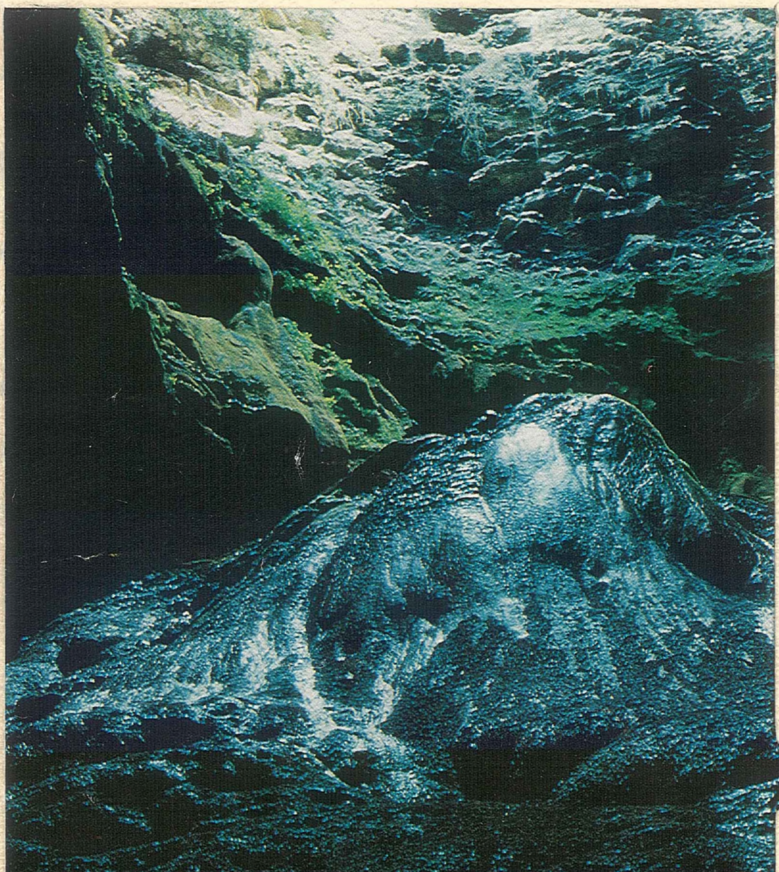
DEVIL'S SINKHOLE AREA--
HEADWATERS OF THE NUECES RIVER

A NATURAL AREA SURVEY
Part VIII of VIII



DIVISION OF NATURAL RESOURCES AND ENVIRONMENT

The University of Texas at Austin

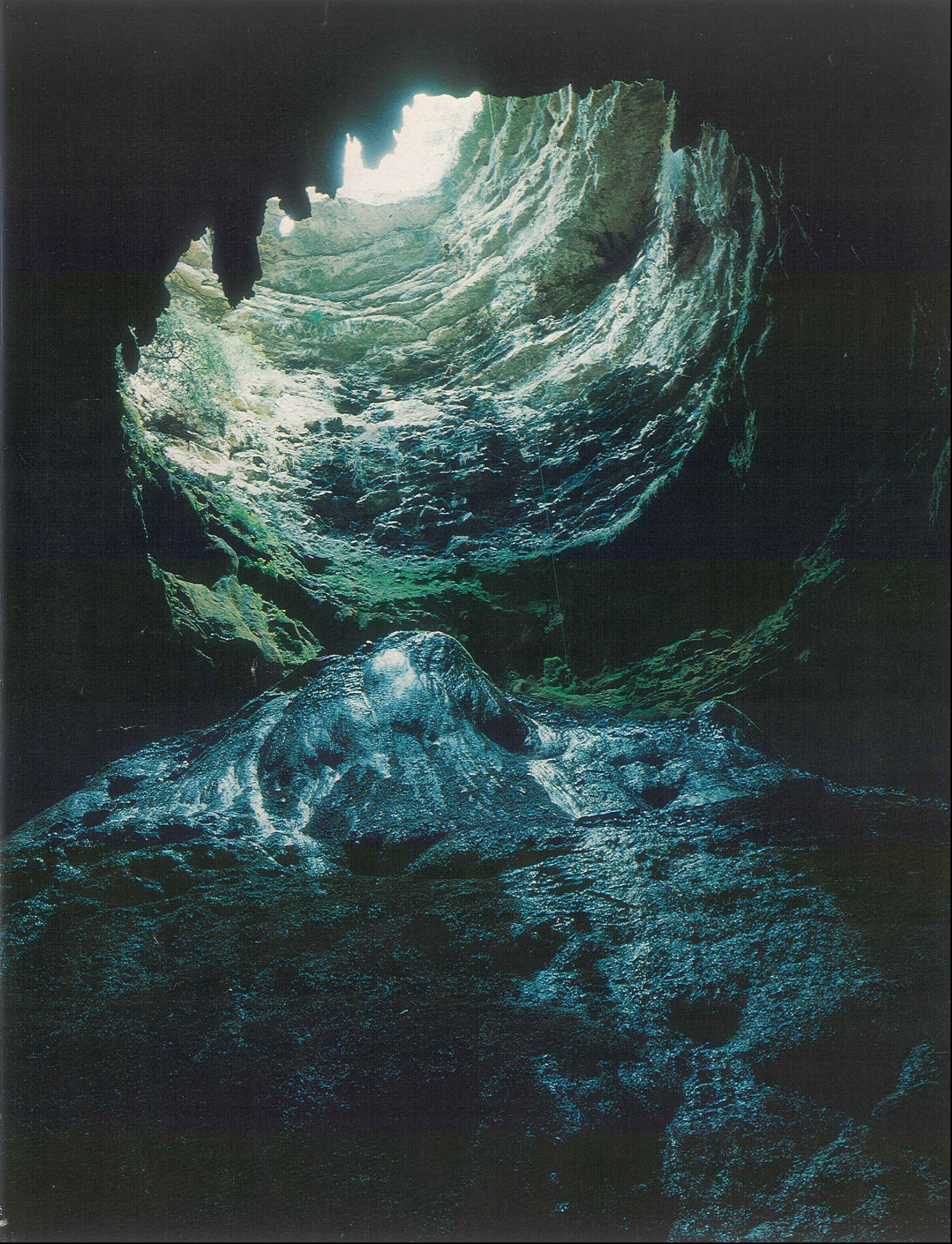


PHOTO CREDIT

The full-color frontispiece is by photographer Reagan Bradshaw and represents but a small part of the work he recorded in the course of the Devil's Sinkhole area survey. Transparencies of all his photos of this and the other four areas have been filed with the Parks and Wildlife Commission. Mr. Bradshaw is one of the finest nature photographers of the Southwest. His work on these five sites is sure to increase public awareness of the need to save and protect.

DEVIL'S SINKHOLE AREA--
HEADWATERS OF THE NUECES RIVER

A NATURAL AREA SURVEY
Part VIII of VIII

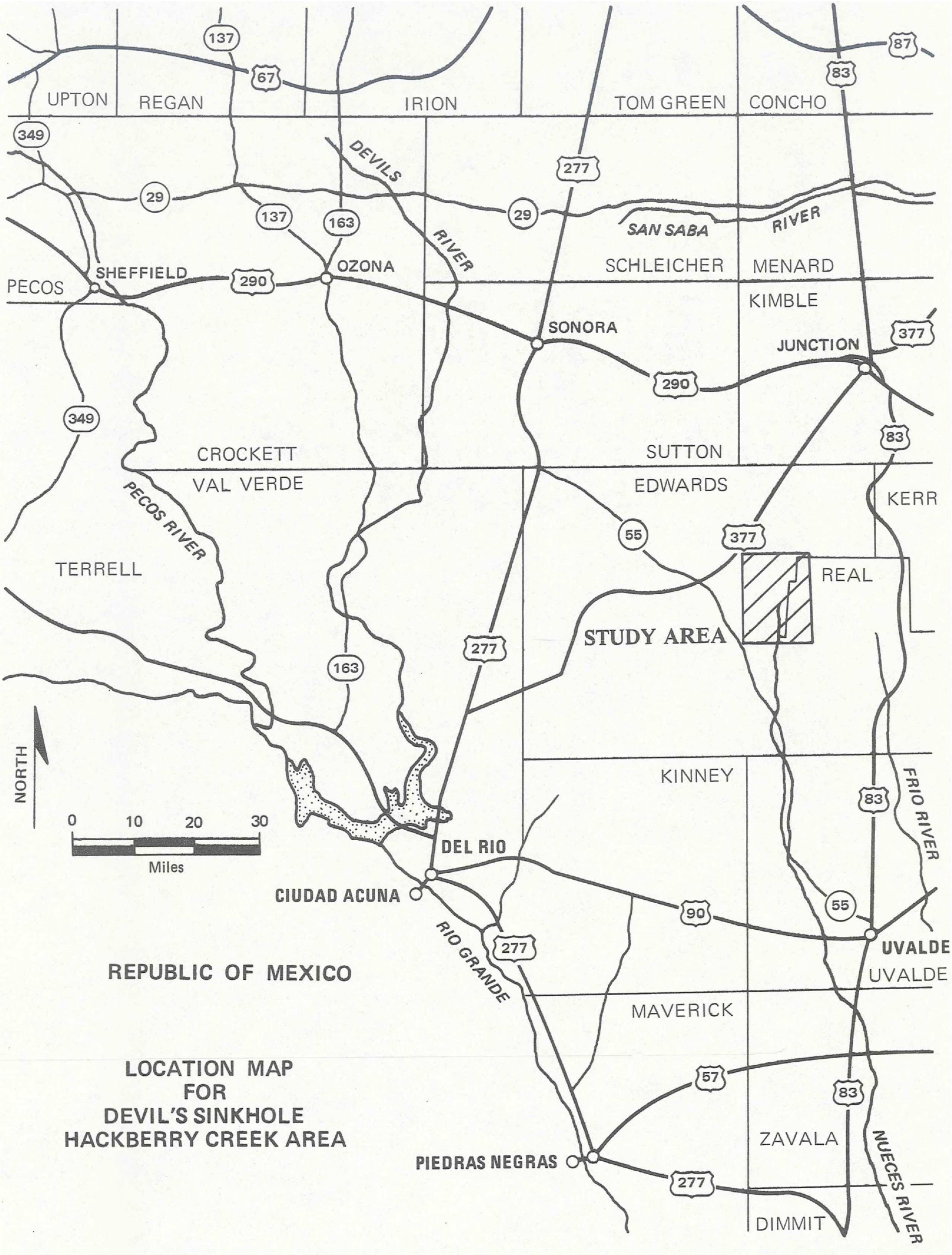
Maps are provided in a separate section.

Prepared for the Texas Parks and Wildlife Department.
Bound separately in 1973 are Part I CAPOTE FALLS, Part II MATAGORDA ISLAND, Part III MOUNT LIVERMORE AND SAWTOOTH MOUNTAIN, and Part IV VICTORIO CANYON. Bound separately in 1975 are Part V BLUE ELBOW SWAMP, Part VI DEVILS RIVER, and Part VII CANADIAN BREAKS.

DIVISION OF NATURAL RESOURCES AND ENVIRONMENT

The University of Texas at Austin

1975



LOCATION MAP
FOR
DEVIL'S SINKHOLE
HACKBERRY CREEK AREA

THE UNIVERSITY OF TEXAS AT AUSTIN
DIVISION OF NATURAL RESOURCES AND ENVIRONMENT
AUSTIN, TEXAS 78712

Campus Address:
Sid Richardson Hall 3.206
Phone—512-471-1762

Mailing Address:
University Station
Box Y

May 15, 1975

Texas Parks and Wildlife Commission
Pearce Johnson, Chairman
John H. Reagan Building
Austin, Texas 78701

Dear Mr. Chairman:

The Division of Natural Resources and Environment of The University of Texas at Austin respectfully submits herewith its report, *Devil's Sinkhole: A Natural Area Survey,* Part VIII of VIII, pursuant to the joint request of the Texas Historical Committee, the General Land Office, and the Texas Parks and Wildlife Commission.

Devil's Sinkhole, like each of the other seven areas – Capote Falls, Part I; Matagorda Island, Part II; Mount Livermore-Sawtooth Mountain, Part III; Victorio Canyon, Part IV; Mount Livermore-Sawtooth Mountain, a supplement to Part III; Blue Elbow Swamp, Part V; Devils River, Part VIII, and Canadian Breaks, Part VII – was scientifically and historically surveyed, mapped, and photographed. In addition, current land ownership was recorded and mapped. The project involved the recruitment and direction of a field team of geologists, archaeologists, botanists, zoologists, cartographers, photographers, historians, and landmen.

Texas is a diverse and beautiful land with a rich heritage and abundant natural and scientific wonders that should be preserved for the use and enjoyment of ourselves and of generations yet to come. As your commission pointed out in requesting this survey, the more significant natural areas are disappearing all too rapidly in Texas. It is our hope that the data gathered here will be instrumental in reversing that trend.

Sincerely,

Don Kennard

Don Kennard
Project Director

FOREWORD

The University of Texas at Austin, through The Division of Natural Resources and Environment, conducted this study of five unique and endangered natural areas of Texas as a pilot project to provide basic data for the Governor, the Legislature, and various state agencies in developing a program to protect and enhance these and similar sites for the benefit and enjoyment of ourselves and of future generations.

This is the second Natural Area Survey undertaken by The University of Texas. Previous studies of Capote Falls, Matagorda Island, Mount Livermore and Sawtooth Mountain, and Victorio Canyon were conducted through the Lyndon B. Johnson School of Public Affairs in 1973.

The basic idea for such a program is not new. It is patterned after the National Park Service's Historic American Building Survey (HABS). The HABS program is both an agency continuously studying architecture of historic importance and a notable national collection of documentary drawings, photographs, and written reports which preserve and proclaim the heritage of our man-made environment. HABS was begun in 1933 by architects of the National Park Service with funds from the federal government, and it is now our public record of the building art in America.

This natural area survey project is designed to accomplish basically the same objectives for the recording and preservation of natural sites in Texas. This and subsequent reports will be filed with the Texas Parks and Wildlife Commission.

In Texas there are more than 500 areas of natural, scientific and/or historical significance. Most of these areas may best be preserved through dedicated private ownership; others should be purchased and protected by the state and federal governments. All of them should be systematically recorded, photographed, mapped and scientifically analyzed.

It is our hope that this survey and the establishment of a continuing program will lead to that end.

Don Kennard
Project Director

ACKNOWLEDGEMENTS

Material for this and the other four reports in this series was assembled and edited by Don Kennard. Editorial contributions to the final manuscript were made by Griffin Smith, jr., Attorney and Senior Editor of *Texas Monthly* magazine; Truett Latimer, Executive Director, Texas Historical Commission; Marshall Johnston, PhD., Professor of Botany, The University of Texas at Austin; Dee Ann Story, PhD., Associate Professor of Anthropology and Director of the Anthropological Laboratories, The University of Texas at Austin, and Curtis Tunnell, State Archaeologist.

Color photography was by Reagan Bradshaw. Candy Abshier prepared the layout with the help of Linda Hill, Bill Crim and the staff of the Texas Department of Agriculture. We are indebted to Dr. Keith Arnold, Ross Shipman, and Frances Tisdale of the Division of Natural Resources and Environment, The University of Texas at Austin; Suzanne Winkler, Jeanne Conway, Bob (Rooney) Burnett, Marsha Meredith, and Susan Fieseler for their assistance in handling the multitude of details and arrangements necessary to produce these reports.

It is difficult to acknowledge without omission the time and effort unselfishly given by so many friends of Texas' natural heritage. With a fear that we may have inadvertently missed others, we wish to give special thanks to:

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Mrs. N. W. Schoolfield, Schoolfield Ranch
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John White, Commissioner of Agriculture
C. V. and Jack N. Whitworth

CONTRIBUTORS

DON KENNARD – B.B.A. The University of Texas at Austin. Fields: Ecology and Government. Consultant to the Division of Natural Resources and Environment, former consultant to the Director of Research, Lyndon B. Johnson School of Public Affairs and Natural Area Survey Project Director.

GRIFFIN SMITH, JR. – B.A. History, Rice University; M.A. Government, Columbia University; J.D., The University of Texas School of Law. Fields: Government, Law, Research, and Journalism. Senior Editor, *Texas Monthly* magazine, former Committee Counsel to the Texas Senate Interim Drug Committee. Project Editor and author of the "Impressions" section of each report.

DWIGHT E. DEAL – B.S. Geology, Rensselaer Polytechnic Institute; M.S. Geology, University of Wyoming; Ph.D. Geology, University of North Dakota. Former Associate Professor of Geology, Sul Ross State University. Geologist for the North Dakota Geological Survey in summers of 1969, 1970, and 1971; Research Scientist Associate, Bureau of Economic Geology, The University of Texas at Austin, 1972-73; Director, National Speleological Society; Geologist and Director, Chihuahuan Desert Research Institute, Alpine, Texas. Coordinator of the Scientific Team and author of the geologic section of each report.

LAWRENCE C. WALKER – B.S., Pennnsylvania State University; M.F. Yale University; Ph.D. Forestry, State University of New York College of Forestry at Syracuse University. Dean of the School of Forestry, Stephen F. Austin State University. Author of the general analysis section of the Blue Elbow report.

* * *

REAGAN BRADSHAW – B.A. Plan II, The University of Texas at Austin. Fields: Landscape, wildlife and industrial photography. Former chief photographer, Texas Parks and Wildlife Commission; Published in *Audubon, National Geographic, Texas Parks and Wildlife, Texas Parade,* and *Texas Monthly* magazines and nationally recognized professionally as one of the outstanding nature photographers of the Southwest.

HERBERT E. BRUNS – B.S. Soil Science, Texas Tech University. Soil Scientist, United States Soil Conservation Service since 1954. Author of S.C.S. surveys for Castro and Parmer Counties, Texas. Fields: Soil Classification and Soil Surveying. Conducted Soil Association Survey of the Alamosa Creek area and authored the soils section of the Canadian Breaks report.

