedar Hill State Park in Dallas County, Cleburne State Park in Johnson County, Cooper Lake State Park in Delta and Hopkins counties, Dinosaur Valley State Park in Somervell County, Eisenhower State Park in Grayson County, Lake Brownwood State Park in Brown County, Lake Mineral Wells Park in Parker County, Lake Whitney State Park in Hill County, Meridian State Park in Bosque County, Mother Neff State Park in Coryell County, Possum Kingdom State Park in Palo Pinto County, and Pat Mayse State Wildlife Management Area in Lamar County. A number of far-sighted local governments are also protecting natural habitats. Examples of these include the Dallas Nature Center, the 3,000-acre Fort Worth Nature Center and Refuge, the Gambill Wildlife Refuge in Lamar County, which is maintained by the City of Paris, Harry S. Moss Park in Dallas, Parkhill Prairie Preserve in Collin County, River Legacy Living Science Center in Arlington, and Tandy Hills Park in Fort Worth.

Non-governmental organizations such as the Nature Conservancy and the Natural Area Preservation Association protect particularly critical pieces of habitat. Two well-known examples are the Nature Conservancy's Clymer Meadow in Hunt County and *Tridens* Prairie in Lamar County. The Heard Natural Science Museum and Wildlife Sanctuary, a 287-acre protected area in Collin County, has numerous conservation activities including a raptor rehabilitation program and a tall grass prairie restoration project (e.g., Steigman & Ovenden 1988). Austin College and its Center for Environmental Studies protects three field laboratories and preserves totaling nearly 300 acres in Grayson County. Other organizations, such as the Native Plant Society of Texas, the Native Prairies Association of Texas, the Texas Committee on Natural Resources, and the Thompson Foundation are actively engaged in educating the public and promoting the importance of plants, natural areas, and conservation. The Lady Bird Johnson Wildflower Center, located in Travis County just south of North Central Texas, is dedicated to the study, preservation, and reestablishment of North American native plants in planned landscapes; it has had an important impact throughout Texas and beyond. The Texas Organization for Endangered Species (TOES) monitors and regularly publishes information about endangered and threatened species and natural communities in North Central Texas as well as throughout the state. The Botanical Research Institute of Texas, in addition to its research activities, has an environmental education program, providing appropriate publications and educational opportunities for school children in the North Central Texas area.

Finally, many individual landowners are also making significant contributions by managing their properties in ways that preserve the natural diversity of the area. Enlightened grazing regimens, setting aside particularly fragile or erosion-prone parcels, or simply purchasing areas to protect are some of the strategies being undertaken by landowners throughout the North Central

Texas region. Other individuals such as Rosa Finsley, Howard Garrett, the late Lynn Lowrey, the late Benny Simpson, and Sally Wasowski have also made large contributions by bringing attention to the superiority of native plants in landscapes and other environmentally sensitive strategies.

All of these efforts are critical because given the rate at which remaining areas of natural habitat are disappearing, unless action is taken by those living today, the opportunity to provide future generations with the chance to experience natural areas in North Central Texas will soon be lost.

A SKETCH OF THE HISTORY OF BOTANY IN TEXAS WITH EMPHASIS ON NORTH CENTRAL TEXAS



BOTANY IN TEXAS

PRIOR TO THE REPUBLIC OF TEXAS / BEFORE 1836



Fig. 25/ THOMAS DRUMMOND, 1780–1835. REDRAWN FROM
A PORTRAIT IN *POPULAR SCIENCE MONTHLY* 74:49, 1909.

Much of the earliest natural history work in Texas was botanical in nature (McCarley 1986). According to Winkler (1915), “The study of Texas plants . . . is as old as the state itself. Prior to her annexation to the Union, and even before the period of the Republic of Texas, Texas had become an interesting field of observation and research for botanists and naturalists.” The first known collection of plants from what is now the state was made by Edwin James in August 1820 in the Texas Panhandle as part of Major S.H. Long’s expedition to the Rocky Mountains (Shinners 1949h). Details of the expedition’s route are provided by Goodman and Lawson (1995). However, the first person to make more extensive collections in the area that would become Texas was Jean Louis Berlandier (1805–1851), a French (or Swiss if today’s borders are accepted) botanist. Berlandier collected in Texas during the years 1828 to 1834 with the earliest of his collections being made in 1828 between Laredo and San Antonio while on a Mexican Boundary Commission expedition to

explore the area along the proposed United States-Mexico border (Winkler 1915; Geiser 1948; Berlandier 1980). His name is recognized in many scientific binomials including the genus *Berlandiera*, greeneyes, a composite group of four species native to the southern United States and Mexico. Berlandier apparently made the first collection of *Lupinus texensis*, one of the six *Lupinus* species which are the state flowers of Texas (Andrews 1986; Turner & Andrews 1986). A two volume translation of his journal has been published (Berlandier 1980).

Another early plant collector was Thomas Drummond (1780–1835), a Scottish botanist and naturalist who came to Texas in 1833 (Fig. 25). While in the area for only a brief period (1833–1834), he made important collections in southeast Texas and stimulated such later collectors as Lindheimer and Wright (discussed below). Drummond’s were the first Texas collections “. . . that were extensively distributed among the museums and scientific institutions of the world” (Geiser 1948). While many Texas plants are named for him, perhaps none is better known

than *Phlox drummondii*, commonly known as Drummond's phlox or pride-of-Texas. Also of note is that it was from several of Drummond's collections that Sir William Jackson Hooker described both *Lupinus subcarnosus* and *Lupinus texensis* (Hooker 1836; Turner & Andrews 1986).

DURING REPUBLIC OF TEXAS TIMES AND EARLY STATEHOOD / 1836–1865

While not chronologically the first collector in the state, Ferdinand Jacob Lindheimer (1801–1879), a German-born collector, is often referred to as the “father of Texas botany” because of his important botanical contributions, particularly on the central Texas flora (Fig. 26). Lindheimer's botanical work in the state, supported in part by George Engelmann and Asa Gray (the pre-eminent Harvard botanist), stretched from 1836 to 1879 (Geiser 1948). Lindheimer's collections were widely distributed by Englemann and Gray under the title “Flora Texana Exsiccata” (Blankinship 1907) and numerous new species were described in the well known *Plantae Lindheimerianae* (Engelmann & Gray 1845). Many Texas plants including *Lindheimera texana*, Texas-star, yellow Texas-star, or Lindheimer's daisy, and *Gaura lindheimeri*, white gaura, are named after him. Details about his life and botanical contributions can be found in Blankinship (1907) and Geiser (1948). Lindheimer's letters to Engelmann have been edited, translated, and discussed by Goynes (1991).



FIG. 26/ FERDINAND JACOB LINDHEIMER, 1801–1879.

USED WITH PERMISSION OF SOPHIENBURG MUSEUM & ARCHIVES,
NEW BRAUNFELS, TX.

A friend and sometimes collecting companion

of Lindheimer was another German, Ferdinand Roemer (1818–1891), who spent the years 1845 to 1847 in Texas (Geiser 1948). While a geologist, sometimes referred to as the “father of the geology of Texas,” he is probably best known for his book, *Texas with Particular Reference to German Immigration and the Physical Appearance of the Country* (Roemer 1849). Roemer, however, also collected plants (Winkler 1915) and his botanical contributions are recognized in such names as *Phlox roemeriana*, gold-eye phlox, and *Salvia roemeriana*, cedar sage.

A further early Texas collector was Charles Wright (1811–1885), whose collections for Asa Gray spanned the years 1837 to 1852 (Geiser 1948). Much of his collecting in western Texas was conducted while accompanying troops to that part of the state, an example being his 1849 expedition across the unexplored region between San Antonio and El Paso. This expedition is of special interest because the Smithsonian's \$150 contribution to defray Wright's expenses was, according to some, one of the early steps taken by that institution toward the formation of a national herbarium (Winkler 1915). Wright is commemorated by such plants as *Datura wrightii*, angel-trumpet, and *Ipomoea wrightii*, Wright's morning-glory. Further information on Wright's Texas travels can be found in Shaw (1987).