ROBERT E. BURNETT – Archaeological and Cartographic Technician, Historic Sites and Restoration Division, Texas Parks Department. Drafted the maps included in the reports.

MARY BUTTERWICK – B.A. Botany, M.S. Botany, The University of Texas at Austin. Botanical Assistant in preparation of collections and in writing the botany section of Devils River and Devil's Sinkhole reports.

WILLIAM R. ELLIOTT – B.S. Biology, The University of Texas at Austin; M.S. Zoology, Texas Tech University; candidate for Ph.D. in Zoology, Texas Tech University. Teaching Assistant Zoology, Texas Tech University. Field: Texas and Mexican Cave Biology. Conducted field investigation and co-authored the fauna section of the Devil's Sinkhole report.

RONALD G. FIESELER – Speleologist. Board Director, National Speleological Association; former Chairman, Texas Speleological Association; former Editor, *Texas Caver*; Editor, *Texas Speleological Survey*; Member of the Association for Mexican Cave Studies. Director of the Speleological Field Team and co-author of the cave resources section of the Devil's Sinkhole report.

C. WAYNE HANSELKA – A.A. Victoria College; B.S., M.S., Ph.D. Range Management, Texas A&M University. Fields: Wildlife Management and Range Management. Associate Professor of Range Animal Science, Department of Range Animal Science, Sul Ross State University. Assisted in the investigations, preparation of collections and in writing the zoological section of the Devils River-Dolan Creek report.

RAY R. HICKS, JR. – B.S.F. and M.S., University of Georgia; Ph.D., State University College of Environmental Science and Forestry, Syracuse University. Assistant Professor of Forestry, Stephen F. Austin State University. Directed botanical field work and principal author of the botany section of the Blue Elbow report.

JAMES C. KROLL – B.S. Zoology, Baylor University; M.S. Zoology, Baylor University; Ph.D. Wildlife Science, Texas A&M University. Assistant Professor of Forest Wildlife, Stephen F. Austin State University. Visiting Professor of Forest Science, Texas A&M University. Conducted zoological investigations and author of the zoological section of the Blue Elbow report.

WILLIAM S. MARMADUKE – B.A. Economics, M.A. Anthropology, doctorial student Anthropology, The University of Texas at Austin. Field survey and testing archaeologist for Texas Highway Department in 1973. Director of the archaeological field work and principal author of the archaeological section of each report.

TERRY C. MAXWELL – B.S. Wildlife Science, Texas A&M University; M.S. Biology, Angelo State University; candidate for Ph.D. in Biology, Texas A&M University. Ornithological Team Leader for Devil's Sinkhole and author of the summer resident bird section of that report.

GERALD G. RAUN – B.A. Geology, Texas Tech University; M.A. Zoology, Ph.D. Zoology, The University of Texas at Austin. Professor and Chairman, Department of Biology, Angelo State University. Supervised and directed the fieldwork and writing of the zoological section of the Devil's Sinkhole report.

JAMES R. REDDELL – B.A. English, The University of Texas at Austin; candidate for Ph.D. in Zoology, Texas Tech University. Field Associate, American Museum of Natural History. Research Assistant, The Museum, Texas Tech University. Field: Texas and Mexican Cave Biology. Co-author of the fauna section of the Devil's Sinkhole report.

JAMES F. SCUDDAY – B.S. Zoology, Sul Ross State University; M.N.S., University of Idaho; Ph.D. Wildlife Science, Texas A&M University. Associate Professor of Biology, Sul Ross State University. Fields: Ecology and Systematics of Vertebrate Animals. Conducted zoological investigations, prepared collections and authored the zoological section of the Canadian Breaks and Devils River-Dolan Creek reports.

LA FERNE SCUDDAY – B.S. Botany, Sul Ross State University; candidate for M.S., Sul Ross State University. Zoological Assistant in preparation of collections and in writing the zoological section of the Canadian Breaks report.

SAMUEL W. SIKES – B.S. Biology; M.S. Botany, Sul Ross State University; candidate for Ph.D. in Botany, The University of Texas at Austin. Botanical Team Leader for Mount Livermore-Sawtooth Mountain and Canadian Breaks; director of the botanical field work and principal author of the botany sections for these two reports.

JAMES KENNETH STINNETT – B.S. Biology and candidate for M.S. Biology, Angelo State University. Graduate Research Assistant and Curator of Vertebrate Research Collection, Angelo State University. Conducted zoological investigation and authored the terrestrial vertebrates section of the Devil's Sinkhole-Hackberry Creek report.

JACKIE M. SMITH – B.A. Botany, M.S. Botany, candidate for Ph.D. Botany, The University of Texas at Austin. Botanical Assistant in preparation of collections and in writing the botany section of the Mount Livermore-Sawtooth Mountain and Canadian Breaks reports. Botanical Team Leader for Devils River and Devil's Sinkhole; director of the botanical field work and principal author of the botany sections for these two reports.

WILLIAM A. WARD – B.A. Anthropology, M.A. History, doctorial student History, The University of Texas at Austin. Anthropological Research and Laboratory Assistant to the Anthropological Laboratories, The University of Texas at Austin, 1973-74. Conducted research and wrote the historical sections of each report.

HAYDEN WHITSETT – B.A. Anthropology, B.A. Journalism, Texas A&M University; graduate student Anthropology, The University of Texas at Austin. Teaching Assistant, Anthropology, Texas A&M University. Archaeological project assistant in the field and in material and report preparation and writing for the archaeology section in each report.

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IMPRESSIONS OF THE DEVIL'S SINKHOLE

Griffin Smith, jr.

Picture yourself suspended from a single thin rope, fifteen feet from the nearest land beside you—if you could reach it, which you can't; and 140 feet from the nearest land below you—which you can reach, easily. By falling. If the rope breaks.

Which ropes have been known to do.

You are disposed, in that situation, to ponder how you got there. If you visited the Devil's Sinkhole with the Natural Areas Survey Project in July, 1974, you got into that situation by strapping yourself into a mountainclimber's harness, donning a motorcycle helmet, clipping your harness to the rope, and stepping as nonchalantly as possible off the edge of the Hole.

One of life's most uncommon experiences is to walk over the edge of a 140-foot cliff without, as they say, *result.* This is the same formidable cliff that you first approached a few moments before on your knees, or perhaps creeping along on your stomach: a large, almost circular pit in the shin oak grasslands of northeastern Edwards County, tucked away in a self-effacing patch of countryside that effectively conceals its presence until you wander up to the perimeter and notice that it just . . . drops. Very far. As far as a fourteen-story building. Farther than it seems prudent to pursue.

But eventually your turn comes, and you stride toward the Hole until your feet tread air. You do not plummet because the rope passes through a boom welded to the bed of a pickup truck parked at the edge of the hole, and thence to the frame of a second pickup truck, where it is, you are told, securely fastened. At the very moment your feet begin to dangle, that second pickup is backing toward the Hole from its position a hundred yards away, lowering you effortlessly down.

As you descend below the surface of the earth, your mind recapitulates forgotten images out of literature: Jonathan Edwards' spider suspended over the void; Jonah engorged by a colossal gullet. Leaving behind the outside world's insistent glare, you find yourself spiraling silently down a stone-lined cylinder of cool air, aware of no sound except the pulley's diminishing squeak. With each rotation of the twisting rope an unexpected sight comes into view: the hives of honeybees, the nests of canyon wrens, a pair of Great Horned Owls. A colony of some 500 cave swallows has built nests with the mud that forms below the fern-lined, seeping walls. Along a narrow ledge, a solitary mountain mulberry struggles toward the light.

Aeons ago, the Sinkhole was an enclosed, water-filled chamber, roofed by a few feet of resistant limestone. But gradually, as the neighboring streams cut deeper, the falling water table drained the Sinkhole. Its unbuoyed ceiling collapsed with a roar, leaving a conical mountain of rubble that now towers 170 feet from the floor.

Released from your harness, you can wander down this steep-sided mountain through a twilight region of deepening shadows where resilient life forms have adapted precisely to changing zones of light. A few minutes of sunshine near the top is enough for meadow spikemoss, but farther down the dim gloom precludes all vegetation. This is the realm of bats: millions of Mexican free-tails hang in the darkest corners, emerging at sunset in an awesome rush that sometimes lasts forty minutes. Fifty-four kinds of arthropods—mostly spiders—scurry, creep, and chew their way across the guano-covered rocks. Occasionally rattlesnakes, racoons, and other surface dwellers tumble by accident into the Sinkhole; the few that survive the impact soon die, bewildered, of starvation, leaving eerie skeletons draped across the rocks.

Halfway down the slope, you receive a spectacular reward for the rigors of the descent. Above, like an immense inverted funnel, the walls slant upward to the Sinkhole's mouth. Brown rocks give way to green ferns, riveting your attention on the central dome of brilliant blue sky. This tiny circle, a window opening onto nothing but air and color and a transient cloud, is the only visible reminder of the world above—the world from which, moments ago, you peered disbelieving into this Plutonic pit. Now that world itself seems vaporous, unreal. It is a triumph of perspective.

Continuing your descent along the slippery rocks, you soon enter a region of perpetual darkness where overhanging ledges shut out the sky. At the foot of the rubble are several small pools in which the Sinkhole's only true cave-adapted species can be found. One, a tiny blind crustacean called *Stygonectes hadenoecus,* is found nowhere else on—or under—earth.

The Sinkhole's pools are actually part of a slow-flowing underground stream that emerges as springs along Hackberry Creek or the Nueces River. The confluence of these two waterways, seven miles to the southeast, takes place in a classic Hill Country setting.

Much of the surrounding area, however, has been subjected to extensive clearcutting and overgrazing.

But in the moist side canyons, undisturbed ferns, cedar sedge, and deciduous oaks can be found; nearby, a few Mexican pinyon fight grimly against their multiple enemies: needleborers, porcupines, and an ever-dryer climate. Along the floodplains of the East Prong of the Nueces, pecans and little walnut trees have prospered since the days when Spanish travelers first named this "River of Nuts." In still, muddy pools, a carnivorous plant called the conespur bladderwort feasts on microorganisms. The few juniper thickets along Hackberry Creek provide nesting sites for the finicky Golden-cheeked Warbler, an endangered bird unique to Texas. Although the climate and vegetation are basically western, a surprising number of eastern vertebrates have made their way along the Hill Country canyons; nearly a third of the terrestrial animals originated in the eastern United States, and nearly a fourth of the birds.

Proximity to the Rio Grande opened the Upper Nueces to Spanish influence far more thoroughly than many other parts of Texas. As early as 1590, rumors of silver brought explorers here; they were followed by surveyors and missionaries. In 1762, the mission of San Lorenzo de Santa Cruz was found 13 miles south of the confluence of Hackberry Creek and the East Prong of the Nueces. Under fire from the Comanches, it was abandoned in 1771 and the site went fallow until American infantrymen returned in 1857 to reoccupy it under the name of Camp Wood.

Though the Army post was permanently closed upon the outbreak of civil war, the road that linked it with other posts along the frontier was later used by settlers occupying the Upper Nueces canyons. Once the Indians were subjugated after the close of the war, bold cattlemen brought the "free grass" ranching era to the open range of South Texas. Soon the hooves of Long Horn cattle bound for market, rumbled through the winding, narrow canyons of the Upper Nueces, past the site of the modern-day Eagle Ranch which a new century's entrepreneurs-Ling-Temco—Vought—would build as a retreat for their executives.

These tricky canyons attracted more than their share of desperadoes and cattle thieves: John Wesley Hardin, Ben Thompson, and Bill Longley in the 1870's; the Black Jack Ketchum Gang, the Pegleg Gang, and Butch Cassidy's Hole in the Wall Gang in the 1880's and 1890's. Long past the time when law and order prevailed elsewhere in Texas, the Upper Nueces persisted as an outlaw sanctuary.

Not surprisingly, there is no record that Butch Cassidy and his partners ever stopped by to gape at the Devil's Sinkhole; their enthusiasms took a different turn. But the local bandits could not have been entirely absent from the mind of a man named H. S. Barber, who managed to descend the Sinkhole and carve his name at the bottom in 1889, temporarily leaving his rope or ladder—and thus his only means of returning—at the mercy of whoever happened by.

If you follow him today, you share his absolute dependence on the good will of anyone on the rim; there is no way to escape unaided. But paradoxically, as you look up to that tiny window, the ties than join you to your fellow men on the surface seem altogether insubstantial. You are merely a particle in the earth's crust, swallowed. You could be anywhere. Not until you reattach yourself to the harness and spiral slowly upward out of the clammy air into the scalding light of the plateau do you restore your conventional perspective. The disorienting shock dispels. You walk away, not wishing to look back down. The pickup driver turns; you wave: "Thanks! Great entertainment."

HISTORICAL SURVEY OF THE UPPER REACHES OF THE NUECES RIVER

William A. Ward

The region of the upper Nueces is one of rugged transition in which the southern limits of the Edwards Plateau are sharply defined by the canyons and hills of the Balcones Escarpment. It is just at the northern edge of the escarpment that the River's source originates from the limestone springs which feed its two initial branches before they merge to form the Nueces proper.

The aboriginal population of this area was a group of tribes which were descended apparently from archaic hunters and called Tonkawas. Their own name for themselves was Tickanwatick, which meant "most human of men." These Indians were not one tribe but a group of tribes who spoke a language apparently unrelated to any other Amerind stock, although it has been suggested that they were related linguistically to the Coahuiltecans and were speaking a dialect of Hokan. These people were typical pre-horse southern plains Indians, living by hunting, fishing, and gathering nuts, fruits, and berries. They lived on the edge of bison country in buffalo hide tepees and used large dogs as beasts of burden. Like most Texas Indians, they tattooed their bodies and practiced ritual cannibalism. Their principal weapons were the bow and lance. They also dipped the points of their arrows in mistletoe juice, presumably because they thought this would act as a poison, but it could also have been part of a hunting ritual or rite to guarantee success. The Tonkawas did not hunt or raid very high on the Texas plains, being restricted to the Edwards Plateau, the better hunting grounds being the province of the Apache and later the Comanche.[1]

The geographical region occupied by the Tonkawas was one which eventually worked against their survival. They were never a particularly billigerent people and were more easily attracted to mission life and its influence than were the Apache and Comanche. The inevitable plagues that struck aboriginal peoples when they gathered around Spanish missions cut into the Tonkawas' numbers and made them easy prey for the Comanches, who swept over their hunting grounds in the nineteenth century.[2] The dual effects of invasion and disease reduced their numbers to but a few hundred by the 1840s. In the 1850s the federal government moved the remnants onto a reservation on the Clear Fork of the Brazos. Shortly the complete expulsion of all Indians from the state was demanded by the Texans, resulting in the Tonkawas being moved to another reservation along the Washita River in southwestern Oklahoma. These remnants gradually died out or were absorbed by other tribes, with the result that the Tonkawa Indian group was extinct by the turn of the century.[3]

At some historically recent—but as yet undetermined—date these wandering Tonkawa tribes began to feel the impact of a new and very hostile Indian nation which had appeared out of the north and very quickly seized the rich hunting grounds of the plains as their own. These were the Apache, who considered all other Indians their enemies. The Apache invasion of the southwest was a disaster for many of the indigenous peoples of the area. They pushed out many of these tribes, exterminated others, and settled into their former homeland to make ceaseless war on those who remained.[4]

At this time the Apaches split into two groups, the eastern and the western Apaches. The western tribes, consisting of the Navaho, San Carlos, Chiricahua, and Mescalero made New Mexico and Arizona their domain, ceasing to be completely nomadic as they learned rudimentary agriculture from the Pueblo Indians with whom they continued to war. The eastern Apaches, consisting of the Jicarillas, Palomas, Carlanas, and Lipans, destroyed the Puebloan culture of the Texas Panhandle and began to exterminate the Jumanos of the Trans-Pecos area, while the Tonkawas were pushed to the southern fringes of the buffalo hunting grounds. With their conquest complete, the eastern Apaches then made semipermanent settlements, with one tribe (the Jicarillas) even beginning to utilize a crude irrigation system to water their corn. The other Apaches, however, remained primarily a buffalo hunting people.[5]

The Apache at this time hunted afoot, a fact which greatly restricted their ability to follow the wide-ranging buffalo for any great distance. When the bison herds migrated north, the Apaches hunted other game and utilized simple agriculture, while assembling themselves into semipermanent camps called rancherias by the Spanish and composed mainly of buffalo hide tepees. With the coming of the

Spanish and the introduction of the horse, the Apaches became even more fierce predators of their weaker rivals, as well as launching devasting attacks on the Spanish frontier communities, leading to an eventual policy of extermination toward them.[6]

Apache preeminence on the plains, however, was to be short-lived. By the beginning of the eighteenth century they found themselves suddenly being attacked by a new people who had only recently come down out of the western mountains and onto the plains where, upon newly acquired ponies, they began a steady and terrible offensive against the eastern Apache nation, one which resulted in the routing of the Apaches from the plains and the extinction of many of their bands. These new people were the Comanches, a people of unyielding purpose and terrifying ferocity who, mounted on Spanish ponies, became one of history's most spectacular and effective cavalries. Culturally, they were northern Shoshones, whose name *Comanche* means "enemy" in the Ute language.[7]

The largest and best-known Comanche band was the Panatekas or Honey Eaters, who were the southernmost of the Comanches and had led the advance onto the southern plains. They spread across the Edwards Plateau and into Central Texas, displacing the Lipan Apache and warring with the Tonkawas, who were not able to offer any effective resistance.[8]

The eventual destruction of the Comanche nation did not begin until after the Anglo period in Texas when the frontier moved steadily westward onto the hunting grounds of the Comanche. In order to subdue the Indians, it became a government policy to destroy the buffalo herds so as to deny the Comanche his source of food and to force him onto the federal reservation in Oklahoma, a policy that was carried out with brutal thoroughness until the back of the Comanche nation was broken.