Another German-born naturalist was Louis Cachand Ervendberg (1809–1863), active in Texas from 1839 to 1855. He corresponded with and collected plants for Asa Gray in Comal County and later in Veracruz, Mexico (Geiser 1948).

John Leonard Riddell (1807–1865), a botanist and geologist, visited Texas briefly in 1839 and contributed to early knowledge about the plants of the state. His name can be seen in *Aphanostephus riddellii*, Riddell's lazy daisy. Detailed information about his travels in Texas are given in Breeden (1994).

Another student of Texas natural history was Gideon Lincecum (1793-1874), a Georgia-born frontier naturalist and pioneer physician who lived and worked in Texas and later Mexico from 1848 to 1874 (Fig. 27). During his career he corresponded with such eminent scientists as Charles Darwin, Spencer Baird, and Joseph Henry. Though self-taught, he published at least two dozen scientific articles and was elected a corresponding member of the Philadelphia

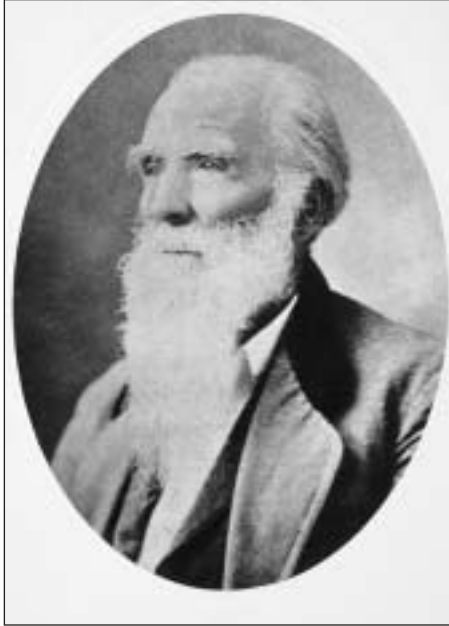


Fig. 27/ GIDEON LINCECUM, 1793–1874.

USED WITH PERMISSION OF THE CENTER FOR AMERICAN HISTORY,
THE UNIVERSITY OF TEXAS AT AUSTIN.

Academy of Natural Sciences. Lincecum sent botanical specimens to such prestigious museums as the Academy of Natural Sciences of Philadelphia, the British Museum, and the Smithsonian Institution. Not only did Lincecum make plant collections but he also became an authority on Texas grasses. Additionally, he made extensive observations of the Texas agricultural (harvester) ant. His work with ants was eventually read by Darwin before the Linnaean Society in London and published in the Society's journal in 1862 (Lincecum 1861, 1862; Geiser 1948; Burkhalter 1965; Lincecum & Phillips 1994; Lincecum et al. 1997). His name is remembered in *Vitis aestivalis* var. *lincecumii*, the pinewoods grape, of East Texas. Detailed information and much of his correspondence can be found in Lincecum and Phillips (1994) and Lincecum et al. (1997).

Important Texas collections were also made in 1849–1850 by the French botanist Auguste Adolph Lucien Trécul (1818–1896). According to Geiser (1948) he "... visited Texas on his scientific mission to North America to study and collect farinaceous-rooted plants used for food by the Indians."

Stillingia treculeana, Trécul's stillingia, and *Yucca treculeana*, Trécul's yucca or Spanish-dagger, are both named in his honor. McKelvey (1955, 1991) gave detailed information about Trécul's travels in southern and central Texas including an outline of his route and some collection numbers. Further information on Trécul can be found in Jovet and Willmann (1957).

In 1852, Captain R.B. Marcy's expedition to explore the Red River to its source (Marcy 1853) resulted in the collection by George G. Shumard (1825–1867), surgeon of the expedition, of 200 plant species (Winkler 1915). This expedition also yielded a published list of species by Torrey (1853) with 20 excellent illustrations, some of which are reprinted in the present volume.

Another interesting early contributor to Texas botany was Samuel Botsford Buckley (1809–1884). He first came to Texas in 1859, twice served as State Geologist of Texas, and collected plants in various parts of the state. According to L. Dorr (pers. comm.), "... it should be noted that Buckley was the first botanist to collect in Texas who then described new taxa from his own collections. Asa Gray took great exception to this infringement upon his virtual monopoly on publishing on Texas plants and Gray published several scathing reviews of Buckley's work. Buckley published in excess of 100 taxa of Texas plants, a number of which are recognized today." Among his scientific papers, several were published in the Proceedings of the Academy of Natural Sciences of Philadelphia (e.g., Buckley 1861 [1862]) including his rebuttal to Gray's criticisms (Buckley 1870). One of the best known species described by Buckley is *Quercus shumardii*, Shumard's red oak, which he named for B.F. Shumard, a geologist under whose direction he at one time worked. Buckley's name is remembered in *Quercus buckleyi*, Texas red oak (Dorr & Nixon 1985). Detailed information about Buckley's life and work can be found in Dorr and Nixon (1985) and Dorr (1997).

AFTER THE CIVIL WAR TO THE END OF WORLD WAR II / 1865–1945

The first woman botanist in Texas, Mrs. Maude Jeannie Young (1826–1882) taught botany in Houston, collected plants, and in 1873 published *Familiar Lessons in Botany with Flora of Texas*. This extensive work (646 pages) is reported to be the first scientific text for the state (Studhalter 1931; Todzia 1998). According to Dorr and Nixon (1985), “It is a curious book. The major portion of the Flora was copied verbatim from Chapman’s *Flora of the Southern United States* (1860), Mrs. Young’s editorial contribution consisting of the deletion of taxa not present or expected to be present in Texas, occasional notes on the distribution of species within Texas and the description of one new species of plant.” Another early Texas female botanist was Mary S. Young (1872–1919) (apparently unrelated to M.J. Young), one of the first botanists at the University of Texas (Fig. 28). She made important plant collections in various parts of the state including the Panhandle and Trans-Pecos and expanded the herbarium of the University of Texas by doubling the number of specimens (Young 1920; Tharp & Kielman 1962; Bonata 1995; Todzia 1998). Her publications included *A Key to the Families and Genera of the Wild Plants of Austin Texas* (Young 1917) and *The Seed Plants, Ferns, and Fern Allies of the Austin Region* (Young 1920).

Other relatively early (pre-1940) contributions to the understanding of Texas botany were those by E. Hall (1873) *Plantae Texanae: A List of the Plants Collected in Eastern Texas*; T.V. Munson (1883) *Forests and Forest Trees of Texas*; V. Havard (1885) *Report on the Flora of Western and Southern Texas*; J.M. Coulter (1891–1894) *Botany of Western Texas*; various works by W.L. Bray among them the *Ecological Relations of the Vegetation of Western Texas* (Bray 1901); J.W. Blankinship (1907) *Plantae Lindheimerianae, Part III*; I.M. Lewis (1915) *The Trees of Texas*; C.H. Winkler (1915) *The Botany of Texas*; B.C. Tharp (1926) *Structure of Texas Vegetation East of the 98th Meridian*; E.D. Schulz (1922) *500 Wild Flowers of San Antonio and Vicinity* and (1928) *Texas Wild Flowers*; M.C. Metz (1934) *A Flora of Bexar County, Texas*; H.B. Parks and V.L. Cory (1936) *The Fauna and Flora of the Big Thicket Area*; E. Whitehouse (1936) *Texas Flowers in Natural Colors*; and V.L. Cory and H.B. Parks (1937) *Catalogue of the Flora of the state of Texas*. This latter work was the earliest attempt to compile a complete list of the vascular plants of Texas.



Fig. 28/ MARY SOPHIE YOUNG, 1872–1919, (AND NEBUCHADNEZZAR).

USED WITH PERMISSION OF THE
TEXAS STATE HISTORICAL ASSOCIATION, AUSTIN.

POST WORLD WAR II TO THE PRESENT / 1945–1998

Following Cory and Parks' (1937) first list, a number of subsequent checklists have been produced by botanists associated with or trained at Texas A&M University, one of the centers of research on Texas botany. These include *Texas Plants—A Checklist and Ecological Summary* (Gould 1962, 1969, 1975a), *Checklist of the Vascular Plants of Texas* (Hatch et al. 1990), and *Vascular Plants of Texas: A Comprehensive Checklist including Synonymy, Bibliography, and Index* (Jones et al. 1997). Other large scale taxonomic works covering the entire state are *Ferns and Fern Allies of Texas* (Correll 1956), *The Legumes of Texas* (Turner 1959), and *The Grasses of Texas* (Gould 1975b). The second of



FIG. 29/ DONOVAN STEWART CORRELL, 1908–1983.
USED WITH PERMISSION OF THE
NEW YORK BOTANICAL GARDEN, BRONX.

these was one of the numerous contributions by Billie Lee Turner of the University of Texas at Austin, who has published extensively on the plants of Texas with particular emphasis on the Asteraceae. Turner was one of the individuals responsible for developing the Botany Department at the University of Texas at Austin into one of the best known and most respected departments in the United States. The extensive work by Frank Gould on grasses (e.g., 1968a, 1975b) at Texas A&M University received national and even international recognition, and his book on Texas grasses is one of the best treatments in the country for a large taxonomic group at the state level.

The first attempt at a comprehensive state-wide flora was the three volume *Flora of Texas* (3 vols.) by C.L. Lundell (1961, 1966, 1969). While never completed, this project of the Texas Research Foundation at Renner (near Dallas) was a valuable contribution to the knowledge of Texas plants. The Texas Research Foundation subsequently published the *Manual of the Vascular Plants of Texas* (Correll & Johnston 1970), which after nearly four decades is still the

only comprehensive source of information about the flora of the entire state. This work was authored by Donovan Stewart Correll (1908–1983) (Fig. 29) and Marshall Conring Johnston (1930–). After service at Harvard University and the United States Department of Agriculture, Correll, who was born in North Carolina and trained at Duke, in 1956 came to the Texas Research Foundation where he directed the *Manual* project. His research specialties included potatoes (*Solanum*), ferns, the Orchidaceae, and economic botany (Schubert 1984). With his wife, Helen B. Correll, he authored the influential and still widely used *Aquatic and Wetland Plants of Southwestern United States* (1972). Marshall Johnston, the second author of the *Manual* and a native Texan reared in the brush country of the Rio Grande delta, spent his career in the Botany Department at the University of Texas at Austin. His research specialties include the Euphorbiaceae, Rhamnaceae, and floristics of Texas and Mexico. Subsequent to the publication of the *Manual*, Johnston published two lists updating that work (Johnston 1988, 1990).

Floras are also available for various regions of the state including South Central Texas (Reeves & Bain 1947), the Big Bend (McDougall & Sperry 1951), North Central Texas (Shinners 1958a; Mahler 1984, 1988), the Texas Coastal Bend (Jones et al. 1961; Jones 1975, 1977, 1982), Central Texas (Reeves 1972, 1977), and the Edwards Plateau (Stanford 1976). More specialized works (e.g., treatments of trees and shrubs or grasses) are available for some regions of the state (e.g., Austin and the Hill Country—Lynch 1981; East Texas—Nixon 1985; Trans-Pecos—Powell 1988, 1994, 1998).

At present there are several long-term flora projects ongoing in Texas. These are a revision of the *Manual* being undertaken by David Lemke of Southwest Texas State University in San Marcos, and the new Flora of Texas Project, conceived by the Botanical Research Institute of Texas (BRIT), with founding members including BRIT, Southwest Texas State University, Texas A&M University, and the University of Texas at Austin. The goal of this latter project is to create an electronic database of information about the approximately 6,000 taxa of native and naturalized vascular plants of Texas, to make these data accessible via the internet, and to use the information to support botanical studies including the production of floras. At a more local scale, the Illustrated Texas Floras Project, a collaboration between BRIT and the Austin College Center for Environmental Studies, is attempting to produce illustrated floras for various parts of the state. This volume is the first in that series and is the first fully illustrated flora to be published for any region of Texas or surrounding states. Currently BRIT is an active center of plant research with one of the largest concentrations of professional taxonomic botanists in the southwestern United States. Five nationally prominent scientists have located at BRIT to continue their research. These are Theodore Barkley (formerly of Kansas State University), Robert Kral (formerly of Vanderbilt University), Joe Hennen (formerly of Purdue University), Henri Alain Liogier (formerly of the Botany Garden of the University of Puerto Rico-San Juan), and Richard Norris (formerly of the University of Washington and the University of California-Berkeley). Other professional biologists or research associates in residence at BRIT are Bruce Benz, Charlotte Bryant, George Diggs, Harold Keller, Barney Lipscomb, Fiona Norris, Robert O'Kennon, John Pipoly, Roger Sanders, S.H. Sohmer, Dora Sylvester, and Lindsay Woodruff.

While a great deal of work was conducted in the 1800s on Texas plants, most of the research was accomplished by non-residents or was funded by outside sources. The result was that few of the early collections remained in the state. According to Shinnars (1949h),

Pioneer collectors [in Texas] were either sent from Europe, or were patronized by botanists in the older parts of the United States. Not until the late 1890s did a Texas institution begin serious study of the flora of the state. Just fifty years ago [now about 100 years ago], W.L. Bray made collections more or less incidentally to ecological studies of the vegetation. These were the earliest collections to remain permanently in Texas and were the beginning of what is now the largest herbarium in the state, that of the University of Texas [at Austin].

Over the past century this situation has changed greatly. As a result of various state and local floristic projects and the collecting efforts of numerous individuals, currently well over two million herbarium specimens are kept in Texas. About 27 herbaria are active in the state, the three largest are the Plant Resources Center at the University of Texas at Austin (about 1,100,000 specimens including the University of Texas and Lundell Herbaria), the Botanical Research Institute of Texas in Fort Worth (860,000 specimens including the Southern Methodist University and Vanderbilt University collections), and the S.M. Tracy Herbarium of the Range Science Department of Texas A&M University (over 217,000 specimens) (Simpson 1996). A substantial number of very early Texas collections have returned to the state through the efforts of Lloyd Shinnars and exchanges with the Milwaukee Public Museum and the Missouri Botanical Garden. For example, slightly less than 1,400 early Texas specimens (dating back to 1839) collected by Ferdinand Lindheimer, Julien Reverchon, Charles Wright, and others are now in the collection at the Botanical Research Institute of Texas (Shinnars 1949h).

Further information on the history of botany in Texas can be obtained from Winkler (1915), Geiser (1945, 1948), (Shinnars 1949h, 1958a), and McKelvey (1955, 1991).