European exploration of the area began in 1535 with the long trek back to Mexico by Cabeza de Vaca and his three shipwrecked companions who had been held more or less as captives of the Atakapan Indians of southeast Texas for some five years. De Vaca's group crossed the Nueces River on about July 20, 1538 as they walked along the base of the Balcones Escarpment. De Vaca first called the river the Nueces, or river of nuts, because of the many pecan trees along it. The path followed by de Vaca led through present Kinney County and then into Val Verde County where the Spaniards crossed the Rio Grande near the present location of Del Rio and followed it north into the Big Bend and then cut westward to the Pacific coast where they were finally rescued by a Spanish slaving expedition.[9]

De Vaca's route generally paralleled the later Spanish Imperial road from San Juan Bautista on the Rio Grande to San Antonio and was known as the Comino Real. This road was laid out in 1691 by the first Spanish governor of the region, Domingo Teran de los Rios, by order of the king of Spain to service the new East Texas missions which had first been initiated as a buffer against possible French incursion. La Salle's ill-fated colony on the coast was the precipitating factor in this action, creating a sudden rush of Spanish activity from the Rio Grande along the base of the escarpment to East Texas, with Alonzo de Leon and Father Massenat leading the Spanish venture eastward.

Prior to the building of the Camino Real several other Spanish expeditions ventured into the area. In 1590 Don Gaspar Castano de Soza led a party of adventurers across the Rio Grande at Eagle Pass in search of silver mines. They crossed the Nueces near Montell and continued to the general area of Salado. Old mine shafts on the upper Nueces may have been the result of this party's activities.[10]

In 1650 an expedition led by Diego Castillo came southeast from New Mexico and traveled down the Nueces before turning back. This expedition was immediately followed by that of Diego de Guadelajara, who with thirty soldiers and two hundred Indian allies explored the length of the Nueces. At almost the same time a small survey party led by Diego Ortego went up the river, making a survey of the Indians living there.[11]

In 1675 a missionary expedition commanded by Fernando del Bosque and accompanied by Father Juan Larios briefly penetrated onto the Edwards Plateau by way of the Nueces River but found nothing of particular interest to them. It was on this occasion, however, that the first authenticated Catholic Mass took place on Texas soil. Father Larios also baptized several hundred Indians before the party returned to Mexico, leaving the Indians, no doubt, in a state of some confusion as to what it all meant, before they happily reverted to their former state and went back to hunting buffalo.[12]

In 1720, as a result of incessant Apache raiding around San Antonio, the Spanish fielded a punitive expedition against their stronghold in the hill country around present-day Bandera. This expedition was led by General Bandera, for whom the county was later named. In a narrow pass now called Bandera Pass the Spanish and Apaches fought a three-day battle which resulted in a complete rout of the Apaches, who retreated and settled in New Mexico.[13]

It was not until the mid-eighteenth century that a permanent Spanish settlement was attempted on the upper Nueces, an effort which came about as the result of two disasters for the Spanish as they tried to stabilize their frontier with the Apaches and the onrushing Comanches. In 1755 a wealthy mine owner in northern Mexico, Pedro Romero de Terreros, offered to finance a mission for the Apaches and to maintain it for three years if his cousin, Father Alonso de Terreros, was placed in charge of the mission. This arrangement was agreed to, and in 1756 Father Terreros and four other Franciscans headed into Apache country on the San Saba River. They were accompanied by one hundred troops under the command of Colonel Diego Ortiz de Parilla. In April, 1757 Father Terreros founded the Mission San Saba de la Santa Cruz on the south bank of the San Saba River in present day Menard County. Some two miles upstream Colonel Parilla built a massive stone presidio which was named San Luis de las Amarillas.[14]

By June of 1758 there were some 3,000 Lipan Apaches camped around the mission. They remained aloof to the mission, however, and shortly left on a buffalo hunt. During the winter, rumors reached the Spanish that the Comanche planned to attack the mission in the spring. The naive fathers ignored these warnings and refused to move into the presidio at Parilla's suggestion, believing the rumors to be only that. Their foundation in fact was made cruelly apparent to the Franciscans when in March of 1759 the mission was suddenly surrounded by 2,000 Comanches who very quickly overwhelmed the mission and massacred everyone they could lay their hands on and burned the buildings. Only four people survived, having barricaded themselves in a room.[15]

After a council of war in San Antonio, it was decided that Colonel Parilla would lead a punitive expedition against the Comanche. In the summer of 1759 Parilla marched north with a force of 500 soldiers and a few pieces of artillery. The Spanish followed the Comanches all the way to the Red River, where they finally confronted them, and to the amazement of the Spanish, were neatly forted up behind the pallisades of a fortified town. The site of this fort was in present Montague County at a Taovayas Indian village which was surrounded by a moat. Above the stockade flew the French flag, as it was a center of French trade with the Indians, who exchanged various goods for French guns and ammunition.[16]

Parilla decided on bold, frontal assault which proved to be a very bad tactic as the Spanish were beaten off and very nearly outflanked because the Comanches sallied out from the village to meet the charge. Parilla was only just able to extricate himself and his men, retreating south as fast as possible and abandoning his baggage and the cannon to the savages. As a result of this defeat, the Spanish never again attempted a military operation against the Comanches. The site of this battle was later named Spanish Fort by Anglo settlers in the nineteenth century.[17]

Parilla led his men back to the presidio on the San Saba. Here he was replaced as commander by Captain Felipe de Rebago y Teran, a man formerly charged with having murdered a priest at another mission. He had been tried and found not guilty, but it was fairly clear to all that he had been. As a result of the double disaster associated with the San Saba Mission, it was decided that a second missionary effort among the Lipans should be made farther south in a region less exposed to Comanche attack.[18]

In 1762 Rebago and Father Diego Jimenez decided on a site on the upper Nueces, which they called El Cañon as the location for a new Lipan mission. Here there was shortly erected the mission San Lorenzo de la Santa Cruz. A short time later at the request of the Apache chief El Turno, or Cross-Eyed, another mission was built some twelve miles south of the first mission on the west side of the Nueces and known as Nuestra Senora de la Candelaria del Cañon. These two missions were built without formal approval of the viceroy who later refused to accede to Rebago's plan for a presidio, as well as refusing to recognize the missions. A detachment of soldiers was, however, maintained in the area, the two missions being commonly referred to as El Cañon.[19]

Initially these two missions were a modest success, but very shortly they attracted the attention of the Comanche. In 1766 the Comanche moved into the hilly country of the Balcones with their motive being to surprise the Lipans in the missions and destroy them at one blow instead of having to wait for them to come out onto the plains on their buffalo hunt. El Turno and his people had heard of this, however, and had abandoned the area. The Candelaria mission personnel were pulled back to San Lorenzo just prior to the Comanche attack by some 300 warriors. The soldiers, having received a warning of the attack, were able to beat it off and repulse the Indians. The Comanche returned a month later, however, and tried again, and after a day-long battle were again repulsed.[20]

By the spring of 1767 the mission was in a state of almost constant seige by war parties. These attacks destroyed any purpose the mission might have had in converting Apaches, for by that time no Apaches were left in the entire area, having abandoned central Texas altogether.[21]

It was at this time that Marquis de Rubi made his famous inspection of the Spanish frontier, visiting as he did the Mission of San Lorenzo in the summer of

1767. Rubi was a Spanish field marshal appointed by the crown to inspect the frontier and to offer suggestions for improving the Spanish position there. Rubi described San Lorenzo as having no real purpose any longer, but recommended that the San Saba presidio be abandoned and its garrison be transferred to the San Lorenzo Mission. In 1769 the commander at San Lorenzo was ordered to send most of his garrison to San Antonio, which meant virtual abandonment of San Lorenzo. In June of 1771 the viceroy ordered final abandonment of San Lorenzo Mission, bringing to an end the Spanish effort to pacify the Lipan Apaches in order to create a buffer between its settlements and the Comanches.[22]

A final Spanish foray into this region occurred in 1790 when Captain Juan de Ugalde of the Mexican Army was sent as the head of a punitive expedition against the Comanches. After fighting a fierce engagement in Sabinal Canyon, Ugalde drove the Indians ahead of him out of the canyon and across the Llano River, burning all their villages in the process. In his honor the city and county of Uvalde were named.[23]

Spanish activity in this region was limited primarily to the Rio Grande, where small settlements had grown up around the mission and presidios. In 1805 the Nueces, however, was made the official boundary between Spanish provinces of Nuevo Santander and Texas.[24]

Anglo settlement in this area began in the early 1830s with the establishment of Beales' Rio Grande Colony. In 1832 John Beales and James Grant received empresario grants to settle emmigrants between the Nueces and the Rio Grande. The first colonists landed at Copano Bay in 1833 and journeyed overland to the site of the first settlement on Las Moras Creek near the Rio Grande. In 1834 the settlers established their first town, naming it Dolores in honor of Beales' wife.[25] The colony was doomed to failure, however, due to marauding Indians, drouth, and lack of irrigation. The outbreak of the Texas Revolution and Santa Anna's threat to drive out all Americans caused a general exodus. The wagon train carrying the settlers away was attacked, however, by Comanche Indians on the Matamoras Road, and all were killed except for two women and their small children who were made captives.[26]

In 1842 the second battle of Bandera Pass occurred between a company of forty Texas Rangers led by Jack Hays and some 100 Comanches. As Hays and his men rode through the pass, they suddenly found themselves enveloped in an ambush as the Indians swooped down on them from the hillsides and engaged them in hand-to-hand combat. The Comanches chief was himself a victim of a Texas Ranger's Bowie knife. As a result of his death the Indians broke off the engagement and withdrew to the north end of the pass while the Rangers moved to the south, each side taking its dead and wounded with it. Five Rangers were killed and six wounded and the Ranger dead were buried in a common grave. After a long night of howling and chanting while they buried their own dead, the Comanches withdrew the next morning. Among those who participated in this battle were Ben McCulloch and Big Foot Wallace.[27]

As the Anglo frontier moved steadily toward the west, a line of forts was established in the Nueces area to guard against Indian attack and marauding bands of Mexican bandits. One of these was Fort Inge which was built on the east bank of the Leona River in Uvalde County and named for Lieutenant Zebulon Inge killed in the Mexican War. The post was established and garrisoned in 1849. In 1856 Robert E. Lee visited it during an inspection tour. The post was occupied by the confederates in the Civil War and then reoccupied by the federals before it was finally abandoned in 1869.[28]

Near Fort Inge another post, Fort Clark, was established at the head of the Las Moras Creek near Bracketville in Kinney County in 1852. It, too, was named in honor of a Mexican war casualty. Fort Clark was used by the confederates and then reverted to federal control where it was used by practically every cavalry regiment. As the land had never been officially obtained by the government, it was purchased for $80,000 from Maury Maverick in 1884. The post remained in continuous use until 1946, when it was deactivated and converted into a guest ranch.[29]

On the north Llano River halfway between Junction and Sonora, Texas another post was built in 1852 and named Fort Terrett for Lieutenant John Terrett, a Mexican war casualty. The Fort was abandoned, however, in 1854.[30]

In 1857 a company of the First Infantry occupied the grounds of the old San Lorenzo Mission and established Camp Wood. In 1858 a company of cavalry was added which patrolled the Nueces for Comanches. With the approach of the Civil War, the Fort was abandoned in 1861.[31]

The old military roads linking these outposts were later used as stagecoach roads. The road between Fort Inge, Fort Clark, and Camp Hudson on the Rio Grande became the route of the San Diego stage from San Antonio. The road linking Fort Inge, Camp Wood, and Fort Terrett was later used by the settlers in opening up the upper Nueces for settlement. Another old stage road followed the divide between the main Nueces and its west prong to connect with the Fort Inge-Fort Concho Road near the Devil's Sink Hole in Edwards County. A portion of this road had been blazed earlier by the Spanish as they moved south from San Saba to the El Cañon missions, a trail later followed by the Marquis de Rubi.[32]

The settlement of the upper Nueces Canyon began soon after the creation of Edwards County. In 1858 the Texas government appointed Charles de Montel of Castroville to survey and map the upper Nueces for distribution of public lands. De Montel's name had been Schudenmontel before he came to America. He was a native of Poland and left during the 1848 uprising, changing his name to de Montel. He was instrumental in founding the town of Bandera, and the later town of Montel was named in his honor.[33]

During the Civil War there occurred in this region the unpleasant affair known as the Battle of the Nueces. On the morning of August 10, 1862 sixty-five Union sympathizers camped on the west bank of the Nueces River some 25 miles from Fort Clark. These men were led by Fritz Tegener. They were representative of the liberal element which had fled Europe in the 1848 revolution which swept through the European states. Their liberal ideas were not in unison with the concepts of the Confederacy, and these men were attempting to reach Mexico. On the morning of August 10 they were attacked by 94 confederates. Nineteen of the unionists were killed outright and nine wounded. These wounded were then executed and their bodies left on the ground unburied. Six more unionists were killed on October 18, 1862 while trying to get across the Rio Grande. Some twenty others managed to escape across the river and continued to California. After the war the bones of those killed on the Nueces were gathered up and buried.[34]

Indian raiding continued with a new ferocity, after the war, resulting in the dispatching to the Nueces and Rio Grande area in 1873 of General Ranald S. Mackenzie and his Fourth Cavalry. With 400 men Mackenzie set out from Fort Clark against the Lipans and bandits who were raiding from Mexico. At the village of Rey Molina he engaged the enemy, destroying a Kickapoo and a Lipan village and capturing the Lipan chief, Castillitos. This expedition resulted in a flurry of protests from Mexico, which diminished when it was shown that these raiders had inflicted some 50 million dollars worth of damage.[35]

In the 1870s this region around the upper Nueces was the center of operation of a large number of desperadoes, cattle thieves, and gunmen. Among the most noted of the gunfighters of this time were Bill Longley, John Wesley Hardin, King Fisher, and Ben Thompson. Hardin was known by the Rangers as the World Champion Desperado, having reputedly killed forty-three men. Hardin gained his reputation during the Sutton-Taylor feud in south Texas. He was eventually arrested in Florida by a Texas Ranger and sent to prison where he studied law. Almost immediately after his release he was involved in a gun fight and killed.[36]

Bill Longley gained his reputation by specializing in shooting innocent Negroes, earning the appellation as the "official nigger killer." One of his favorite stunts was to ride into a Negro camp meeting and begin shooting. On one occasion he was brought in for trial by a friend who, after collecting the $1,500 reward, pulled a gun on the jailer, released Longley, and divided the reward with him. Longley was also one of the few men to be hanged twice. On the first occasion, the rope was shot in two by his friends and he escaped. The second hanging proved to be more successful, however, and Longley died in 1878 with a reputed record of 32 killings.[37]

King Fisher became a bandit leader very early in his life, for by the time he was twenty, he was in charge of a gang of some 100 outlaws who ruled the country between Castroville and the Rio Grande. He had a ranch near Uvalde and on the road to it a large sign was posted which read, "This is King Fisher's Road. Take the other." King Fisher was finally arrested by Ranger Captain Leander McNelly as Fisher walked casually down the street in Piedras Negras. He was taken to Del Rio where he was charged with eighteen homicides. The citizens of Del Rio, however, were realists and knew what would happen if King Fisher stood trial. He was therefore turned loose, along with nine of his men. The citizens took no chances because they also turned loose all the stolen cattle the Rangers had rounded up. It was this kind of behavior that caused the Rangers to resort on future occasions to the *ley de fuga* in which a suspect was generally killed trying to escape or resisting arrest. Fisher very shortly performed a dramatic about-face after marrying, even serving as a deputy sheriff in Uvalde. After several terms, he ran for sheriff but was killed with his old friend, Ben Thompson, in San Antonio before the election.[38]

Ben Thompson, who had been born in Yorkshire, England, was every inch the cold-blooded killer. For a while he was city marshal of Austin, where he would walk up and down Congress Avenue, waiting for a cowboy to start a fight with him so he could kill him. A drunken cowboy once knocked Thompson's hat off into the street. Thompson responed by shooting off the cowboy's ears. Thompson was killed in San Antonio when he and King Fisher walked into an ambush set up to kill him in a saloon; Fisher was the unfortunate victim of a plot to kill Thompson.[39]

In 1877 the Frontier Battalion of the Texas Rangers began what was known as the Kimble County Clean-up. At the head of the Nueces River and along the Llano there was operating at that time a large-scale cattle and horse thieving operation, as well as its being the headquarters for a large number of outlaws and gunfighters of every description. The depredation had become so intense that the ranchers were losing up to fifty head of cattle and horses a day. As a result, the townspeople and ranchers began arming for vigilante action. All the available ammunition for Winchester and Sharps carbines was sold out in a very short time.[40]

It was at this point that Judge W. A. Blackburn wrote from Lampasas to Major J. B. Jones of the Texas Rangers that the situation in Kimble County was at the flash point and indicated that unless the Rangers intervened, a small war was about to break out. Major Jones responded at once and set in motion a large-scale sweep of Kimble County to capture the outlaws. Operating out of Junction, his troop of Rangers moved out over the surrounding countryside where they rounded up some forty outlaws who were taken to Junction, then called Kimbleville, where they were put into a bull-pen. Court was convened under a large live oak tree with Judge Blackburn presiding, and a large number of indictments were returned by the grand jury, indictments which included the county sheriff and judge, who forthwith resigned.[41]

In the 1880s and '90s, the upper Nueces area of Junction, Rocksprings, and Sonora became again the headquarters of several organized bands of outlaws. These included the Black Jack Ketchum gang which operated around Sonora, the Pegleg gain which operated in Kimble and Edwards Counties, and the Hole in the Wall gang which operated in the Nueces Canyon. This latter group, known also as "the Wild Bunch from Robbers' Roost," was led by George Leroy Parker, better known as Butch Cassidy. Other members of the gang included Harry Longabough, Harry Logan and Kid Curry. Due to increasing pressure from the law, the gang broke up with Cassidy, Longabrough and Logan fleeing to South America. Logan was later killed while on a climbing expedition in the Andes. Cassidy and Longabough attempted to become peaceful ranchers but apparently incurred the enmity of the local authorities who raided their ranch. Longabough was killed in his sleep, but Cassidy fought a day-long battle from a rocky corral before shooting himself in the head with the last bullet from his notched gun as the soldiers rushed him.[42]

After the Civil War and the elimination of the Indian menace in the area, a large scale "free grass" ranching industry grew up, based around South Texas longhorns and, later, sheep and goats. One prong of the Western Trail to Dodge City went through this area. Originating in Uvalde, Edwards and Kimble Counties, the branch went north to join the main trail at Fort Griffin.[43]

Every spring large herds of longhorns heading northward would pass through the winding canyons of the upper Nueces. The trail drivers reputedly dreaded the difficult drive through the Nueces headwater country, as they had to string out their herds sometimes as far as two miles to get them through the crooked canyons. The cowboys working the herds were often a quarter of a mile apart, allowing cattle rustlers to rush in and cut out a few trailing cattle and run them into a nearby ravine. Here they would hobble the animals, change the brand, and then herd them to market.[44]

As ranching expanded in the area, a new concept was introduced which revolutionized the cattle industry. This was barbed wire, which was developed in the 1870s from a multitude of patents. The most commonly used type was that developed by J. F. Glidden and put into production by 1880. One of his salesmen, John W. "Bet-a-Million" Gates, quickly popularized the product in Texas. Gates, utilizing a flair for showmanship, put up a section of barbed wire in the San Antonio Plaza and bet curious ranchers that they could not drive a cow through it.[45]

The introduction of wire fencing led very shortly to a major clash between "free grass" cattlemen who grazed their herds on the open ranges and those ranchers who had bought or leased their pastures and had begun to fence them. In this first rush of fence building, access to rivers, water holes, public roads and even schools and churches was cut off. The result was a rush of fence cutting in the early 1880s which reached its peak in 1883. So intense was this clash that the fence cutters even set pastures on fire. A special session of the legislature was called in 1884 to deal with the problem which had already caused some 20 million dollars in damage. Criminal statutes were enacted against building fences across public roads, enclosing public land and cutting off access to another man's property. It was even made a crime to own wire-cutting tools. These laws were enforced by the Texas Rangers and the fence-cutting wars very shortly petered out.[46]

In the 1880s, sheep and goat ranching was introduced into the area and quickly replaced cattle as the chief form of ranching. This region of the upper Nueces and Edwards Plateau came to be one of the great centers of the sheep and goat ranching industry, with the world's chief source of mohair centered there.

On these large sheep ranches, the work was divided among four types of employees along the lines of the

Spanish or Mexican system, whose terminology was retained. The lowest in rank was the *pastor* who, along with his dogs, kept watch over his flock of some 1000-1500 sheep. Supervising the work of the two or three *pastores* was the *vaquero* who decided on the areas the flocks were to be grazed in from day to day. Over several *vaqueros* was a *caporal* and over the *caporales* was the *major-domo* who was in charge of the entire operation. Most of these shepherds were Mexicans.[47]

As this industry approached significant proportions, the Merino became the most popular breed of sheep and the Angora the most popular breed of goat. On a typical ranch the Mexican herders received a salary of $12.00 per month plus a $6.00 food allowance, while wool and mohair brought in an average of 30 cents a pound, or about $1.50 per animal. There was therefore created a sizeable return on the investment with a minimum of expense. Sheep, goat and cattle ranching remain today the chief economy of this region.[48]

One final curiosity of the region is not a man-made feature but one of nature's dramatic oddities. This is the Devil's Sink Hole in Edwards County near Rocksprings. Here, the dome of an ancient cavern collapsed, leaving a vast hole in the ground some 75 feet across at the top. Cattle grazing in the area are extremely wary of this vast pit and will not come within a thousand yards of it. Its location is not easily identified except in the evening when above it a black spiraling cloud of bats forms, extending upward some 150 feet into the air. From the lip of the cave mouth to the bottom is a straight drop of 325 feet. It was formerly thought to be 407 feet, but this was later determined to be in error. At the bottom the sink hole is some 300 feet across and can be reached only by descending in a bosun's chair on a cable. From the bottom there extends to varying depths caverns or chambers in which are found the so-called Emerald Pools of water with their blind fish, crustaceans and exotic rock formations. The entire length of the caverns has not been totally explored, but they are thought to represent a sizeable area, earning the Sink Hole the title of the Carlsbad Cavern of Texas.[49]

In retrospect it is seen that this scenic, hilly, canyon-filled country has been the focus of a very colorful and dramatic history. From the terrible and traumatic period of Apache and Comanche depredations and the brave folly of the Franciscan fathers to the age of the cattle baron and the outlaw, the region has echoed repeatedly with the sounds of war, conquest, and cruelty before the softening effects of civilization and law and order banished for the time being the violent color of its past, replacing it with the softer hues of the mundane rancher and the ubiquitous tourist.

FOOTNOTES

1. T. R. Fehrenbach, *Lone Star* (New York, The McMillan Co., 1968) p. 14-15.
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5. Ibid.
6. Ibid, p. 16-17.
7. Ibid., p. 157.
8. Newcomb, p. 157.
9. Allen A. Stovall, *Breaks of the Balcones* (Austin, Firm Foundation Publishing House, 1967) p. 13.
10. Ibid., p. 14.
11. Ibid.
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24. Ibid., p. 291.
25. Ibid., p. 128.
26. Ibid.
27. Ibid., p. 105.

28. Ibid., p. 627.

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33. Ibid., p. 104.

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39. Stovall, p. 211.

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41. Webb, p. 332-334 and Stovall, p. 231.

42. Stovall, p. 253-254.

43. *Texas Handbook,* p. 886.

44. Stovall, p. 217.

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48. Ibid., p. 434.

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GEOLOGIC ENVIRONMENT OF THE DEVIL'S SINKHOLE - HACKBERRY CREEK AREA NUECES RIVER HEADWATERS EDWARDS AND REAL COUNTIES, TEXAS

Dwight Deal
Chihuahuan Desert Research Institute, Alpine, Texas

INTRODUCTION

This report is prepared for the Natural Areas Survey, Division of Natural Resources and Environment, the University of Texas at Austin. It is intended to be used by both geologists and nongeologists and at the same time to provide a resource document on the geology of the area. The general geologic setting of the Devil's Sinkhole-Hackberry Creek area in the upper Nueces River headwaters is fairly simple: the exposed bedrock is all resistant limestones of the Edwards Group, and the only other sediments are unconsolidated slope debris and valley-fill material of Quaternary age.

Limited field work was done in the area in July, 1974. There are three published geologic maps that cover the study area (Long, 1958 and 1963; Barnes *et al.*, 1974), and I spent most of my field time checking that work.

I have attempted, for the purposes of this report, to reduce technical jargon to a minimum. This has not been possible when quoting directly the words of others, and nongeologists will find the *Glossary of Geology* (Gary *et al.*, 1972) a useful reference. This area is quite similar to the area around Dolan Falls on the Devils River visited by the Natural Areas Survey field team earlier in the summer of 1974. Climate, rocks, and ground-water resources are so similar that I am avoiding making many needless repetitions by referring to the companion report on that area (Deal, 1974).

PHYSIOGRAPHY AND CLIMATE

The Devil's Sinkhole-Hackberry Creek area is in the southwestern Edwards Plateau physiographic province. The headwater tributaries of the Nueces River have cut deep canyons below the plateau surface which remains undissected in the northern part of the study area. Local relief is 500 to 600 feet.

The climate is typical of the semiarid regions of the Edwards Plateau. Average annual precipitation on the plateau ranges from more than 35 inches in the east to less than 20 inches in the west (Long, 1963, p. 15). Average temperatures increase in that direction. This east-to-west change may be illustrated by comparing the average annual precipitation and temperature for Real, Edwards, and Val Verde Counties (table I and II; Deal, 1974, tables I and II). Temperatures are slightly lower and rainfall slightly higher in this area than it is in the Dolan Falls area (Deal, 1974). The distribution of rainfall is uneven and intermittent in the Devil's Sinkhole-Hackberry Creek area, just as it is in the Dolan Falls area (Deal, 1974). Because this area is closer to the drainage headwaters, the upstream catchment areas are much smaller here than they were in the Dolan Falls area and the chance of truly catastrophic flooding of the river valleys is less.

ROCK UNITS

All the bedrock in the study area is Cretaceous in age and consists of two divisions of the Edwards Group: the lower Fort Terrett Formation and the upper Segovia Formation. These units are equivalent in time to the Devils River Limestone exposed in the Dolan Falls area. A fairly extensive discussion of the problems with the terminology of the Edwards rocks is included in that report (Deal, 1974).

Most of the problem stems from the fact that the massive, hard limestones underlying the Edwards Plateau vary tremendously in details of composition and in mode of deposition from place to place. There are many different ways that rocks classified as limestone can form.

Rose (1972) summarizes the internal divisions of the Edwards Group as follows:

> In the subsurface of south-central Texas the Lower Cretaceous Edwards Group consists of about 400 to about 600 feet of porous dolomite and limestone that accumulated on the Comanche shelf as shallow marine, intertidal, and supratidal deposits in the lee of the Stuart City Reef. The Edwards thickens southwestward to about 1,000 feet near the Maverick basin and thins northeastward, by basinward thinning and facies change, to zero in the North Texas–Tyler basin. In between, on the San Marcos Platform, it is separated into the Kainer Formation (new) below and the Person Formation (new) above by a thin, widely traceable argillaceous layer called the Regional Dense Member (informal), the base

TABLE I

Temperature Data for the Devil's Sinkhole - Hackberry Creek Area
Degrees Fahrenheit

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
1964													
Rocksprings	47.6	46.6	57.9	67.1	74.3	78.7	82.0	83.2	75.1	63.4	59.1	50.0	65.4
Camp Wood	47.3	48.2	60.9	69.6	76.1	80.9	84.4	83.9	78.1	63.7	60.2	50.3	67.0
Leakey	47.1	47.1	58.9	68.0	74.8	78.4	82.3	81.9	76.9	64.1	60.4	51.0	65.9
Prade Ranch	45.0	44.6	58.1	66.8	74.3	78.6	80.1	80.8	75.0	61.8	57.7	48.3	64.3
1965													
Rocksprings	49.8	45.1	52.5	69.3	71.3	75.9	80.5	80.1	78.0	—	62.2	53.4	—
Camp Wood	52.6	49.3	55.4	70.2	73.9	79.3	82.1	82.2	79.5	66.2	63.2	55.1	67.4
Leakey	53.5	49.5	55.9	70.0	73.0	78.5	81.1	81.2	78.3	64.7	62.1	53.7	66.8
Prade Ranch	51.1	47.4	52.4	68.4	70.8	—	—	—	77.1	63.3	60.4	52.8	—
1966													
Rocksprings	42.8	47.9	57.4	67.7	71.3	77.0	82.4	77.5	74.1	—	—	48.9	—
Camp Wood	45.4	49.5	59.5	69.2	73.8	78.8	84.9	80.9	76.5	66.5	62.7	50.3	66.6
Leakey	44.3	48.6	57.5	68.1	72.0	76.8	81.5	78.9	74.7	65.0	60.1	48.4	64.7
Prade Ranch	42.0	46.4	56.4	66.2	71.4	77.4	81.8	78.7	74.3	63.5	59.3	46.5	63.7
1967													
Rocksprings	50.3	51.1	65.4	71.1	73.8	79.2	82.6	79.0	71.3	66.3	58.1	47.5	66.3
Camp Wood	49.8	52.4	66.7	75.0	77.1	83.4	84.4	80.4	73.4	66.6	59.1	49.1	68.1
Leakey	48.2	50.1	64.7	73.4	75.1	81.5	82.5	79.1	72.8	65.4	57.7	47.5	66.5
Prade Ranch	47.1	48.9	—	71.1	71.8	79.9	81.1	72.4	—	—	—	46.1	—
1968													
Rocksprings	47.0	46.7	54.6	63.2	71.0	76.9	78.3	80.8	72.9	69.5	54.4	48.6	63.7
Camp Wood	49.9	48.7	56.7	67.1	74.1	78.9	80.2	82.6	74.9	71.0	56.3	49.8	65.9
Leakey	48.7	48.0	55.4	66.8	72.6	77.6	78.9	81.3	73.5	69.2	56.0	49.2	64.8
Prade Ranch	47.3	45.6	53.9	64.7	71.8	75.9	76.9	77.9	69.8	65.9	51.5	45.1	62.2
1969													
Rocksprings	51.8	53.4	53.0	66.1	69.4	79.5	84.3	—	—	65.6	55.4	54.6	—
Camp Wood	53.4	55.2	54.9	67.3	72.3	81.7	76.3	84.2	78.5	67.6	55.0	53.0	67.5
Leakey	51.7	53.8	54.8	67.1	71.2	80.1	84.4	82.6	77.5	68.0	55.5	52.6	66.6
Prade Ranch	48.4	49.8	52.7	64.6	70.7	78.9	82.4	80.1	74.0	64.3	52.5	—	—
1970													
Rocksprings	46.3	52.3	53.7	67.0	69.0	74.6	81.2	81.6	74.6	65.6	54.8	55.2	64.7
Camp Wood	46.3	54.4	55.6	67.3	70.4	76.9	81.1	83.4	72.3	65.5	56.0	57.4	66.0
Leakey	46.4	53.8	55.4	68.1	70.4	76.6	80.6	81.2	75.9	64.2	54.6	54.5	65.1
Prade Ranch	—	—	—	65.7	—	—	—	—	—	—	—	—	—
1971													
Rocksprings	55.3	53.7	61.1	65.5	74.2	77.5	79.0	74.6	74.3	66.5	58.8	53.1	66.1
Camp Wood	55.8	55.2	63.7	68.2	76.9	81.1	81.1	77.4	76.8	69.3	60.1	55.3	68.5
Leakey	53.2	—	—	—	—	—	—	—	—	—	—	—	—
Prade Ranch	—	—	—	—	—	—	—	—	—	—	57.5	57.9	—
1972													
Rocksprings	52.2	54.5	64.5	70.8	69.9	78.0	78.9	76.6	76.8	68.2	53.4	49.3	66.1
Camp Wood	52.6	56.0	66.5	72.4	72.2	79.7	81.5	—	—	—	53.5	48.7	—
Prade Ranch	49.9	52.5	63.2	70.5	69.6	51.8	79.5	77.5	75.9	66.1	50.3	46.5	62.8
1973													
Rocksprings	44.2	48.7	61.0	62.5	72.4	75.1	77.8	77.7	75.6	67.7	62.5	50.2	64.6
Camp Wood	43.8	79.0	61.2	63.0	72.6	77.0	80.2	79.6	77.7	69.0	61.5	48.4	65.3
Prade Ranch	42.9	47.7	59.6	61.2	71.1	74.5	72.4	77.0	75.0	66.3	61.2	47.9	63.5
1974													
Rocksprings	50.4	55.2	67.0	67.6	74.2								
Camp Wood	48.4	53.4	65.9	68.2	76.4								
Prade Ranch	48.9	51.6	65.3	66.8	75.1								

TABLE II

Precipitation Data for the Devil's Sinkhole - Hackberry Creek Area
Inches per Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964													
Rocksprings	1.61	.86	1.14	1.65	1.39	.05	––	3.35	9.57	1.19	1.43	.66	22.89
Camp Wood	1.44	.97	2.62	2.69	2.34	.49	.60	2.50	12.52	.83	.30	.53	27.83
Leakey	3.28	1.41	3.22	2.55	2.04	2.04	.18	2.50	8.89	1.53	.65	.55	28.74
Prade Ranch	1.95	1.37	3.05	2.45	1.75	2.57	2.52	3.54	9.17	.77	1.30	.32	30.76
1965													
Rocksprings	.80	1.96	.41	.65	4.62	2.38	.05	.25	2.13	1.43	.16	1.72	16.56
Camp Wood	1.06	2.73	1.20	1.86	4.72	3.38	.00	.36	3.45	2.21	1.29	2.71	24.97
Leakey	2.58	3.10	1.68	1.57	5.31	1.65	T	.88	5.71	3.00	1.63	3.35	30.46
Prade Ranch	2.59	2.61	1.47	1.82	6.10	.54	.49	.74	3.32	2.56	.97	1.94	25.15
1966													
Rocksprings	1.39	.94	1.03	4.82	1.52	1.60	.47	7.59	4.62	.68	.15	T	25.81
Camp Wood	1.26	.74	.92	4.42	1.00	1.81	.78	7.24	2.81	.46	.30	T	21.74
Leakey	1.64	1.72	.45	3.36	3.75	1.85	3.22	14.90	4.03	.04	.00	T	34.96
Prade Ranch	1.65	1.33	.86	2.93	2.54	1.10	5.73	8.34	6.66	.16	.00	T	31.28
1967													
Rocksprings	T	.60	.36	3.03	1.41	.00	2.71	2.80	3.51	2.70	3.28	.29	20.69
Camp Wood	.19	.62	.66	1.44	1.19	.21	3.60	4.25	5.77	4.56	2.83	1.00	26.32
Leakey	.10	.52	.45	2.31	.56	.14	4.55	.24	5.32	2.38	3.34	.70	20.61
Prade Ranch	.27	.55	.41	1.57	.98	T	8.56	1.47	4.62	4.58	3.47	.71	27.19
1968													
Rocksprings	5.67	1.77	2.93	4.16	1.60	.63	1.98	.06	2.87	T	2.94	.00	24.61
Camp Wood	3.81	1.58	1.74	2.43	6.41	3.27	4.60	1.03	3.68	.41	4.08	.10	33.14
Leakey	3.97	1.55	1.76	2.51	5.17	1.94	3.99	1.48	4.00	.31	3.34	.19	30.21
Prade Ranch	3.96	1.46	2.08	4.15	1.67	.46	3.32	1.84	2.82	.18	4.39	.00	26.33
1969													
Rocksprings	.67	1.09	.77	3.22	2.66	1.30	.65	4.62	2.72	2.30	2.14	1.10	23.24
Camp Wood	.60	1.44	.92	3.82	2.76	1.21	.95	3.36	4.66	10.56	2.91	.96	34.16
Leakey	.45	1.57	1.11	4.10	1.87	1.34	2.16	1.54	1.94	12.16	2.86	1.31	32.41
Prade Ranch	.60	1.18	1.24	4.10	2.17	2.67	3.21	6.53	1.65	7.95	3.30	2.03	36.63
1970													
Rocksprings	.95	1.18	.81	.85	5.75	2.11	.56	1.62	4.25	.00	.00	.21	18.92
Camp Wood	.34	2.40	.95	1.45	3.29	3.85	.38	2.65	5.48	.79	.00	.68	22.26
Leakey	.46	2.73	1.56	.60	6.28	1.23	.54	.91	4.97	1.83	T	.29	21.40
Prade Ranch	.37	2.71	––	1.54	7.78	––	––	––	––	––	––	––	––
1971													
Rocksprings	.00	1.32	.18	1.84	.61	6.50	2.82	8.67	1.03	6.90	.32	.51	30.70
Camp Wood	.00	1.07	.12	1.01	.54	6.75	.08	16.17	1.79	8.18	.71	1.14	37.56
Leakey	.06	––	––	––	––	––	––	––	––	––	––	––	––
Prade Ranch	––	––	––	––	––	––	––	––	––	––	.40	1.40	––
1972													
Rocksprings	.00	.20	.13	1.37	2.26	4.41	1.09	5.93	9.51	5.17	.33	.00	30.40
Camp Wood	1.93	.30	.34	3.04	3.38	2.19	2.52	––	––	.99	.77	.05	––
Leakey	––	––	––	––	––	––	––	––	––	––	––	––	––
Prade Ranch	.71	.25	.45	2.06	7.22	2.08	.84	7.76	3.68	1.25	1.23	.10	27.63
1973													
Rocksprings	1.29	3.75	.00	.00	1.13	2.32	4.59	.10	1.06	9.30	.22	.00	23.76
Camp Wood	1.78	1.85	1.11	1.67	1.04	8.96	4.47	1.35	2.15	10.66	.13	T	35.17
Prade Ranch	1.56	1.90	1.67	1.49	.76	1.04	6.45	.38	3.00	9.34	.20	.10	27.89
1974													
Rocksprings	.10	.00	.73	4.38	1.66								
Camp Wood	.42	T	.94	1.40	5.56								
Prade Ranch	.29	.03	1.88	2.23	3.20								