BOTANY IN NORTH CENTRAL TEXAS

EARLY CONTRIBUTIONS / PRIOR TO 1970

While botanical exploration, observation, and collecting occurred early in North Central Texas (e.g., Smythe 1852; Parker 1856; Buckley—See Dorr & Nixon 1985; Munson 1883, 1909), the first botanist to extensively collect in the north central part of the state was Julien Reverchon (Fig. 30). By the time of his death in 1905, Reverchon's collection numbered about 20,000 specimens of more than 2,600 Texas species. It was the best collection of the state's flora then in existence (Geiser 1948). Reverchon corresponded extensively with Asa Gray, one of the leading American botanists of the nineteenth-century, and was even visited by Gray. In addition to his collecting, Reverchon was a member of the Torrey Botanical Club, published a number of scientific papers (e.g., Reverchon 1879, 1880, 1903), and during the last decade of his life served as Professor of Botany in the Baylor University College of Medicine and Pharmacy at Dallas (Geiser 1948). Gray eventually named the monotypic genus *Reverchonia* (Euphorbiaceae) in his honor (Geiser 1948) as well as the Texas endemic *Campanula reverchonii*, basin bellflower. According to Shinnars (1958a),



FIG. 30/ JULIEN REVERCHON
1837–1905

Born at Lyons, France, in 1837, he [Reverchon] came with his father to La Reunion (now part of the city of Dallas) in 1856. Though early interested in plants, he did not begin serious collecting until 1876. His early specimens went to Asa Gray at Harvard University, who encouraged him to make extended trips west of our area. Later he collected much more prolifically for William Trelease of the Missouri Botanical Garden, aided by the grant of passes on railroads. After his death in 1905 his entire personal herbarium went to the Garden, in St. Louis. Through the good offices of Dr. Robert E. Woodson [and the work of Lloyd Shinnars] over a thousand duplicates of Reverchon's specimens came back to Dallas, starting in 1949, and are now incorporated in the Herbarium of Southern Methodist University [now at BRIT]. The specimens and the manuscript field-notes which often accompany them show Reverchon to have been a keen and discerning collector, but more than this, a perceptive naturalist, recording a wealth of information about the plants and their habitats. Whether from diffidence or under terms of agreement with the eminent botanists who were purchasing his specimens, he

unfortunately published almost nothing. The Missouri store-keeper, Benjamin Franklin Bush, who was for a time herbarium assistant to Trelease, visited Reverchon and also collected in our area. . . . The growth of a large city [Dallas] and its suburbs has eliminated many species which he found here, and our knowledge of Texas plants would be faulty indeed were it not for his work. Undoubtedly still more species should appear in this book than are cited. But his collections are dispersed among the 1,500,000 at St. Louis, and though I have spent periods of a few days to several months there in each of some eight years, I have by no means checked them all. In the city where he worked, Reverchon is remembered now only by the small Reverchon Park, but hardly anyone knows for whom it was named.

Regarding the history of North Central Texas botany, Shinnars (1958a) went on to say,

Fort Worth can boast our next resident botanist, Albert Ruth, born in 1844 [Fig. 31]. Forced into unwilling retirement from his position as superintendent of schools in Knoxville, Tennessee, he turned his back on the state where he had been an active amateur botanist and spent his last twenty years (1912–1932) collecting in Texas. He was almost as prolific as Reverchon Ruth's specimens (unlike Reverchon's) were very widely distributed, and he apparently did not attempt to preserve a complete collection himself. His quite incomplete personal herbarium was purchased by the Fort Worth Park Board after his death It is now on deposit at Texas Christian University [currently at Fort Worth Museum of Science and History]. Though Ruth did some collecting as far away as Bexar and Garza counties, most of his activity was confined to our local area, chiefly Tarrant County, and to a much smaller extent Dallas and Denton counties. In 1929 a set of 300 specimens was collected for Dr. W.M. Longnecker of Southern Methodist University, primarily for class use. These are the first specimens now part of the [SMU, now BRIT] Herbarium there to have been acquired. About 500 additional Ruth collections, obtained from several sources, have augmented this original set. [BRIT has in its library a lengthy unpublished typescript by Ruth of a *Manual of Texas Flora*.]

Fort Worth can also claim our third resident botanist, William Larrey McCart, whose interests in science began while he was a student at Central High School there, and were continued, with special attention to plants, by Mrs. Hortense Winton under whom he took freshman work at Texas Christian University. He attended The University of Texas briefly, to take a course in plant taxonomy under Dr. B.C. Tharp, subsequently going to North Texas State College in Denton, where in due course he took his master's degree. He then returned to Fort Worth, where family affairs made it necessary for him to take employment, and severely curtailed botanical activities for more than a decade. A little work



FIG. 31/ ALBERT RUTH (1844–1932).

FROM THE COLLECTION OF THE FORT WORTH PUBLIC LIBRARY.

was done at the Botanical Garden, where his own herbarium shared storage space with that of Albert Ruth. From 1954 to 1957 he took additional work at The University of Texas, resumed collecting, ordered up the W.A. Silveus Grass Collection which had been bequeathed to the University, and then returned to Denton as a member of the staff of North Texas State College. His chief early period of activity was from 1937 to 1940, during which time he set out to collect systematically, county by county, to establish distributions of species — the first time work of this kind had been done in our area. He also made great efforts to send off collections to specialists for accurate determinations. During that time, the best organized [organized] and most thorough work on the state's flora being carried out was done by him. His personal herbarium of some 4,000 specimens is now incorporated in that of Southern Methodist University [now BRIT], and has been an invaluable help in the completion of this book.



Fig. 32/ LLOYD HERBERT SHINNERS, 1918–1971.

In 1939 Mrs. Norma Stillwell published her “Key and Guide to the Woody Plants of Dallas County,” a pamphlet treating some 90 species, the first independent publication dealing with our local flora (and only the third such publication of any kind, its only predecessors being Reverchon’s brief note “Notes on some introduced plants in Dallas County, Texas,” in the *Botanical Gazette* vol. 5 p. 10, 1880; and the “Directions for Plant Collections” and “Flowering Plants” section in “Natural History Manual of T.C.U. Vicinity,” by Hortense Winton and Sadie Mahon, which reached a fifth edition in 1929). Mrs. Stillwell was an enthusiastic and talented amateur who attempted with the aid of garden-club friends to compile a popular local flora, portions of which were mimeographed. Unfortunately only a few permanent specimens were made which were adequate for preservation in a herbarium. Some, however, are of special interest - for example, the type specimen of *Rosa ignota*. Mrs. Stillwell’s manuscript notes and specimens were turned over to S.M.U. when she moved from the city.

Beginning in 1940, Dr. C. L. Lundell, an alumnus of S.M.U., then at the University of Michigan, began systematic collecting toward an ambitious *Flora of Texas*. His work paralleled that of McCart — organised [organized] geographic exploration, getting identifications from specialists — but this time it was done by an experienced, professional botanist, with ample financial backing. The S.M.U. Herbarium was formally organised by him in 1944. But promotional and public relations work with what was to become the Texas Research Foundation made increasing inroads on his time, almost completely halting his botanical field work. From 1945 on, this was continued by three additions to the staff of the new Herbarium: myself [L.H. Shinnery] in February, Dr. Eula Whitehouse [see Flook 1974 for more information] in June, and Mr. V.L. Cory in September. During several years we were assisted by visiting botanists: Drs. Donovan S. Correll, C.H. Muller, and Rogers McVaugh. Collecting was done in all parts of the state, that of the visiting botanists especially being carried on chiefly away from our local area. But since it would hardly have been possible to reach satisfactory conclusions without examining collections from elsewhere, all this work contributed to the preparation of a local flora.

When I [L.H. Shinnery] assumed charge in 1948, the Herbarium had reached a total of slightly under 21,000 specimens. Now, ten years later, the higher plants total 150,000 [from this beginning BRIT/SMU, including VDB, has grown to about 860,000 specimens as of 1998]. My own collection numbers since coming to Texas amount to almost 20,000 (which with duplicates means perhaps 100,000 specimens),

of which about 40% are from the local area. This is really not very much compared with the amount of work that has been done in New England, the Philadelphia area, the central California Coast, or many parts of Europe; it seems like even less when one considers the richness of the flora and the size of the area being covered. I have often remarked that the first edition of this book [*Spring flora of the Dallas-Fort Worth area Texas*] will be a Flora of the Main Highways, the second will include the back roads, and perhaps the third will begin to cover the country.