of which is the conformable Person-Kainer boundary. The Edwards is conformable with the Glen Rose Formation below and disconformable with the Georgetown Formation above. The overlying Georgetown, Del Rio, and Buda Formations consist chiefly of argillaceous lime mud and represent marine open-shelf deposition. To the northeast the Kainer grades into the classic Walnut/Comanche Peak/Edwards sequence of the North Texas type area, and the Person grades into the lower Duck Creek Member of the Georgetown. To the southwest the Kainer and Person Formations pass into the Devils River Formation.

At the surface in the eastern Edwards Plateau of Central Texas the Edwards Group consists of about 400 to about 600 feet of dolomite and limestone similar to that of the subsurface Kainer and Person Formations; it thickens southward from the Central Texas Platform and grades into rudist limestone of the Devils River Formation. The Edwards is divided into the Fort Terrett Formation (new) below and the Segovia Formation (new) above, separated by a widely traceable marly interval, the Burt Ranch Member (new), at the base of the Segovia. The Glen Rose–Edwards, Edwards–Del Rio, and Del Rio–Buda boundaries are disconformable, but the Fort Terrett–Segovia boundary is conformable. The Georgetown is absent, probably by facies change into Edwards-type rocks, and the thin Del Rio and Buda Formations consist of the fine-grained marine open-shelf deposits. Southeastward across the Edwards Plateau the Burt Ranch Member acquires miliolid and rudistid limestone at the expense of marl so that only a thin marly layer remains at the top as the Edwards goes into the subsurface; this is the Regional Dense Member.

Fredericksburg and Washita rocks in Texas represent nine major depositional environments, which were controlled by circulation patterns of marine waters, water depth, and terrigenous material in sea waters. Each environment can be recognized in the rock record by a combination of mineralogy, faunal content, sedimentary structures, and tectonic setting. The nine environments are: open deep marine; open shelf; open shallow marine, moderate to high-wave energy; open shallow marine, low-wave energy; restricted shallow marine; tidal flat; euxinic evaporitic shelf basin; evaporite-dominated supratidal flat; coastal terrigenous.

Dolomite is confined chiefly to restricted shallow marine, intertidal, and supratidal deposits, which were controlled chiefly by positive tectonic elements and areas of restricted circulation in the interior of the platform. Collapse breccias originated by solution and removal of gypsum shortly after deposition and during the Pleistocene and Holocene. Crystalline limestone is related to Cretaceous exposure, present weathering, and alteration of dolomite beds beneath dissolving gypsum. Pulverulite is related to contemporary weathering. The subsurface Edwards is more porous and permeable toward the top, as a result of early exposure of mobile fault blocks and the unconformity at the top of the group. The surface Edwards is porous throughout, but cavernous porosity and permeability at the base produce a widespread, effective aquifer. Ground water probably is enhancing porosity now.

From northeast to southwest, Edwards and equivalent units form two complete carbonate facies complexes. The lower (Fredericksburg) complex reflects extremely shallow water, high salinities, and low subsidence rates. The upper (Lower Washita) complex is a facies assemblage more like the standard carbonate model, with low-angle clinoforms along the subsiding basin margins and increasing dolomite toward the interior of the Central Texas Platform. Rate of subsidence was the chief factor controlling the formation of clinoforms. Upper Washita open-shelf units filled in and then blanketed Lower Washita topography.

Through Fredericksburg and Washita time, facies tracts retreated onto higher parts of the Central Texas Platform as it was progressively inundated during deposition of three units of successively deeper-water sediments.

Fort Terrett Formation (Rose, 1972)

Lozo and Smith (1964) recognized but did not formally name two stratigraphic units within the Edwards north of the Devils River trend, the basis for subdivision being an unconformity at the base of the thin marly horizon called "Dr. Burt." Smith chose Fort Terrett as an informal name for the lower unit and has suggested (personal communication, May 1968) that the term be adopted formally in the present report, since it has already found common informal usage. Accordingly, the term Fort Terrett is here formally proposed for the lower unit. The Fort Terrett measured section includes Smith's type locality of the Fort Terrett Formation as well as the upper unit of the Edwards; the lithic description is this writer's, but the graphic profile of the Fort Terrett was drawn by Smith, who allowed its use in this report. Smith (1970, p. 36) stated that the unnamed lower unit of Lozo and Smith (1964) is the Del Carmen Formation of the Big Bend region, West Texas (Maxwell et al., 1967, p. 36), and used Del Carmen in the western Edwards Plateau. Fort Terrett is preferred in the eastern part of the plateau because: (1) There is a gap of several hundred miles between the Big Bend area and the eastern Edwards Plateau in which the lower unit has not been mapped; (2) although physical continuity between the two is probable, greatly increased restriction, elevated salinities, and higher evaporation rates are indicated by common dolomite and evaporite in the Fort Terrett, neither of which is mentioned in Maxwell et al.'s descriptions of the Del Carmen.

The type locality is in road cuts of U.S. Highway 290 where the highway rises out of the valley of North Llano River onto the Edwards Plateau about 0.5 mile south of Roosevelt, Kimble County, Texas. The name comes from old Fort Terrett (abandoned), about 8 miles west, one of a series of frontier army posts built and occupied in the 1850s.

The Fort Terrett Formation is only 160 feet thick at the type locality. This is the thinnest known interval of the formation in the map area and may indicate that the

Roosevelt high was mobile during Fredericksburg time. Isopachous mapping shows that the formation thickens evenly from about 180 feet along the northern edge of the map area to more than 300 feet on the northern edge of the map area to more than 300 feet on the northern margin of the Devils River belt. A small "thin" on the Kerr-Bandera County line conincides with the Medina axis and may be an indication of its mobility during Fredericksburg time. Comparison of regional Fort Terrett dolomite distribution with structure maps shows a striking correlation between highly dolomitized areas and structurally positive areas. Because much dolomitization is thought to be related to deposition or very early diagenesis in extremely shallow water or supratidal environments, this is another indication of Early Cretaceous movement of the Medina axis and other positive features near the Devils River belt.

Lithofacies mapping of this interval by Fisher and Rodda (1967, 1969) on the south flank of the Central Texas Platform does not agree with findings of this report. They showed (1967, fig. 5; 1969, fig. 7) too little dolomite (less than 10 percent vs. more than 30 percent) in Kerr, northern Real, and Bandera counties. Also they indicated (1967; 1969, fig. 12) a broad area southwest of Junction where the grainstone/mudstone ratio ranges from 0.8 to 5. The South Llano, North Fork Composite, West Frio, Vanderpool, and Medina Mountain measured sections show clearly that mud-supported rocks in that area are two to four times more abundant than grain-supported rocks in the Fort Terrett Formation. Finally, they indicated (1969, fig. 13) that chert becomes regularly less abundant southwest of the Central Texas Platform. This pattern seems more apparent than real: Some measured sections near the platform, such as Cherry Spring, have proportionately much fewer chert horizons than do some measured sections far to the southwest, such as West Frio and Vanderpool.

The term Fort Terrett Formation is applicable to the lower unit of the Edwards throughout the area of the geologic map north of the Devils River belt. The formation is divided as follows: Basal Nodular Member, Burrowed Member, Dolomitic Member, and Kirschberg Evaporite (Barnes, 1944).

Basal Nodular Member (informal)—The lowest unit of the Fort Terrett Formation is present throughout the area and can be recognized even in the base of the Devils River mass. It contains terrigenous sand in outcrops near the Llano Uplift and on the Roosevelt high, but the detrital admixture becomes insignificant toward the top of the member. Over most of the area the member consists of soft, recessive, silty oyster marl grading upward to nodular biomicrite with scattered clams and snails. It generally weathers to a covered, heavily vegetated, rubbly slope. Its upper boundary is gradational. The Basal Nodular Member is ordinarily 25 to 40 feet thick, becoming thicker southward.

The units "Walnut" and "Comanche Peak" of Barnes's mapping in Gillespie, Blanco, and Kendell counties (1952-1967) constitute approximately the Basal Nodular Member. His terminology has not been adopted for two reasons:

(1) His units are not profitably mappable at the scale of the geologic map, 1:250,000 (pl. 1).

(2) Recommendations of Lozo and Smith (1964, p. 290) and Moore (1967, p. 69) are followed in restricting usage of Walnut and Comanche Peak to the area north and east of the Llano Uplift.

Burrowed Member (informal)—Massive, resistant layers of porous, burrowed limestone are common in the lower half of the Fort Terrett and are the basis for recognition of the Burrowed Member. The lower boundary of the unit is placed at the lowest occurrence of thick sequences of nonargillaceous burrowed micrite and biomicrite. Irregular nodules of bluish-gray and brown chert and thin dolomite beds are also common constituents. Except for the Medina axis salient, dolomitic content of the Burrowed Member decreases away from the Llano Uplift. Toward the top of the unit thin beds of miliolid and mollusc-fragment biosparite, some rippled and cross-bedded, alternate with the thin dolomite beds. There are a few beds of marl, many of which have been altered to pulverulent limestone.

Over most of the area the Burrowed Member is 70 to 90 feet thick but near the Llano Uplift it thins (to 55 feet in the Edwards Creek section and to 35 feet in the Cherry Spring section). Its upper boundary is gradational.

The Burrowed Member is the chief water-bearing zone of the Edwards. The porosity is the result in part of preferential leaching and removal of burrow-fillings, producing superb honeycomb porosity.

Dolomitic Member (informal)—In the upper part of the Fort Terrett Formation massive- to thin-bedded, fine- to medium-crystalline, homogeneous dolomite becomes the dominant rock type. The base of the Dolomitic Member is placed at the lowest occurrence of thick sequences of dolomite overlying predominantly burrowed rocks. Beds of fine-crystalline limestone alternate with the dolomite near the top of the unit; at the Vanderpool section the two are intertongued. There are a few beds of miliolid and rudistid biosparite, and chert is abundant throughout. In the Stieler Ranch, Kerrville, and North Fork sections a caprinid biostrome is present at the base of the unit. Some dolomite has been altered to pulverulite.

Most of the dolomite is the homogeneous burrowed variety, but stromatolitic hard crusts, root marks, mud cracks, and bird's-eye structure indicating tidal flat deposits are found in northern measured sections. Ripple marks, current streaks, fine planer cross-beds, and flat mud clasts are scattered through the member. Evidence of restriction and high salinity is provided by indications that the dolomitic sediments once contained gypsum nodules. In many outcrops spheroidal vugs are arranged in long rows parallel to bedding. Some of these vugs contain miniature collapse breccias, always at the bottoms of the cavities. These are almost certainly the remains of gypsum nodules that have been dissolved.

The Dolomite Member ranges from about 40 to 90 feet thick; it is thinnest near the Llano Uplift and thickens southward.

Kirschberg Evaporite Member (emended)–Barnes (1944) proposed the term Kirschberg Evaporite for a gypsum horizon in the Edwards in Gillespie County and clearly intended that the term should apply not only to the small amount of gypsum remaining near Fredericksburg and Menard but also to the widespread disturbed and altered zone that marks its former presence as well. Subsequent workers (Lozo and Smith, 1964, fig. 8; Moore, 1967, p. 68) have therefore used "Kirschberg breccia" and stated that it correlates with the gypsum of Gillespie County.

Comparison of the Gypsum Quarry and Cherry Spring measured sections indicates that the bulk of the gypsum interval correlates not with breccia but with a thick zone of coarse-crystalline limestone and travertine that has only a thin breccia at the top. A similar zone of altered, recrystallized limestone, dolomite, and travertine is prevalent throughout the map area and commonly contains two zones of breccia. Accordingly, the term Kirschberg is emended so that it includes the entire altered interval, and in addition, the few remaining feet of dolomite and limestone between the gypsum horizon and the top of the Fort Terrett. This uppermost Fort Terrett interval contains thin-bedded lithographic to porcellaneous micrite, hard miliolid biosparite, and gray fine-crystalline dolomite. It is present both as a collapse breccia and as more or less undisturbed beds and is a distinctive and reliable field mapping marker. Commonly, the porcellaneous micrite is intricately fractured but not severely disrupted–this pattern is referred to as incipient brecciation.

At the Gypsum Quarry section the gypsum is 27.5 feet thick, but Barnes (1944, p. 40) reported up to 35 feet in the vicinity. The gypsum is massive, light to dark gray, and distinctively nodular or "augen-structured" rather than laminated. It contains irregular nodules of grayish-brown chert, reddish-brown travertine, and thin discontinuous lenses of soft brown homogeneous dolomite.

The emended Kirschberg Evaporite ranges from 40 to 80 feet thick. It is present throughout the map area and shows very little lithologic variation. Type locality is the Cherry Mountain area north of Fredericksburg, in the vicinity of locality 6. The lowest stratigraphic occurrence of the breccia is over the axis of the Central Texas Platform, but at its widest extent the breccia appears as a thin sheet-like deposit that covered the entire platform. Thus the evaporite appears to have expanded outward through time (Fisher and Rodda, 1967, p. 57).

Segovia Formation (Rose, 1972)

The Upper Unnamed Formation of Lozo and Smith (1964) is here named the Segovia Formation. The type section (Joy Creek composite section), was measured in new highway road cuts of Interstate Highway 10 from 5 to 10 miles southeast of the old settlement of Segovia, eastern Kimble County, Texas.

The Segovia Formation is lithically heterogeneous, consisting in general of marly limestone toward the bottom, dolomite and collapse breccia in the middle, and miliolid and mollusc-fragment biosparite toward the top. Considered as a gross unit, it is lithically similar to the Fort Terrett. Unlike the Fort Terrett, however, which is subdivided into four intergradational members, the Segovia is for the most part subdivided on the basis of thin, distinctive, widespread key beds that are readily recognized on aerial photographs. These are the *Gryphaea* Bed (Curry, 1934), Orr Ranch Bed (new informal name), and Black Bed.

In the western part of the map area dolomite and collapse breccia become less common in the Segovia, and farther west, in Sutton County, the Segovia interval consists mostly of thick beds of rudist and miliolid limestone separated by substantial intervals of ammonite-bearing marl. These rocks reflect a somewhat more marine origin and probably should be given a formal name to distinguish them from the Segovia. At any rate "Segovia" is intended to refer to the heterogeneous but generally dolomitic sequence above the Fort Terrett and below the Del Rio or Buda. It probably should not be used west or north of the map area; its southern and eastern limits of applicability are, respectively, the Devils River belt and the wide gap between the Balcones fault zone and the Edwards outcrop of Blanco and Kendall counties. "Person" rather than "Segovia" should be used in the Balcones fault zone. Segovia, rather than Santa Elena or Sue Peaks (Maxwell et al., 1967), should be used in the eastern Edwards Plateau for the "Upper Unnamed Unit" of Lozo and Smith for the same reasons that Fort Terrett, rather than Del Carmen, should be applied to their "Lower Unnamed Unit." The difference in genesis is even more striking, however: The Santa Elena–Sue Peaks sequence reflects open-marine deposition and normal salinities, whereas the Segovia represents restricted circulation and elevated salinities in a very shallow shelf interior.

The overall similarity of the Segovia and Fort Terrett Formations justifies, indeed demands, the use of Edwards Group to refer to the whole carbonate mass in the eastern Edwards Plateau. Accordingly, the proposition of Moore (1967, pp. 61, 69) that the term Edwards be applied only to the lower unit (=Fort Terrett) as far south as the Devils River belt is rejected.

Thickness of the Segovia can be established only in the western part of the map area where the top of the member has not been eroded, but isopachous mapping in that area shows the Segovia to be a wedge that thickens southward from about 230 feet at Fort Terrett to more than 360 feet along the northern edge of the Devils River trend.