My [L.H. Shinnery] earliest studies depended chiefly on the specimens collected by Dr. and Mrs. Lundell, Miss Whitehouse, and Mr. Cory, and on loans from the Missouri Botanical Garden (these often extended for periods of as much as several years). These were gradually augmented by my own collections and those of Reverchon, Ruth and McCart, as already noted. But nothing of course can take the place of seeing the plants live, again and again, year after year.



FIG. 33/ EULA WHITEHOUSE, 1892–1974.

Without a doubt, Lloyd Herbert Shinnery (1918–1971), a native Canadian who received his botanical training at the University of Wisconsin-Madison, is the most important twentieth-century North Central Texas botanist (Fig. 32). He came to Southern Methodist University in Dallas in 1945, became the Director of the Herbarium in 1949, and was on the faculty there until his death (Mahler 1971b). Not only did he almost single-handedly develop the herbarium which today forms the core of the collection at BRIT, but he also created one of the best botanical libraries in the United States, did extensive field work, and published a total of 276 articles and a 514-page flora (Flook 1973). His contributions to botanical nomenclature are particularly impressive, totaling 558 new scientific names and combinations (Flook 1973). Among his most lasting achievements are the *Spring Flora of the Dallas-Fort Worth Area Texas* (Shinnery 1958a) and the journal, *Sida, Contributions to Botany*, which he founded in 1962 (Mahler 1973b). Shinnery's *Spring Flora* was the first

completed, original, technical book on Texas plants prepared by a resident of the state. It was extensively used by high schools, colleges, and universities as a textbook for classes, and is still in use today. For a synopsis of Shinnery's life see Mahler (1971b); for a guide to his botanical contributions see Flook (1973).

Eula Whitehouse (1892–1974) (Fig. 33), mentioned above, is best known for her *Texas Flowers in Natural Colors* (1936), the first color-illustrated guide to Texas wildflowers (Flook 1974). Her career was at the Houston Municipal Hospital, the Texas Memorial Museum in Austin, the University of Texas College of Mines, and Southern Methodist University. While at SMU she studied bryophytes (Whitehouse & McAllister 1954), published taxonomic revisions (e.g., Whitehouse 1945, 1949), and did extensive art work. Some of her illustrations were used in Shinnery's *Spring Flora* and are reproduced in this volume.

Another important North Central Texas botanist was Cyrus Longworth Lundell (1907–1994), mentioned above (Fig. 34). Lundell is best known as founder of the Texas Research Foundation, author (with collaborators) of the *Flora of Texas*, and as a specialist on the Myrsinaceae. His institute was instrumental in establishing Texas as an important center of taxonomic botany.

RECENT CONTRIBUTIONS / 1970–1998

More recently, Wm. F. “Bill” Mahler (1930–) (Fig 35), Director Emeritus of BRIT, had an extensive role in the botany of the north central part of the state. After receiving his Ph.D. from the University of Tennessee at Knoxville, he joined the faculty of Southern Methodist University in 1968, became editor of *Sida* in 1971, and assumed leadership of the herbarium in 1973. Mahler is probably best known for his *Shinners’ Manual of the North Central Texas Flora* (1984, 1988), well known for its clarity and ease of use. This manual was an expanded version of Shinners’ (1958) *Spring Flora of the Dallas-Fort Worth Area Texas* that also included the summer and fall flora for North Central Texas. Other notable publications by Mahler were the *Keys to the Plants of Black Gap Wildlife Management Area, Brewster County, Texas* (1971a), *Flora of Taylor County, Texas* (1973a) and *The Mosses of Texas* (1980), an elaboration upon Eula Whitehouse’s research on the mosses of Texas. Mahler’s specialties included Fabaceae, *Baccharis* (Asteraceae), mosses, floristics, and the study of endangered species. He served as the first Director of the Botanical Research Institute of Texas (1987–1992) and along with Barney Lipscomb and Andrea McFadden, was instrumental in its establishment as a free-standing research institution.

Jack Stanford (1935–), of Howard Payne University in Brownwood on the very southwest margin of North Central Texas, also made an important contribution to the knowledge of Texas botany with his publication in 1976 of *Keys to the Vascular Plants of the Texas Edwards Plateau and Adjacent Areas*. This work covered portions of the Lampasas Cut Plain, which is included in the current delineation of North Central Texas. Stanford has also done extensive collecting in the Lampasas Cut Plain and Edwards Plateau and has found many important distributional records (e.g., Stanford & Diggs 1998).

Another important figure in the history of botany in North Central Texas and the state as a whole is Benny Simpson (1928–1996) (see Appendix 15). Serving for many years with the Texas Research Foundation and later with the Texas A&M Research and Extension Center at Dallas,



Fig. 34/ CYRUS LONGWORTH LUNDELL, 1907–1994. WORKING IN FRONT OF HIS THATCHED HUT HEADQUARTERS AT TIKAL, GUATEMALA.



Fig. 35/ WILLIAM FRED "BILL" MAHLER

Simpson is possibly best known as the author of *A Field Guide to Texas Trees* (Simpson 1988). For a list of his publications see Davis (1997). However, among botanists and native plant enthusiasts he is correctly best remembered as the "Pioneer of the Native Plant Movement" in Texas (Nokes 1997). Simpson understood that the scarcity of water is one of the biggest challenges facing Texas' future and that native plants, well-adapted to the state's climate, are an important resource (e.g., Simpson & Hipp 1984; Simpson 1993). Through his research, nine superior selections of native plants were released to the nursery industry including three forms of *Leucophyllum* (Scrophulariaceae), widely known as Texas purple-sage (Nokes 1997; Kiphart 1997). In addition to his other contributions, Simpson was one of the founding members and a former president of the Native Plant Society of Texas and was active in that organization until his death (Nokes 1997; Pickens 1997).

Other notable contributors to the botany of North Central Texas include Robert Adams (Baylor University), Geyata Ajilvsgi (Austin), John Bacon (University of Texas at Arlington), Lewis Bragg (University of Texas at Arlington), M.D. "Bud" Bryant (Austin College), William Carr (The Nature Conservancy of Texas), Wayne Clark (Fort Worth Nature Center), Sally Crosthwaite (Austin College), Arnold Davis (Native Prairies Association of Texas), Charles Finsley (Dallas Museum of Natural History), Hugh Garnett (Austin College), Harold Gentry (Grayson County), Glenn Kroh (Texas Christian University), Fred Gelbach (Baylor University), Joe Hennen (BRIT), George High (Austin), Walter Holmes (Baylor University), Harold Keller (Central Missouri State University), Joe Kuban (Nolan High School, Fort Worth), Shirley Lusk (Gainesville), David Montgomery (Paris Junior College), Jeff Quayle (Fort Worth), Elray Nixon (Las Vegas, Nevada), Donald Smith (University of North Texas), John Steele (BRIT), Connie and John Taylor (South-eastern Oklahoma State University), Dora Sylvester (Fort Worth Nature Center & BRIT), Geoffrey Stanford (Dallas Nature Center), Jerry Vertrees (Texas Wesleyan University), and Sally Wasowski (Taos, New Mexico).

As noted above, with Lundell's (1961, 1966, 1969) unfinished but important *Flora of Texas* and the *Manual of the Vascular Plants of Texas* (Correll & Johnston 1970), both published in the Dallas-Fort Worth Metroplex, North Central Texas has been one of the centers of research on the state's flora. The publications by Lloyd Shinnars (1958a) *Spring Flora of the Dallas-Fort Worth Area Texas*, Jack Stanford (1976) *Keys to the Vascular Plants of the Texas Edwards Plateau and Adjacent Areas*, and William Mahler (1984, 1988) *Shinnars' Manual of the North Central Texas Flora* have been extremely valuable and useful guides to the region's flora. In addition to such books, a number of scientific journals originated in North Central Texas including *Field & Laboratory*, *Wrightia*, *Sida*, *Contributions to Botany*; and *Sida, Botanical Miscellany*. *The Southwest Naturalist*, a prominent, regional, natural history journal also has close ties to North Central Texas, with Lloyd Shinnars serving as its first editor. Most of the botanical work in North Central Texas has been completed at private institutions, a tradition which continues today. Until the 1970s and 1980s respectively, the Texas Research Foundation and Southern Methodist University were leaders in the field. In recent years, Austin College, Baylor University, the Botanical Research Institute of Texas, and Howard Payne University have all been actively engaged in botanical research. A number of public colleges and universities in the area also have taxonomic botanists. Among these are Paris Junior College, Tarleton State University, Texas Christian University, Texas Wesleyan University, the University of North Texas, and the University of Texas at Arlington.





ABRONIA AMELIAE / AMELIA'S SAND-VERBENA / P. 836 / [RJO]



AGALINIS HOMALANTHA / FLAT-FLOWER GERARDIA / P. 993 / [GMD]



ALETIS AUREA / YELLOW STAR-GRASS / P. 1194 / [RJO]



AESCULUS PAVIA VAR. **PAVIA** / RED BUCKEYE / P. 738 / [RJO]



ALOPHIA DRUMMONDII / PURPLE PLEAT-LEAF / P. 1173 / [RJO]



ANDROPOGON GERARDII SUBSP. **GERARDII** / BIG BLUESTEM / P.1238 / [GMD]



ANEMONE BERLANDIERI / TEN-PETAL ANEMONE / P.918 / [GMD]



◀ **APIOS AMERICANA** / GROUNDNUT / P.628 / [GMD]



ARISAEMA DRACONTIUM / GREEN-DRAGON / P.1092 / [RJO]



AQUILEGIA CANADENSIS / COMMON COLUMBINE / P.918 / [RJO]



APHANOSTEPHUS SKIRRHOBASIS / ARKANSAS LAZY DAISY / P.314 / [RJO] ▶



ASCLEPIAS TUBEROSA SUBSP. **INTERIOR** / BUTTERFLY-WEED
WITH GRAY HAIRSTREAK BUTTERFLY / P. 280 / [JAC]



ASCLEPIAS ASPERULA SUBSP. **CAPRICORNU** / ANTELOPE-HORNS / P. 278 / [RJO]



ASCLEPIAS VIRIDIFLORA / GREEN-FLOWER MILKWEED / P. 282 / [RJO]



ASCLEPIAS VARIEGATA / WHITE-FLOWER MILKWEED / P. 280 / [JAC]



AUREOLARIA GRANDIFLORA VAR. **SERRATA** / DOWNY OAKLEECH / P. 994 / [RJO]



BAPTISIA AUSTRALIS VAR. **MINOR**
BLUE WILD INDIGO / P. 636 / [MAK]



BAPTISIA × **BICOLOR** / TWO-COLOR WILD INDIGO / P. 636 / [MAK]



BAPTISIA SPHAEROCARPA / GREEN WILD INDIGO / P. 638 / [GMD]



BAPTISIA BRACTEATA VAR.
LEUCOPHAEA
PLAINS WILD INDIGO
P. 638 / [MAK]



BAPTISIA × **VARIICOLOR**
VARICOLORED WILD INDIGO / P. 638 / [GMD]



BAPTISIA × **BUSHII** / BUSH'S WILD INDIGO / P. 638 / [MAK]



BAPTISIA × **VARIICOLOR**
VARICOLORED WILD INDIGO
P. 638 / [GMD]



CALLICARPA AMERICANA / AMERICAN BEAUTY-BERRY / P. 1049 / [GMD]



▲ **BOUTELOUA PECTINATA** / TALL GRAMA / P. 1248 / [GMD]



CALLIRHOE INVOLUCRATA VAR. **INVOLUCRATA** / LOW WINECUP / P. 807 / [GMD] ►



CAMASSIA SCILLOIDES / WILD-HYACINTH / P. 1200 / [GMD]



CAMPSIS RADICANS / COMMON TRUMPET-CREEPER / P. 442 / [RJO]



CASTILLEJA PURPUREA VAR. **PURPUREA** / PURPLE PAINTBRUSH / P. 998 / [GMD]



CASTILLEJA INDIVISA / TEXAS PAINTBRUSH / P. 996 / [RJO]



CASTILLEJA PURPUREA VAR. **CITRINA** / YELLOW PAINTBRUSH / P. 998 / [RJO]

CENTAUREA AMERICANA / AMERICAN BASKET-FLOWER / P. 332 / [RJO]



CEPHALANTHUS OCCIDENTALIS
COMMON BUTTONBUSH / P. 962 / [GMD]



CENTAURIUM BEYRICHI / ROCK CENTAURY, MOUNTAIN-PINK / P. 724 / [RJO]



CENTROSEMA VIRGINIANUM / BUTTERFLY-PEA / P. 639 / [RJO]



CHAMAECRISTA FASCICULATA / PARTRIDGE-PEA / P. 642 / [RJO]



CERCIS CANADENSIS VAR. **CANADENSIS** / EASTERN REDBUD WITH FEMALE CARDINAL
P. 640 / [JAC]



CEVALLIA SINUATA / STINGING CEVALLIA / P. 794 / [RJO]



CIRSIUM HORRIDULUM / BULL THISTLE / P. 340 / [RJO]



CIRSIUM TEXANUM / TEXAS THISTLE / P. 340 / [RJO]



CIRSIUM UNDULATUM / WAVY-LEAF THISTLE / P. 340 / [RJO]



CLAYTONIA VIRGINICA / VIRGINIA SPRING-BEAUTY
P. 908 / [RJO]



CLEMATIS TEXENSIS / SCARLET CLEMATIS
P. 922 / [RJO]

CNIDOSCOLUS TEXANUS / TEXAS BULL-NETTLE
P. 596 / [GMD]



COOPERIA PEDUNCULATA / GIANT RAIN-LILY / P. 1200 / [RJO]



▲ **COREOPSIS TINCTORIA** / PLAINS COREOPSIS / P. 342 / [GMD]



COMMELINA ERECTA VAR. **ERECTA** / ERECT DAYFLOWER / P. 1100 / [RJO]

CORYPHANTHA SULCATA / PINEAPPLE CACTUS / P. 485 / [RJO]





DALEA AUREA / GOLDEN DALEA / P. 646 / [RJO]



DALEA LASIATHERA / PURPLE DALEA / P. 650 / [RJO]



CUCURBITA FOETIDISSIMA / BUFFALO GOURD / P. 568 / [RJO]



CUCURBITA TEXANA / TEXAS GOURD / P. 568 / [JAC]

DASISTOMA MACROPHYLLA / MULLEIN SEYMERIA / P. 999 / [GMD]





▲ **DATURA WRIGHTII**
INDIAN-APPLE
P. 1020 / [RJO]



DODECATHEON MEADIA / COMMON SHOOTING-STAR / P. 913 / [GMD]



◀ **DELPHINIUM CAROLINIANUM** SUBSP.
VIRESCENS / PRAIRIE LARKSPUR
P. 924 / [RJO]

▼ **DRACOPIS AMPLEXICAULIS**
CLASPING CONEFLOWER / P. 346 / [RJO]



DICLIPTERA BRACHIATA / FALSE MINT
P. 212 / [RJO]



ECHINOCACTUS TEXENSIS / HORSECRIPPLER
P. 486 / [RJO]



DYSCHORISTE LINEARIS / NARROW-LEAF SNAKEHERB
P. 213 / [RJO]