As in the Fort Terrett, dolomite content of the Segovia seems to be related to areas now structurally high, and the Medina axis and south flank of the Llano Uplift are clearly reflected by dolomite percentages in the member.

Burt Ranch Member–A persistent and widespread zone of marly limestone was informally designated the Dr. Burt zone by Pavlovic, Hazzard, and others. As used by all workers, the term Dr. Burt referred only to a thin, soft, fossiliferous marl just above the porcellaneous micrite of the uppermost Kirschberg. There is, however, a widespread interval of generally marly limestone about 60 feet thick above the Kirschberg for which the term Burt Ranch Member is here proposed, which includes at its base the thin Dr. Burt zone of traditional informal usage. The base of the member is placed at the lowest marl above porcellaneous micrite breccia; the top is ordinarily drawn at the base of a resistant miliolid biosparite bed beneath thick grayish-brown dolomite beds.

The Burt Ranch Member consists generally of marl, marly micrite, miliolid biosparite, and rudist biosparite, with a few scattered beds of solf massive dolomite. Clayey or marly fossiliferous zones are particularly common near the base and toward the top and contain *Exogyra texana, Lunatia* sp., turritellid snails, *Enallaster* sp., heart clams, *Cyprimeria* sp., and rare oxytropidoceroid ammonites. The unit weathers to form a topographic bench with a tree-line just below the map unit, and photo-mapping must be ground-checked at fairly close intervals to insure accuracy. The bed is farmed in the eastern part of the area. The type locality is locality 9 on the upper reaches of Chalk Creek about 11 miles south of Junction (pl. 12, C and D). This is part of the old Dr. Fred Burt ranch and in 1967 was part of the Tomlinson lease.

According to Lozo and Smith (1964, p. 291 and fig. 8) and Moore (1967, p. 68) the base of the Dr. Burt zone is a disconformity; cited evidence is that the top of the Fort Terrett is an abrupt lithic boundary or discontinuity surface that is in many places iron-stained, bored by rockboring molluscs, and plastered with oysters. On the other hand, the erosional nature of the contact is not proven because no rock or biostratigraphic units are missing at the interface.

Correlation of 20 measured sections and geologic mapping between them shows that a single continuous discontinuity surface does not lie everywhere at the base of the Dr. Burt zone. Nearly all limestone/marl contacts within the Burt Ranch Member are abrupt, but there are commonly two or three such contacts at each outcrop, not just one. Many such interfaces are iron-stained, possibly as a result of different permeabilities to ground water or of modern weathering. Only a few of these surfaces are bored or attached-to by oysters. This evidence casts doubt on the existence of a single widespread surface of discontinuity.

Most bored surfaces are developed in particulate limestones that are overlain by marl. Bored surfaces are present a few feet below the Dr. Burt zone in the thin-bedded limestone of the upper Kirschberg (Segovia measured section), at the base of the Dr. Burt (Fort Terrett measured section and localities 14, 37, and 45), a few feet above the base of the Dr. Burt zone (Vanderpool section and localities 55 and 67), and near the top of the Burt Ranch Member (North Fork composite and Medina Mountain sections). At many localities (Mountain Home and Edwards Creek sections, localities 3, 9, and 25) no bored surface was found at all; at the Bee Caves Ranch section there are two, and at the Medina Mountain section three bored surfaces are present.

The foregoing relations suggest conflicting conclusions: either (1) that occurrences of subaerial exposure and lithification were frequent and widely scattered; or (2) that submarine cementation was a continuing process, related perhaps to sediment type.

Examination of individual bored surfaces themselves also indicates that submarine cementation was involved in their formation. Individual borings are filled with very pure fine lime mudstone and pellet wackestone; the shells of the clams that made them are still present in some of the borings. The perimeter of the borings are typically iron stained and they truncate shell fragments in the host rock, showing that the matrix was indurated when bored. Upon examination of bored surfaces in both plane and cross-sectional view, multiple periods of borings can be recognized based upon successive truncation of earlier borings by subsequent borings. Such superimposed or "bored borings" have been recognized by Shinn (1969) and Purser (1969) as characteristic of submarine-cemented carbonates. As they pointed out, "bored borings" must call either for on-going submarine lithification or for extraordinary oscillation of relative sea level so as to allow for repeated alternations of: (1) submergence and boring, and (2) subaerial exposure and lithification of the sediment that fills the boring. The reader will recognize the same conflict mentioned in the previous paragraph.

No "inverted borings" such as those described by Shinn and Purser were observed, but closely spaced successions of bored beds similar to those observed by Shinn in the Persian Gulf were found at the Medina Mountain section.

It can be clearly demonstrated that unbored, unstained limestone beds high in the Kirschberg were lithified, beveled, and brecciated before still higher Kirschberg limestone beds were deposited, and certainly long before the proposed regional exposure and lithification of Lozo and Smith (1964) and Moore (1967). So, again, either subaerial exposure occurred frequently, or these beds were indurated by a submarine lithification process.

It seems more harmonious with the observed facts that these beds were lithified by submarine processes and bored during periods either of nondeposition or of submarine exposure and lithification. Nevertheless, even if the subaerial interpretation of bored surfaces is accepted, repeated and sporadic local subaerial exposure in very shallow environments of carbonate deposition should be the rule rather than the exception, and in a unit such as the Edwards, many discontinuity surfaces at different stratigraphic levels and of different temporal significance should be expected as a matter of course.

Two lateral variations are apparent in the Burt Ranch Member. It becomes thinner southward toward the Devils River belt, and it acquires increasing quantities of particulate limestone southward and eastward. Both tendencies probably reflect shallower water to the south and east. Toward the east the chief addition of limestone seems to be as thin beds of miliolid biosparite, intrasparite, and biomicrite in the lower part of the unit (*see*

Edwards Creek section). Towards the south, however, particularly in proximity to the Devils River belt, an irregular rudist and miliolid biostrome develops in the middle of the Burt Ranch Member.

At the Louis Real section this middle limestone layer is 33 feet thick, but over most of southern Kerr and northern Real counties it is 15 to 25 feet thick. At the Tommy Priour segment of the North Fort composite section in western Kerr County, drape or accretion beds that dip about 5 degrees south are present at the top of the middle limestone layer, and at locality 61, about 3 miles southeast, similar large-scale inclined beds can be seen in bluff exposures along the North Fork of the Guadalupe River. The top of this middle limestone is a red-stained, bored surface at the Medina Mountain and Bee Cave Ranch sections.

Two anomalous areas appear. In the area around the Louis Real section, where the middle limestone bed is quite thick and reefy, the total Burt Ranch Member is unusually thick and contains a high proportion of particulate limestone. Near the Vanderpool section and localities 47, 55, and 65, the member is thin and contains a low proportion of limestone. Both localities lie on the Medina axis, suggesting that it was active during deposition of the Burt Ranch.

Where the Burt Ranch Member is not recognizable, the Fort Terrett and Segovia Formations are no longer readily separable and the entire rock mass is called Devils River Formation (Lozo and Smith, 1964, fig. 8). Three closely spaced sections (Bee Caves Ranch, West Frio, and Leakey) indicate the nature of the southward stratigraphic changes in the member as it disappears into the Devils River mass. Limestone beds become increasingly, prevalent southward, particularly in the middle and lower part of the Burt Ranch, until only a thin marly zone is present near the top. Rudist and miliolid beds next intervene in this upper marly zone and ultimately occupy the Burt Ranch interval completely just south of the Leakey section. Similar changes appear to take place along north-south lines of cross section farther east.

The Burt Ranch Member represents distinctly more marine depositional conditions than the underlying Fort Terrett. The rich and diverse mollusc fauna with scattered ammonites indicates deposition on a shallow open shelf. Young (MS.) showed that clayey rock units in the Comanche Series tend to contain cosmopolitan rather than endemic ammonite faunas. He interpreted this to mean that argillaceous rock units, particularly the widespread ones, represent times of relative flooding, when there was communication between shallow seas on the Comanche shelf and the open ocean. This generalization suggests that the Burt Ranch Member is a marine transgressive unit of minor rank, and that the limestone beds contained within it formed in more agitated marine waters that prevented accumulation of clay. In this context it is significant that in the Burt Ranch Member, limestone tends to be more prevalent over the areas that were topographically or structurally highest, such as the Llano Uplift, Medina axis, and Devils River high.

There is a second implication worth mentioning. Inasmuch as carbonate production (and commonly accumulation) tends to be inversely proportional to water depth, and suspended terrigenous clay tends to retard production of organic carbonate, it follows that accumulation should have been relatively slower for Burt Ranch marl than for limestone. This is in harmony with the previous suggestion that the widespread bored surface reported by Lozo and Smith, and Moore, represents a period of submarine nondeposition when deepening waters flooded the Central Texas Platform. Moreover, it is compatible with Shinn's (1969) hypothesis that submarine cementation requires slow accumulation rates.

Allen Ranch Breccia—Above the Burt Ranch Member and below the *Gyphaea* Bed is an interval of cherty dolomite and thin-bedded siliceous micrite 50 to 80 feet thick. East of a north-south line through Junction, this unit contains an irregular, discontinuous collapse-breccia here named the Allen Ranch Breccia. The name comes from exposures on the Allen ranch, just east of U.S. Highway 83 in the bed of Allen Creek, southern Kimble County, but the type locality is in new road cuts of Interstate Highway 10, 1 mile northwest of the intersection of U.S. Highway 290 and Interstate 10. The breccia contains limestone, dolomite, and chert fragments, and the matrix commonly consists of fine-crystalline limestone, probably dedolomite. The Allen Ranch Breccia is thickest at the type locality—22 feet—but a collapse breccia in road cuts of U.S. Highway 83 just north of locality 55 at approximate Allen Ranch level appears to be somewhat thicker. Although no gypsum has been found at Allen Ranch level, the breccia was presumably formed by solution and removal of gypsum, like the Kirschberg breccia.

At approximate Allen Ranch level in the Bee Caves Ranch section, well-formed, presumably algal hemispheres about 1 foot across can be seen in the road cut. The mounds are evenly spaced, and micrite drapes and ripples fill the intermound areas. Similar mounds were not seen elsewhere.

Gryphaea Bed—The *Gryphaea* Bed is a key bed marker in the middle of the Segovia Formation. On air photos it is expressed as a persistent line or double line of heavy vegetation with a broad grassy slope above and a steeper, less open slope below. It is the most prominent mapping unit in the area.

At the outcrop the *Gryphaea* Bed consists of one to three resistant beds of oyster biomicrite 6 inches to 2 feet thick that weather out at the foot of a covered slope. Many of the shells are superficially silicified and weather so as to stand out in sharp relief from the softer matrix.

The *Gryphaea* Bed disappears along an irregular east-west line parallel to and about 20 miles north of the Devils River trend. The character of the bed remains constant to within a mile or two of the line of disappearance, where the bed becomes thinner, dolomitic, and cherty. Immediately south of the line of disappearance massive beds of *Toucasia* biomicrite are present at the level of the *Gryphaea* Bed. It is interpreted that the *Gryphaea* Bed disappears by pinching out against low banks on the north flank of the Devils River trend, and that the narrow band of alteration north of the pinch-out line was produced by early exposure of the thinning bed on low mounds.

At localities 27 and 44 limestone- and chert-pebble conglomerate is found at the level of the *Gryphaea* Bed, which probably represents Cretaceous caliche. Many pebbles are coated and the matrix is identical to modern and fossil caliches.

Over all but the southwestern part of the area, the covered slope above the *Gryphaea* Bed is developed upon soft, massive dolomite and dolomitic limestone, but at the Orr Ranch section the interval consists of massive, soft, slightly recrystallized micrite.

Orr Ranch Bed—This is an informal name for a mapping unit identified primarily from its air-photo characteristics. The Orr Ranch Bed forms a prominent light outcrop band in a limited area in northern Real and southwestern Kerr counties. At the outcrop this band is a bare, covered slope developed on crystalline limestone, dolomite, and calichified marl. Type locality is the Orr Ranch measured section, W. E. Orr ranch, northern Real County. Just below the Orr Ranch Bed is a prominent massive ledge of limestone with abundant caprinids, *Toucasia,* and *Chondrodonta.* This ledge ranges widely in thickness and composition; locally, it is a distinctive mapping unit, but because of lateral changes and poor expression in flat areas it cannot be utilized readily as an area-wide mapping horizon. This caprinid zone is indicated on cross sections 40, 41, and 42. Small silicified caprinid mounds are found throughout the map area at this level (localities 4, 22, 42, 43). These mounds commonly support a flora different from that of surrounding areas and can be recognized from afar by post-oak trees, very tall range grass, and reddish soil. Large silicified caprinids and nerineid snails are the most common fossils. The size of the caprinids in the silicified mounds increases southward toward the Devils River trend. Unfortunately, both matrix and fossils are silicified, rendering liberation of fossils by acid etching impossible.

Petrified wood is common throughout the eastern Edwards Plateau (localities 5, 29, 41) and nearly all is found weathering out of slopes just above the level of the Orr Ranch Bed. Indeed, large fragments of petrified wood are usually scattered about the headquarters of almost every ranch whose pastures lie at this level; the wood is found in pastures by ranch workers and carried in as a curiosity. Size of fragments ranges generally from hand-size fragments to logs 18 inches across and 4 feet long. At locality 41 in western Kerr County a tree truck 24 feet long and 12 to 18 inches in diameter is weathering out of deep soil as a series of segments on a low hilltop. Although no wood has been found in place in the Segovia, its ubiquity at a single stratigraphic horizon indicates that it is indigenous to that level, not residual from higher formations now eroded away, or of Pleistocene origin, and that there must have been significant areas of land nearby during deposition of the upper Segovia. Whether the forests grew on broad emergent areas, scattered islands, or a single large mass (the Devils River trend?) is not known. Barnes's (1952-1967, Geol. Quad. Map 15) report of *Teredo*-bored petrified logs from a locality at Orr Ranch level southwest of Harper indicates that the tree trunks were exposed to sea water.

Black Bed—The upper 40 to 60 feet of the Segovia Formation consists of medium- to coarse-grained miliolid and mollusc-fragment biosparite beds alternating with recessive, calichified, presumably marly intervals. Near the top of the Segovia is a prominent grassy bench (the "Calvert Slope") below a resistant massive rounded ledge of porous biosparite that supports a dense growth of juniper and shin oak. This combination shows clearly on air photos as a dense tree-line just above an open, pale strip. Distinctive nodules of dark-gray to black micrite containing caliche-filled cracks commonly weather out of the covered slope. This is the Black Bed.

Ward et al. (1968) described black limestone nodules forming around the margins of shallow saline lakes on Isla Mujeres, Quintana Roo, Mexico, and attributed their origin to modern calichification and surface alteration in a reducing environment. The black color is thought to be chiefly the result of sulfate-reducing bacterial action. Ward (personal communication, 1969) pointed out that such material may provide indications of ancient exposure surfaces or disconformities.

Examination of Black Bed micrite from several localities indicates that the Black Bed occurs in several different habits, reflecting several different modes of origin or subsequent alteration. In part, the black micrite was emplaced during subaerial exposure and diagenesis: At locality 15, floors of solution cavities are coated with laminated black micrite, which is overlain by horizontal layers of vadose silt. Remaining voids in the solution cavities have been filled by sparry mosaic calcite. The black micrite laminae are roughly concordant with cavity floors, and in situ laminations are essentially horizontal. The highly rounded, smooth pebbles and cobbles characteristic of the Black Bed may also represent reworking by an ancient sea; bored black cobbles contained in coarse skeletal lime sand are associated with erosional surfaces at localities 16, 68, and 69. The sporadic occurrence of the black micrite is harmonious with scattered hypersaline lakes, analogous to Ward et al.'s Yucatan example. Commonly, the black micrite is emplaced in caliche, but whether this caliche is Cretaceous or modern is not yet determined. Finally, comparison of Black Bed micrite and Ward's black micrite suggests that they are sufficiently similar to have formed in similar ways. Particularly striking is the fact that grains and crystallites in both rocks are coated by a thin black film that is probably responsible for the opacity of the rocks. Organic carbon analyses, however, indicate that concentrations of organic carbon are so low that some factor other than organic carbon must be responsible for the dark color.

Isopachous mapping of the interval between the Black Bed and the top of the Segovia shows considerable irregularity and suggests the possibility of truncation of uppermost Segovia beds only one place, about 2 miles northwest of Garven Store, does the Black Bed itself appear to be truncated, but obscure field relations there prohibit certainty. At several places, however (localities 19 and 69), the Black Bed lies only 2 or 3 feet below the top of the Segovia, but southwestward toward Rocksprings the interval between the Black Bed and the top of the Segovia thickens regularly, and an interval of 54 feet was measured 3 miles northeast of Rocksprings. An alternative interpretation is that this irregularity is the result of the disconformity associated with the Black Bed, and that uppermost Segovia beds lap onto an irregular erosion surface developed upon the weathered and altered "Calvert Slope" sequence.

QUATERNARY SEDIMENTS

Unconsolidated sediments, locally cemented with soil-associated caliche deposits, veneer slopes and fill stream valleys. These deposits are usually thin, although stream terraces 20 feet above the stream channels were noted in the study area.

GROUND-WATER RESOURCES

The ground-water resources in the area have been summarized by Long (1958, 1963). This is a region of perennial springs and is the headwaters of the permanently flowing Nueces River. Most of the springs issue from cave-conduit aquifers (see Deal and Fieseler, this volume). These aquifers tend to be easily polluted by improper waste-disposal practices. Disposal wells and septic tank/leaching field systems of human waste disposal will only result in eventual ground-water contamination in most of this area. Water resources seem adequate for most nonurban development along the stream valleys.