ERODIUM TEXANUM / STORK'S-BILL / P. 730 / [JAC]



ECHINOCACTUS COCCINEUS VAR. **PAUCISPINUS** / CLARET-CUP CACTUS / P. 486 / [RJO]



ECHINOCACTUS REICHENBACHII / LACE CACTUS / P. 486 / [RJO]



ERYNGIUM LEAVENWORTHII
LEAVENWORTH'S ERYNGO / P. 252 / [RJO]



ERYNGIUM YUCCIFOLIUM
RATTLESNAKE-MASTER / P. 252 / [RJO]



ERYTHRINA HERBACEA / CORAL-BEAN / P. 658 / [RJO]



ERYSIMUM ASPERUM
WESTERN WALLFLOWER / P. 468 / [RJO]



ERYTHRONIUM MESOCHOREUM
DOG-TOOTH-VIOLET / P. 1201 / [RJO]



ESCOBARIA MISSOURIENSIS VAR. **SIMILIS**
PLAINS NIPPLE CACTUS / P. 488 / [GMD]



EUPHORBIA MARGINATA / SNOW-ON-THE-MOUNTAIN / P. 608 / [RJO]



ESCOBARIA VIVIPARA VAR. **RADIOSA** / SPINY-STAR / P. 488 / [RJO]



EUSTOMA RUSSELLIANUM / BLUEBELL GENTIAN / P. 727 / [GMD]

FUNASTRUM CYNANCHOIDES / CLIMBING-MILKWEED / P. 283 / [GMD]



FUNASTRUM CRISPUM / WAVY-LEAF TWINEVINE / P. 283 / [JAC]



GAILLARDIA PULCHELLA / INDIAN-BLANKET WITH GAILLARDIA MOTH / P. 358 / [RJO]



GLANDULARIA BIPINNATIFIDA / DAKOTA VERVAIN / P. 1050 / [RJO]

HELIANTHUS MAXIMILIANI / MAXIMILIAN SUNFLOWER WITH
ERYNGIUM LEAVENWORTHII / LEAVENWORTH'S ERYNGO / P. 370 / [JAC]



▲ **GRINDELIA PAPPOSA** / SAW-LEAF DAISY
P. 362 / [RJO]



HELIANTHEMUM GEORGIANUM
GEORGIA SUN-ROSE / P. 543 / [RJO]

HELIANTHUS ANNUUS / COMMON SUNFLOWER / P. 369 / [GMD]





HERBERTIA LAHUE SUBSP. **CAERULEA**
HERBERTIA / P. 1173 / [RJO]



HEXALECTRIS NITIDA / SHINING HEXALECTRIS
P. 1216 / [RJO]



HESPERALOE PARVIFLORA / RED-FLOWERED-YUCCA / P. 1079 / [RJO]



HEXALECTRIS WARNOCKII / TEXAS PURPLE-SPIKE
P. 1218 / [RJO]



HIBISCUS LAEVIS / HALBERD-LEAF ROSE-MALLOW
P. 810 / [RJO]



HIBISCUS TRIONUM / FLOWER-OF-AN-HOUR
P. 812 / [RJO]



HYMENOCALLIS LIRIOSME / WESTERN SPIDER-LILY / P. 1204 / [JAC]



HOFFMANSEGGIA GLAUCA / SICKLE-POD RUSH-PEA / P. 663 / [RJO]



IBERVILLEA LINDHEIMERI / BALSAM GOURD / P. 569 / [GMD]



HYDROLEA OVATA / HAIRY HYDROLEA / P. 740 / [JAC]

IPOMOPSIS RUBRA / STANDING-CYPRESS / P. 890 / [GMD]



INDIGOFERA MINIATA VAR. **LEPTOSEPALA**
WESTERN SCARLET-PEA / P. 664 / [GMD]



◀ **IPOMOEA PANDURATA** / BIG-ROOT MORNING-GLORY / P. 556 / [RJO]



JUSTICIA AMERICANA / AMERICAN WATER-WILLOW / P. 213 / [RJO]



◀ **IPOMOEA CORDATOTRILOBA** VAR. **CORDATOTRILOBA** / SHARP-POD MORNING-GLORY
P. 556 / [RJO]





LIATRIS ASPERA / TALL GAYFEATHER / P. 384 / [GMD]



LIATRIS SQUARROSA VAR. **GLABRATA**
SMOOTH GAYFEATHER / P. 386 / [GMD]



KRAMERIA LANCEOLATA / TRAILING RATANY / P. 750 / [RIO]



LINUM RIGIDUM VAR. **BERLANDIERI**
BERLANDIER'S FLAX / P. 792 / [JAC]

▼ **LANTANA URTICOIDES** / COMMON LANTANA / P. 1053 / [RIO]





LITHOSPERMUM INCISUM / NARROW-LEAF GROMWELL / P. 452 / [RJO]

LOBELIA CARDINALIS / CARDINAL-FLOWER / P. 498 / [RJO]



LONICERA SEMPERVIRENS / CORAL HONEYSUCKLE / P. 510 / [RJO]



LOBELIA SIPHILITICA VAR. **LUDOVICIANA**
BIG BLUE LOBELIA / P. 498 / [JAC]



LOMATIUM FOENICULACEUM SUBSP. **DAUCIFOLIUM** / CARROT-LEAF LOMATIUM / P. 255 / [RJO]



LUDWIGIA PEPLOIDES / WATER-PRIMROSE / P. 860 / [GMD] ▲

LUPINUS TEXENSIS / TEXAS BLUEBONNET / P. 672 / [GMD]



LUPINUS TEXENSIS / TEXAS BLUEBONNET
WITH *OENOTHERA SPECIOSA* / SHOWY PRIMROSE / P. 672 / [JAC]

MAMMILLARIA HEYDERI / LITTLE-CHILIS / P. 489 / [RJO]



LYGODESMIA TEXANA / TEXAS SKELETON-PLANT / P. 386 / [RJO]





MANFREDA VIRGINICA SUBSP. **LATA**
WIDE-LEAF FALSE ALOE / P. 1079 / [RJO]



MARSHALLIA CAESPITOSA VAR. **SIGNATA** / BARBARA'S-BUTTONS / P. 387 / [GMD]



MATELEA EDWARDSSENSIS
PLATEAU MILKVINE / P. 284 / [RJO]



MATELEA RETICULATA / NET-VEIN MILKVINE / P. 284 / [RJO]

MATELEA BIFLORA / TWO-FLOWER MILKVINE / P. 284 / [RJO]





◀ **MAURANDYA ANTIRRHINIFLORA** / SNAPDRAGON-VINE / P. 1002 / [RJO]



MIMOSA ROEMERIANA / ROEMER'S SENSITIVE-BRIAR / P. 678 / [RJO]



MIRABILIS NYCTAGINEA / WILD FOUR-O'CLOCK
P. 840 / [JAC]



◀ **MONARDA FISTULOSA** VAR. **MOLLIS**
WILD BERGAMOT / P. 765 / [GMD]

MONARDA CITRIODORA / LEMON BEEBALM
P. 765 / [JAC]



MONARDA PUNCTATA VAR. **INTERMEDIA**
SPOTTED BEEBALM / P. 766 / [GMD]





MONOTROPA UNIFLORA / INDIAN-PIPE / P. 584 / [JAC]



MYOSURUS MINIMUS / TINY MOUSETAIL / P. 924 / [GMD]

NEMASTYLIS GEMINIFLORA / PRAIRIE CELESTIAL
P. 1174 / [GMD]



◀ **NELUMBO LUTEA** / YELLOW LOTUS / P. 834 / [RJO]

NYCTAGINIA CAPITATA / SCARLET MUSKFLOWER
P. 842 / [RJO]



NEMOPHILA PHACELIODES / BABY BLUE-EYES / P. 742 / [JAC]



NYPHAEA ODORATA / WHITE WATER-LILY / P. 845 / [RJO]



OENOTHERA MACROCARPA SUBSP. **MACROCARPA** / FLUTTER-MILL / P. 864 / [RJO]



OENOTHERA SPECIOSA / SHOWY-PRIMROSE / P. 866 / [JAC]



OPUNTIA TUNICATA VAR. **DAVISII**
GREEN-FLOWER CHOLLA / P. 492 / [RJO]

OXYTROPIS LAMBERTII / LOCOWEED / P. 682 / [RJO]



OPUNTIA ENGELMANNII VAR. **LINDHEIMERI** / TEXAS PRICKLY-PEAR / P. 490 / [RJO]





PASSIFLORA INCARNATA / MAYPOP PASSION-FLOWER / P. 878 / [GMD]



PASSIFLORA AFFINIS / BRACED PASSION-FLOWER
P. 878 / [RJO]



PASSIFLORA TENUILOBA
SPREAD-LOBE PASSION-FLOWER / P. 878 / [RJO]



PENSTEMON COBEA / WILD FOXGLOVE
P. 1007 / [GMD]

PAVONIA LASIOPETALA / WRIGHT'S PAVONIA
P. 816 / [RJO] ➤



PENSTEMON DIGITALIS / SMOOTH PENSTEMON / P. 1007 / [GMD]



PHLOX DRUMMONDII SUBSP. **DRUMMONDII** / DRUMMOND'S PHLOX / P. 892 / [JAC]



PHLOX DRUMMONDII SUBSP. **WILCOXIANA** / DRUMMOND'S PHLOX / P. 892 / [RJO]



PHLOX ROEMERIANA / GOLD-EYE PHLOX / P. 892 / [JAC]

PHYSOSTEGIA PULCHELLA / BEAUTIFUL FALSE DRAGON'S-HEAD / P. 770 / [RJO] ➤



◀ **PLATANTHERA CILIARIS** / YELLOW FRINGED ORCHID / P. 1218 / [GMD]



POLANISIA DODECANDRA SUBSP. **TRACHYSPERMA** / CLAMMYWEED / P. 506 / [RJO] ➤





PROBOSCIDEA LOUISIANICA / COMMON DEVIL'S-CLAW / P. 880 / [RJO]



QUINCULA LOBATA / PURPLE GROUND-CHERRY / P. 1026 / [RJO]

GALLS ON **QUERCUS FALCATA** / GALLS ON SOUTHERN RED OAK / P. 714 / [GMD] ►



RHYNCHOSIDA PHYSOCALYX / SPEAR-LEAF SIDA / P. 816 / [RJO]



RATIBIDA COLUMNIFERA / MEXICAN-HAT / P. 400 / [GMD] ▼



SABATIA CAMPESTRIS / PRAIRIE ROSE GENTIAN / P. 728 / [GMD]



SALVIA FARINACEA / MEALY SAGE / P. 776 / [RJO]

SALVIA AZUREA VAR. **GRANDIFLORA** / BLUE SAGE
P. 774 / [GMD] ➤



SCUTELLARIA WRIGHTII / WRIGHT'S SKULLCAP / P. 780 / [JAC]

SILPHIUM ALBIFLORUM / WHITE ROSINWEED / P. 404 / [RJO]



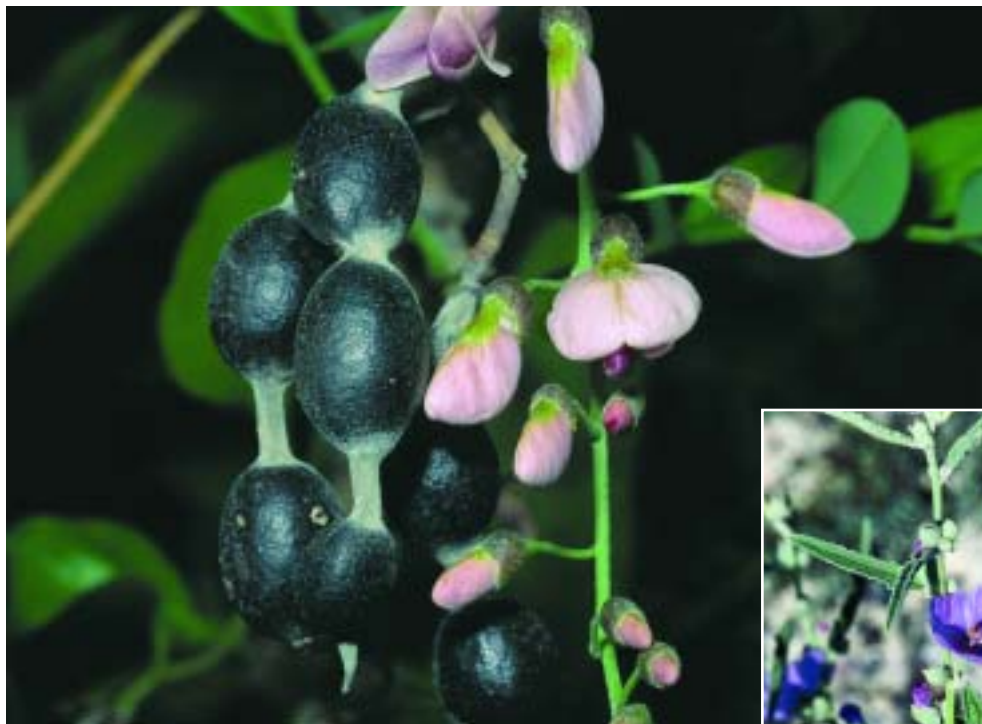
SILPHIUM RADULA / ROUGH-STEM ROSINWEED / P. 406 / [RJO] ➤



SENNA ROEMERIANA / TWO-LEAF SENNA / P. 696 / [RJO]



SILPHIUM LACINIATUM / COMPASSPLANT / P. 404 / [RJO] ➤



SOPHORA AFFINIS / EVE'S-NECKLACE / P. 697 / [GMD]



SPHAERALCEA ANGUSTIFOLIA SUBSP. **CUSPIDATA**
NARROW-LEAF GLOBE-MALLOW / P. 820 / [RJO]



SISYRINCHIUM PRUINATUM / DOTTED BLUE-EYED-GRASS / P. 1178 / [GMD]



SOLANUM CITRULLIFOLIUM / MELON-LEAF NIGHTSHADE / P. 1028 / [RJO]



SOLANUM DIMIDIATUM / WESTERN HORSE-NETTLE / P. 1028 / [GMD]



TALINUM AURANTIACUM / ORANGE FLAMEFLOWER / P. 911 / [RJO]

SPIRANTHES LACERA VAR. **GRACILIS** / SLENDER LADIES'-TRESSES / P. 1220 / [GMD] ➤



TALINUM CALYCIUM / ROCK-PINK / P. 911 / [GMD]



TEUCRIUM LACINIATUM / CUT-LEAF GERMANDER / P. 783 / [RJO]



TINANTIA ANOMALA / FALSE DAYFLOWER / P. 1101 / [RJO]



ZINNIA GRANDIFLORA / PLAINS ZINNIA / P. 433 / [RJO]



YUCCA NECOPINA / GLEN ROSE YUCCA / P. 1083 / [RJO] ➤



TRADESCANTIA OHIENSIS / OHIO SPIDERWORT
P. 1104 / [GMD]



UNGNADIA SPECIOSA / MEXICAN-BUCKEYE
P. 982 / [RJO]



VERBENA HALEI ▼
SLENDER VERVAIN / P. 1056 / [GMD]



◀ **UTRICULARIA GIBBA** / CONE-SPUR BLADDERWORT / P. 787 / [GMD]