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A VEGETATIONAL SURVEY OF THE DEVIL'S SINKHOLE-HACKBERRY CREEK AREA

Jackie Smith and Mary Butterwick

INTRODUCTION

For over a century the Edwards Plateau has been subjected to overgrazing by sheep and goats, clear-cutting by man, floods, and droughts. The countryside reflects these events and is now a mosaic of juniper-oak thickets and sparse grasslands (fig. 1). Mexican juniper (*Juniperus ashei*), shin oak (*Quercus pungens* var. *vaseyana*) and scrub live oak (*Quercus fusiformis*). The open, sparse grasslands are characterized by blue three-awn (*Aristida glauca*), hairy tridens (*Erioneuron pilosum*), Texas speargrass (*Stipa leucotricha*), and sideoats grama (*Bouteloua curtipendula*). The areas near the creeks are subjected to periodic floods which temporarily remove the herbaceous ground cover of frostweed (*Verbesina virginica*), American germander (*Teucrium canadense* var. *canadense*), and smallspike falsenettle (*Boehmeria cylindrica* var. *cylindrica*), leaving the more permanently established thickets of little walnut (*Juglans minor*), pecan (*Carya illinoinensis*), old honeyballs (*Cephalanthus occidentalis*), netleaf hackberry (*Celtis reticulata*), wintergrape (*Vitis berlandieri*), Carolina snailseed (*Cocculus carolinus*), saw greenbrier (*Smilax bona-nox*), and Mexican juniper, and trees such as little walnut, pecan, sycamore (*Platanus occidentalis*), and chinkapin oak (*Quercus muehlenbergii*).

Some areas do exist that have been relatively undisturbed. Those occurring in isolated side canyons have more moist environments, allowing the growth of various ferns such as Mexican fern (*Anemia mexicana*) and purple cliffbrake (*Pellaea atropurpurea*), sedges such as cedar sedge (*Carex planostachys*), and deciduous oaks, such as Spanish oak (*Quercus texana*).

The Edwards Plateau is known as a region of endemism. Numerous endemic species were collected in the Devil's Sinkhole-Hackberry Creek area, including Mexican pinyon (*Pinus cembroides* var. *remota*), scarlet clematis (*Clematis texensis*), wand butterfly bush (*Buddleja racemosa*), silktassle (*Garrya lindheimeri*), and rockdaisy (*Perityle lindheimeri* var. *lindheimeri*).

Many lithophyllous species occur on the Edwards Plateau. We collected Alabama lipfern (*Cheilanthes alabamensis*), littleleaf cloakfern (*Notholaena parvifolia*), purple cliffbrake, giant helleborine (*Epipactis gigantea*), Dutchman's pipe (*Aristolochia coryi*), wand butterfly bush, and rockdaisy.

METHODS

General collections were made to determine what species were present. Species identification was aided by the use of the *Manual of the Vascular Plants of Texas* (Correll and Johnston, 1970) and the University of Texas herbarium. Ground surveys were used to determine the nature and extent of ground cover.

Fourteen plots were selected as representative of the Devil's Sinkhole-Hackberry Creek area, i.e., cleared slopes, heavily covered slopes, creek bottoms, flats, and floodplains. In five of the plots a 1/10-meter quadrat (rectangular frame) was placed along a straight line, 100-meter steel tape, every ten meters. Each quadrat was analyzed as to the number and percent ground cover of each species. The tape was moved laterally approximately ten meters, and another series of quadrats was recorded. This process was continued until no new species was encountered.

The other nine plots contained large numbers of shrubs and trees. These plots were sampled by counting the number coming in contact with, or above or below, a straight line, 100-meter tape and the area covered along the tape by each species. Relative density, raw cover, and relative dominance of each species were determined by this method.

In addition a 5150-square meter area was analyzed for shrub and tree cover. An area was delimited and the trees and shrubs within it counted. Relative density of each species was determined.

Vegetation maps were made, using aerial photographs.

DISCUSSION

The area surveyed in this study included the Devil's Sinkhole and the surrounding land, and the drainages of the land between Hackberry Creek and the east prong of the Nueces River from their origin to their confluence. The vegetation of this area is typical of the Edwards Plateau, with a brushy overstory of Mexican junipers, shin oak, and scrub live oaks and a mid-grass understory of blue three-awn, sideoats grama, and curly mesquite (*Hilaria belangeri*). Also characteristic of the Plateau and the study area are grasslands cleared of Mexican junipers, and occasionally of other brushy vegetation as well. The floodplains of the creeks and rivers are dominated by little walnut, pecan, chinkapin oak, sycamore, and netleaf hackberry with an herbaceous undergrowth of frostweed. Mexican pinyons were scattered throughout the survey area, with some populations being extensive and viable.

Four major associations were defined. The two most prevalent associations were the Mexican juniper-shin oak scrub, and the shin oak-grasslands which occurred throughout the area except on the floodplains where the little walnut-pecan association was restricted. The Mexican juniper-shin oak-Mexican pinyon association was distributed sporadically throughout.

Mexican juniper-Shin oak Association

This association, one of the two dominant associations, is found on ridges, slopes, canyons, and flats. The dominant component is Mexican juniper, accounting for ca. 50% of the total coverage. The second major component, shin oak, is responsible for ca. 20% of the total coverage.

Within the association two variants were observed. One had dense shrub and tree coverage, averaging ca. 78%, with no understory, or with infrequent tufts of cedar sedge (Tables 5, 6, 7, 8, 12, and 14; Figs. 2, 3, and 8). Other significant shrub and tree components were Mexican persimmon (*Diospyros texana*), Texas mountain laurel (*Sophora secundiflora*), evergreen sumac (*Rhus virens*), escarpment blackcherry (*Prunus serotina* var. *eximia*), and Spanish oak.

The other variant had significantly less shrub and tree cover, ca. 45% and a complex understory of grasses, ca. 22% of the total coverage and herbs, ca. 6% of the total coverage (Tables 5 and 14; Fig. 9). Aside from the dominant components, other shrubs and trees found were scrub live oak, evergreen sumac, Mexican persimmon, and agarito (*Berberis trifoliolata*). The major grasses were cane bluestem (*Bothriochloa barbinodis* var. *barbinodis*), hairy grama (*Bouteloua hirsuta*), and blue three-awn. Common herbs were cedar sedge and mealy sage (*Salvia farinacea*). Shallow soil on limestone outcrops was often clothed by Wright's selaginella (*Selaginella wrightii*).

On the lower slopes, dry creek beds, and on bluffs along Hackberry Creek, a minor association, Mexican juniper-Lacey oak (*Quercus glaucoides*), was noted (fig. 8). Here the Lacey oak accounted for ca. 33% of the total coverage. The accompanying shrubs and understory were comparable to that of the dense shrub and tree-covered variant.

Shin oak-Grassland Association

The range of this association is comparable to that of the Mexican juniper-shin oak. The major difference is a paucity of Mexican juniper due to the practice of clear-cutting (figs. 4, 6, 9, and 10). Total coverage of the different quadrat plots ranged from 41.12% to 63.60%, averaging 41.18%. Grasses are the dominant component of this association (ca. 70% of total coverage). The more common grasses are sideoats grama, blue three-awn, Texas speargrass, hairy tridens, and curly mesquite. Shin oak was the dominant tree in the associations, accounting for ca. 63% of the total tree coverage. Other trees were scrub oak and Mexican juniper. Tree coverage comprised ca. 15% of the total coverage. Shrubs such as agarito and Mexican persimmon are minor components of the association (ca. 7% of the total coverage). Common herbs are gray vervain (*Verbena canescens*), mealy sage, one-seeded croton (*Croton monanthogynus*), bighead evax (*Evax prolifera*), and noseburn (*Tragia ramosa*). Another minor component of the association, herbs accounted for ca. 8% of the total coverage.

Variation in amount of shrub and tree cover is due to clear-cutting practices which range from removal of all trees and shrubs except oaks to removal of Mexican juniper alone.

Little Walnut-Pecan Association

Although restricted in geographic extent, the little walnut-pecan association is distinguished by its diversity and density of flora. Neither of the major components in this association was clearly dominant as related to relative density. In terms of cover and relative dominance, however, pecan surpassed little walnut (tables 11 and 15; fig. 7). Minor tree components were netleaf hackberry, sycamore, Mexican juniper, chinaberry (*Melia azedarach*), chinkapin oak, bald cypress (*Taxodium distichum*), narrowleaf arroyo willow (*Salix lasiolepis* var. *bracelinae*), black willow (*Salix nigra* var. *nigra*), Arizona walnut (*Juglans major*), cedar elm (*Ulmus crassifolia*), littleleaf leadtree (*Leucaena retusa*), and western soapberry (*Sapindus saponaria* var. *drummondii*). In isolated locales various species or groups of species are numerous enough to warrant consideration as minor associations. For instance, solid stands of sycamore were seen sporadically along the stream. Also chinkapin-cedar elm assemblages were observed. Shrubs within the association are Mexican persimmon, old honeyballs, Roosevelt weed (*Baccharis neglecta*), and ironweed (*Bumelia lanuginosa* var. *texana*). Occasionally dense thickets of little walnut, pecan, netleaf hackberry, Mexican juniper, sawbrier, Carolina snailseed, and wintergrape line the creek.

In the heavily shaded wooded areas, ground cover is dominated by prolific frostweed. In the more open areas along the bank's edge, American germander and smallspike falsenettle are common. Infrequently carpeting the banks are St. Augustine (*Stenotraphrum secundatum*) and dallis grass (*Paspalum dilatatum*). In disturbed man-made areas (such as roads) abundant weedy species include sacred datura (*Datura wrightii*), jimsonweed (*Datura stramonium*), roughseed clammyweed (*Polanisia dodecandra* var. *trachysperma*), flannel mullein (*Verbascum thapsus*), common devil's claw (*Proboscidea louisianica*), and cowpen daisy (*Verbesina encelioides*). On limestone bluffs overlooking the creek are several lithophyllous species, namely southern maidenhair fern (*Adiantum capillus-veneris*), rockdaisy, Dutchman's-pipe, and giant helleborine. Limestone banks of the creek support spikesedge (*Eleocharis caribea*), large spike spikesedge (*Eleocharis macrostachys*), snowy whitetop (*Dichromena nivea*), water pimpernel (*Samolus cuneatus*), centaury (*Centaurium beyrichii* var. *beyrichii*), rosita (*Centaurium calycosum* var. *breviflorum*), and coastal waterhyssop (*Bacopa monieri*). An unusual plant, conespur bladderwort (*Utricularia gibba*)—with delicate, slender, creeping stems and branches and leaves bearing carniverous bladderlike traps with a valvelike action for trapping microorganisms—is found in muddy, still, shallow pools at the water's edge. Partially or completely submerged in the more calm waters of the creek are watercress (*Rorippa nasturtium-aquaticum*), common hornwort (*Ceratophyllum demeraum*), shining pondweed (*Potamogeton illinoensis*), and American waterwillow (*Justicia americana*).

Mexican juniper-Shin oak-Mexican pinyon Association

Scattered throughout the study area are small numbers of Mexican pinyons. Some populations were viable and extensive enough to be considered as a major association (see map; figs. 5 and 11). As expected, Mexican juniper was clearly dominant, accounting for 53.39% of the total coverage. Mexican pinyon and Spanish oak each comprised 9.8% of the total coverage. Although shin oak did not account for as much of the total coverage as Spanish oak, only 7.94%, more individuals of shin oak were recorded and observed. Also with more coverage (9.23%) of the total than shin oak was escarpment blackcherry. Again, however, there were fewer individuals (table 10). Other shrubs in the association were Mexican persimmon, netleaf foresteria (*Forestiera reticulata*), Texas mountain laurel, and evergreen sumac.

On the south-facing slope of the north branch of Mullen Hollow (see map) a healthy stand of Mexican pinyons exists. Many seedlings and juvenile trees were noticed. In other areas, however, such as the southwestern boundary of Eagle Ranch (see map) the Mexican pinyons have been attacked in the last few years by "needleborers" which cause destruction of the foliage, often resulting in the death of the tree. Although the needles of the trees obviously were being damaged, no insects were seen bothering the trees. Local ranchers referred to the injury as that done by "needleborers." In addition, porcupines, recent inhabitants of the region, are girdling the bark on some trees. Also, in extensively grazed areas soil erosion is a factor in exposure of the root system and in preventing establishment of seedlings. Against these three destructive forces, the relict, endemic populations are vulnerable.

DEVIL'S SINKHOLE

The vegetation surrounding the Devil's Sinkhole is characteristic of the shin oak grassland association (table 1; fig. 4). About 25 feet below the lip of the Devil's Sinkhole a population of ferns circumscribes the wall. A mountain mulberry (*Morus microphylla*) and other herbaceous species were seen above the ferns, but specimens could not be collected due to their inaccessibility. On the rubble pile formed by accumulated breakdown, meadow spikemoss (*Selaginella apoda*) was found carpeting the rocks. Farther down the rubble pile vegetation ceased due to lack of light.

ENDEMIC LIST

Numerous endemic species were found in the Devil's Sinkhole-Hackberry Creek study area. Those collected in the Mexican juniper-shin oak association were San Angelo yucca (*Yucca reverchoni*), Spanish oak, and silktassle. In the shin oak-grassland association was the blackfoot euphorbia (*Euphorbia angusta*). Occurring on the limestone bluffs in the little walnut-pecan association were four-o'clock (*Mirabilis grayana*), scarlet clematis, mountain hawthorne (*Crataegus traceyi*), Texas milkpea (*Galactia texana*), wand butterfly bush, hairy leastdaisy (*Chaetopappa bellidifolia*), rockdaisy, and crownbeard (*Verbesina lindheimeri*). The endemics in the Mexican juniper-shin oak-Mexican pinyon association are Mexican pinyon and meadow daucosma (*Daucosma laciniatum*).

OVERALL PURVIEW

The average of all the quadrat plots was 51.29% coverage. Grasses accounted for 60.31%, herbs for 9.30%, shrubs for 8.42%, and trees for 21.86%. The average of all the lines was 65.89% coverage. Mexican juniper accounted for 23.86% of this average and shin oak for 11.00%.

CONCLUSION

Although the Edwards Plateau has been overgrazed and clear-cut for years, proper range management could restore the native grasses, decrease the amount of chaparral-type vegetation, and reduce soil erosion. Perhaps the "needleborer" problem could be investigated for possible biological controls.

Potential for rejuvenation and restoration still exists for the Edwards Plateau, including the Devil's Sinkhole-Hackberry Creek region. Even a limited area set aside for restoration would yield much valuable data and insight into the succession and development from an unstable, disturbed state into a stable, climax state.

LOCALITY DATA FOR TABLES

Tables 1-5 are quadrat transects.

Table 1—Ca. 50 meters southwest of the southern rim of the Devil's Sinkhole (Devil's Sinkhole 7.5-minute quadrangle map).

Table 2—Ca. 0.25 miles south of Texas Highway 41, ca. 2.1 miles north northeast of the Devil's Sinkhole (Devil's Sinkhole 7.5-minute quadrangle map).

Table 3—North-facing slope of Graveyard Mountain in cleared area east of fenceline, ca. 0.2 miles west of Hackberry cemetery (Hackberry 7.5-minute quadrangle map).

Table 4—North-facing slope of Schoolhouse Mountain, ca. 0.1 miles south of Cade Spring (Hackberry 7.5-minute quadrangle map).

Table 5—North-facing slope of Graveyard Mountain in second growth of cleared area west of fenceline, ca. 0.3 miles west of Hackberry cemetery (Hackberry 7.5-minute quadrangle map).

Tables 6-14 are lines.

Table 6—West-facing slope ca. 0.4 miles southwest of windmill, ca. 2 miles northeast of Kalentine Hole along Hackberry Creek (Hackberry 7.5-minute quadrangle map).

Table 7—East-facing slope ca. 0.4 miles southwest of windmill, ca. 2 miles northeast of Kalentine Hole along Hackberry Creek (Hackberry 7.5-minute quadrangle map).

Table 8—Creek bottom beginning at the junction of two drainages, ca. 0.5 miles southwest of windmill, ca. 2 miles northeast of Kalentine Hole along Hackberry Creek (Hackberry 7.5-minute quadrangle map).

Table 9—Same as table 1.

Table 10—South-facing slope above northern fork of Mullen Hollow, ca. 0.5 miles southwest of Eagle Ranch Headquarters (Joy Hollow 7.5-minute quadrangle map).

Table 11—Floodplain just east of Hackberry Creek, ca. 0.5 miles north northwest of the confluence of Hackberry Creek and East Prong of the Nueces River (Hackberry 7.5-minute quadrangle map).

Table 12—North-facing slope, northwest branch of West Rose Draw, ca. 0.8 miles southwest of Red Arrow Cave (Joy Hollow 7.5-minute quadrangle map).

Table 13—Same as table 3.

Table 14—Same as table 5.

Table 15 is the tree density count.

Table 15—Same as table 11.

Explanation of symbols used in the tables:

Q = Total quadrats in which species occurred.

RFi = Raw Frequency = Percent quadrats in which species occurred.

$$\text{RFii} = \text{Relative Frequency} = \frac{\text{Q of species}}{\text{Total Q}}$$

TI = Total individuals

$$\text{RDi} = \text{Relative Density} = \frac{\text{Total individuals of species}}{\text{Total individuals of all species}}$$

TA = Total area covered by species.

$$\text{RC} = \text{Raw Cover} = \frac{\text{Total area covered by species}}{\text{Total area sampled}}$$

$$\text{RDii} = \text{Relative Dominance} = \frac{\text{Area covered by species}}{\text{Area covered by all species}}$$

* annual ** introduced

TABLE 1

Quadrat 1

	Q	RFi	RFii	TI	RDi	TA	RC	RDii
GRASSES								
Aristida glauca	12	60	21.82	33	25.58	215	10.75	22.87
Bothriochloa ischaemum var. songarica**	2	10	3.64	2	1.55	15	0.75	1.60
Bouteloua rigidiseta	3	15	5.45	6	4.65	25	1.25	2.66
Erioneuron pilosum	3	15	5.45	4	3.10	20	1.00	2.13
Hilaria belangeri	13	65	23.64	43	33.33	190	9.50	20.21
Stipa leucotricha	6	30	10.91	12	9.30	60	3.00	6.38
HERBS								
Chaetopappa bellidifolia*	1	5	1.82	1	0.76	5	0.25	0.53
Euphorbia prostrata*	1	5	1.82	1	0.76	5	0.25	0.53
Portulaca mundula	5	25	9.09	17	13.18	25	1.25	2.66
Rhynchosia texana	1	5	1.82	1	0.76	5	0.25	0.53
Sida filicaulis	2	10	3.64	2	1.55	10	0.50	1.06
SHRUBS								
Berberis trifoliolata	1	5	1.82	1	0.76	60	3.00	6.38
Diospyros texana	1	5	1.82	1	0.76	50	2.50	5.32
Opuntia leptocaulis	1	5	1.82	1	0.76	5	0.25	0.53
TREES								
Quercus pungens var. vaseyana	3	15	5.45	4	3.10	250	12.50	26.60
TOTAL	55			129	99.90%	940%	47.00%	99.99%

TABLE 2

Quadrat 2

	Q	RFi	RFii	TI	RDi	TA	RC	RDii
GRASSES								
Aristida glauca	43	61.43	32.57	143	30.42	780	11.14	26.12
Bouteloua curtipendula	5	7.14	3.79	17	3.62	80	1.14	2.68
Bouteloua hirsuta	6	8.57	4.54	13	2.76	55	0.78	1.84
Eragrostis cilianensis**	2	2.86	1.51	3	0.64	10	0.14	0.33
Eragrostis lugens	1	1.43	0.76	1	0.21	15	0.21	0.50
Erioneuron pilosum	3	4.28	2.27	6	1.28	20	0.28	0.67
Hilaria belangeri	45	64.28	34.09	232	49.36	1570	22.43	52.58
Stipa leucotricha	15	21.43	11.36	41	3.14	220	3.14	7.37
HERBS								
Euphorbia serpens*	2	2.86	1.51	2	0.42	10	0.14	0.33
Evax prolifera	2	2.86	1.51	2	0.42	10	0.14	0.33
Oxalis dillenii	1	1.43	0.76	1	0.21	5	0.07	0.17
Verbena canescens	1	1.43	0.76	1	0.21	5	0.07	0.17
SHRUBS								
Berberis trifoliolata	1	1.43	0.76	1	0.21	50	0.71	1.67
Opuntia leptocaulis	2	2.86	1.51	4	0.85	16	0.23	0.54
Opuntia lindheimeri	1	1.43	0.76	1	0.21	35	0.50	1.17
TREES								
Quercus fusiformis	2	2.86	1.51	2	0.42	105	1.50	3.52
TOTAL	132			470	99.96%	2986%	42.62%	99.99%

TABLE 3
Quadrat 3

	Q	RFi	RFii	TI	RDi	RA	RC	RDii
GRASSES								
Aristida glauca	21	42	12.65	35	8.03	225	4.50	7.08
Bouteloua curtipendula	26	52	15.66	104	23.85	540	10.80	16.98
Erioneuron pilosum	8	16	4.82	30	6.88	105	2.10	3.30
Hilaria belangeri	3	6	1.81	9	2.06	35	0.70	1.10
Leptoloma cognatum	2	4	1.20	2	0.46	15	0.30	0.47
Schizachyrium scoparium	7	14	4.22	21	4.82	80	1.60	2.52
Stipa leucotricha	6	12	3.61	26	5.96	275	5.50	8.65
Tridens muticus	27	54	16.26	121	27.75	435	8.70	13.68
HERBS								
Carex planostachys	1	2	0.60	1	0.23	10	0.20	0.31
Cassia lindheimeriana	2	4	1.20	5	1.15	15	0.30	0.47
Cassia roemeriana	1	2	0.60	1	0.23	5	0.10	0.03
Cooperi drummondii	1	2	0.60	1	0.23	5	0.10	0.16
Croton monanthogynus	4	8	2.41	4	0.92	20	0.40	0.63
Linum rupestre*	3	6	1.81	6	1.38	25	0.50	0.79
Phyllanthus polygonoides	3	6	1.81	3	0.69	15	0.30	0.47
Polygala lindheimeri	1	2	0.60	1	0.23	5	0.10	0.03
Salvia farinacea	12	24	7.23	18	4.13	155	3.10	4.87
Tragia ramosa	6	12	3.61	9	2.06	30	0.60	0.94
Verbena canescens	4	8	2.41	4	0.92	20	0.40	0.63
Verbesina virginica	3	6	1.81	3	0.69	20	0.40	0.63
SHRUBS								
Berberis trifoliolata	4	8	2.41	4	0.92	70	1.40	2.20
Diospyros texana	4	8	2.41	4	0.92	65	1.30	2.04
Opuntia lindheimeri	2	4	1.20	2	0.46	10	0.20	0.31
Sophora secundiflora	2	4	1.20	2	0.46	125	2.50	3.93
TREES								
Juniperus ashei	5	10	3.01	5	1.15	270	5.40	8.49
Quercus fusiformis	3	6	1.81	3	0.69	245	4.90	7.70
Quercus pungens var. vaseyana	5	10	3.10	12	2.75	360	7.20	11.32
TOTAL	166			436	100.02%	3180%	63.60%	99.73%

TABLE 4
Quadrat 4

	Q	RFi	RFii	TI	RDi	TA	RC	RDii
GRASSES								
Aristida glauca	15	37.5	11.28	25	4.90	155	3.87	9.19
Bouteloua cutipendula	8	20.0	6.01	23	4.51	97	2.42	5.75
Eragrostis lugens	16	40.0	12.03	38	7.45	161	4.02	9.54
Erioneuron pilosum	2	5.0	1.50	2	0.39	10	0.25	0.59
Leptoloma cognatum	34	85.0	25.56	322	63.14	715	17.87	42.38
Muhlenbergia lindheimeri	2	5.0	1.50	6	1.17	160	4.00	9.48
Stipa leucotricha	2	5.0	1.50	2	0.39	15	0.37	0.89
HERBS								
Carex planostachys	2	5.0	1.50	8	1.57	25	0.62	1.48
Cassia lindheimeriana	2	5.0	1.50	2	0.39	4	0.10	0.24
Croton monanthogynus	13	32.5	9.77	19	3.72	60	1.50	3.56
Evax prolifera	16	40.0	12.03	39	7.65	94	2.35	5.57
Marrubium vulgare**	1	2.5	0.75	1	0.20	10	0.25	0.59
Phyllanthus polygonodes	1	2.5	0.75	1	0.20	3	0.07	0.17

Salvia farinacea	2	5.0	1.50	2	0.39	70	1.75	4.15
Sida filicaulis	3	7.5	2.25	3	0.59	17	0.42	1.01
Tragia ramosa	6	15.0	4.51	8	1.57	17	0.42	1.01
Verbena bipinnatifida*	2	5.0	1.50	2	0.39	10	0.25	0.59
Verbena canescens	3	7.5	2.25	4	0.78	9	0.22	0.53
SHRUBS								
Berberis trifoliolata	1	2.5	0.75	1	0.20	10	0.25	0.59
Diospyros texana	1	2.5	0.75	1	0.20	15	0.37	0.89
TREES								
Quercus pungens var. vaseyana	1	2.5	0.75	1	0.20	30	0.75	1.78
TOTAL	133			510	100.00%	1687%	42.12%	99.98%

TABLE 5

Quadrat 5

	Q	RFi	RFii	TI	RDi	TA	RC	RDii
GRASSES								
Aristida glauca	7	14	5.51	15	4.52	95	1.90	3.11
Bothriochloa barbinodis var. barbinodis	38	76	29.92	111	33.43	810	16.20	26.51
Bouteloua curtipendula	1	2	0.79	3	0.90	10	0.20	0.33
Bouteloua hirsuta	10	20	7.87	56	16.87	127	2.54	4.16
Erioneuron pilosum	3	6	2.36	10	3.01	30	0.60	0.98
Leptoloma cognatum	3	6	2.36	3	0.90	25	0.50	0.82
Stipa leucotricha	1	2	0.79	3	0.90	10	0.20	0.33
HERBS								
Carex planostachys	17	34	13.39	63	18.98	190	3.80	6.22
Cheilanthes alabamensis	1	2	0.79	1	0.30	5	0.10	0.16
Croton monanthogynus	2	4	1.57	2	0.60	6	0.12	0.20
Linum rupestre*	1	2	0.79	1	0.30	5	0.10	0.16
Phyllanthus polygonoides	1	2	0.79	1	0.30	5	0.10	0.16
Polygala lindheimeri	1	2	0.79	2	0.60	5	0.10	0.16
Salvia farinacea	1	2	0.79	2	0.60	15	0.30	0.49
Selaginella wrightii	3	6	2.36	3	0.90	60	1.20	1.96
Sida filicaulis	1	2	0.79	2	0.60	5	0.10	0.16
Tragia ramosa	4	8	3.15	10	3.10	22	0.44	0.72
Yucca reverchonii	1	2	0.79	1	0.30	5	0.10	0.16
SHRUBS								
Diospyros texana	2	4	1.57	2	0.60	65	1.30	2.13
Forestiera reticulata	2	4	1.57	2	0.60	35	0.70	1.15
Rhus virens	4	8	3.15	4	1.20	320	6.40	10.47
TREES								
Juniperus ashei	13	26	10.24	16	4.82	655	13.10	21.44
Quercus fusiformis	3	6	2.36	4	1.20	80	1.60	2.62
Quercus pungens var. vaseyana	6	12	4.72	12	3.61	455	9.10	14.89
TOTAL	127			332	99.95%	3055%	61.10%	99.98%

TABLE 6

Line 1

	TI	RDi	RC	RDii
Diospyros texana	3	5.66	4.75	6.25
Forestiera reticulata	1	1.89	1.00	1.31
Juniperus ashei	13	24.53	40.00	52.63
Quercus pungens var. vaseyana	27	50.95	22.00	28.95
Rhus virens	1	1.89	1.0	1.31
Sophora secundiflora	8	15.08	7.25	9.54
TOTAL	53	100.00%	76.00%	99.99%

TABLE 7

Line 2

	TI	RDi	RC	RDii
Diospyros texana	3	5.66	4.75	6.25
Forestiera reticulata	1	1.89	1.00	1.31
Juniperus ashei	13	24.53	40.00	52.63
Quercus pungens var. vaseyana	27	50.95	22.00	28.95
Rhus virens	1	1.89	1.00	1.31
Sophora secundiflora	8	15.08	7.25	9.54
TOTAL	53	100.00%	76.00%	99.99%

TABLE 8

Line 3

	TI	RDi	RC	RDii
Juniperus ashei	7	33.33	29.25	38.06
Prunus serotina subsp. eximia	1	4.76	1.00	1.30
Quercus glaucoides	6	28.57	25.00	32.53
Quercus pungens var. vaseyana	3	14.28	13.00	16.92
Quercus texana	3	14.28	8.50	11.06
Sophora secundiflora	1	4.76	0.10	0.13
TOTAL	21	99.98%	76.85%	100.00%

TABLE 9

Line 4

	TI	RDi	RC	RDii
Berberis trifoliolata	3	9.68	3.25	9.34
Diospyros texana	17	54.84	8.30	23.85
Quercus fusiformis	1	3.23	0.25	0.72
Quercus pungens var. vaseyana	10	32.25	23.00	66.09
TOTAL	31	100.00%	34.80%	100.00%

TABLE 10

Line 5

	TI	RDi	RC	RDii
Diospyros texana	1	2.44	0.50	0.66
Forestiera reticulata	4	0.76	3.75	4.94
Juniperus ashei	15	36.58	40.50	53.39
Pinus cembroides var. remota	5	12.19	7.50	9.89
Prunus serotina subsp. eximia	2	4.88	7.00	9.23
Quercus pungens var. vaseyana	4	9.76	6.00	7.91
Quercus texana	2	4.88	7.50	9.89
Rhus virens	1	2.44	0.10	0.13
Sophora secundiflora	7	17.07	3.00	3.95
TOTAL	41	100.00%	75.85%	99.99%

TABLE 11

Line 6

	TI	RDi	RC	RDii
Carya illinoiensis	11	36.66	50.00	43.01
Celtis reticulata	7	23.33	31.00	26.66
Juglans microcarpa	12	40.00	35.25	30.32
TOTAL	30	99.99%	116.25%	99.99%

TABLE 12

Line 7

	TI	RDi	RC	RDii
Juniperus ashei	22	57.89	47.25	49.22
Quercus glaucoides	8	21.05	34.50	35.94
Quercus pungens var. vaseyana	2	5.26	11.00	11.46
Sophora secundiflora	5	13.16	2.25	2.34
Yucca reverchonii	1	2.63	1.00	1.04
TOTAL	38	99.99%	96.00%	100.00%

TABLE 13

Line 8

	TI	RDi	RC	RDii
Berberis trifoliolata	1	7.14	0.25	3.57
Diospyros texana	1	7.14	1.50	21.43
Quercus fusiformis	11	78.57	1.25	17.86
Quercus pungens var. vaseyana	1	7.14	4.00	57.14
TOTAL	14	99.99%	7.00%	100.00%

TABLE 14

Line 9

	TI	RDi	RC	RDii
Berberis trifoliolata	6	15.79	3.85	8.60
Bumelia lanuginosa var. texana	1	2.63	0.10	0.22
Diospyros texana	2	5.26	0.60	1.34
Juniperus ashei	15	39.47	19.20	42.90
Quercus glaucoides	1	2.63	4.50	10.05
Quercus pungens var. vaseyana	6	15.79	11.25	25.14
Rhus virens	7	18.42	5.25	11.73
TOTAL	38	99.99%	44.75%	99.98%

TABLE 15

	TI	RDi
Bumelia lanuginosa var. texana	1	0.24
Carya illinoinensis	152	37.25
Celtis reticulata	72	17.65
Diospyros texana	28	6.86
Juglans microcarpa	145	35.54
Juniperus ashei	8	1.96
Melia azedarach	1	0.24
Platanus occidentalis	1	0.24
TOTAL	408	99.98%

SPECIES LIST

Explanations of symbols used in list:

A – annual **P – perennial**
N – native **I – introduced**
*** – endemic**

SPECIES		**COMMON NAME**
Selaginellaceae		**Spikemoss Family**
Selaginella apoda (L.) Spring	NP	meadow spikemoss
Selaginella wrightii Hieron.	NP	Wright's selaginella
Schizaeaceae		**Curly-grass Family**
Anemia mexicana Kl.	NP	Mexican fern
Polypodiaceae		**True Fern Family**
Adiantum capillus-veneris L.	NP	southern maidenhair
Asplenium resiliens Kunze	NP	little ebony spleenwort
Cheilanthes alabamensis (Buckl.) Kunze	NP	Alabama lipfern, smooth lipfern
Cheilanthes horridula Maxon	NP	rough lipfern
Notholaena candida (Mart. & Gal.) Hook. var. *copelandi* (C. Hall) R. Tryon	NP	cloakfern
Notholaena parvifolia R. Tryon	NP	littleleaf cloakfern
Notholaena sinuata (Lag.) Kaulf. var. *integerrima* Hook.	NP	wavy cloakfern
Pellaea atropurpurea (L.) Link	NP	purple cliffbrake
Pellaea ovata (Desv.) Weath.	NP	cliffbrake
Thelypteris kunthii (Desv.) Morton	NP	southern shieldfern
Pinaceae		**Pine Family**
Pinus cembroides Zucc. var. *remota* Little*	NP	Mexican pinyon, pino piñonero
Taxodiaceae		**Taxodium Family**
Taxodium distichum (L.) Rich.	NP	bald cypress
Cupressaceae		**Cypress Family**
Juniperus ashei Buchh.	NP	post cedar, rock cedar
Ephedraceae		**Ephedra Family**
Ephedra sp.	NP	Mormon tea
Potamogetonaceae		**Pondweed Family**
Potamogeton illinoensis Morong	NP	shining pondweed
Poaceae		**Grass Family**
Agrostis semiverticillata (Forsk.) Christ	IP	water bentgrass
Andropogon glomeratus (Walt.) B.S.P.	NP	bushy bluestem, bushy beardgrass
Aristida glauca (Nees) Walt.	NP	blue three-awn
Aristida purpurea Nutt.	NP	purple three-awn
Arundo donax L.	IP	giantreed
Bothriochloa barbinodis (Lag.) Herter var. *barbinodis*	NP	cane bluestem
Bothriochloa ischaemum (L.) Keng var. *songarica* (Rupr.) Celarier & Harlan	IP	King Ranch bluestem
Bouteloua curtipendula (Michx.) Torr.	NP	sideoats grama
Bouteloua hirsuta Lag.	NP	hairy grama
Bouteloua rigidiseta (Steud.) Hitchc.	NP	Texas grama, bell grama
Buchloe dactyloides (Nutt.) Engelm.	NP	buffalograss
Cenchrus incertus M.A. Curtis	NP	grassbur, coast sandbur
Elymus canadensis L.	NP	Canada wildrye
Eragrostis cilianensis (All.)	IA	stinkgrass
Eragrostis lugens Nees	NP	mourning lovegrass
Erioneuron pilosum (Buckl.) Nash	NP	hairy tridens

Hilaria belangeri (Steud.) Nash	NP	common curly mesquite grass
Leptochloa dubia (H.B.K.) Nees	NP	green sprangletop
Leptoloma cognatum (Schult.) Chase	NP	fall witchgrass
Muhlenbergia lindheimeri Hitchc.	NP	Lindheimer muhly
Panicum hallii Vasey	NP	Halls panicum
Panicum lindheimeri Nash	NP	Lindheimer panicum
Paspalum dilatatum Poir	IP	Dallis grass
Schizachyrium scoparium (Michx.) Nash var. *frequens* (F.T. Hubb.) Gould	NP	little bluestem
Setaria glauca (L.) Beav.	NA	yellow foxtail
Setaria scheelei (Steud.) Hitchc.	NP	southwestern bristlegrass
Sorghum halepense (L.) Pers	IP	Johnson grass
Stenotaphrum secundatum (Walt.) Kuntze	IP	St. Augustine grass
Stipa leucotricha Trin. & Rupr.	NP	Texas speargrass
Tridens muticus (Torr.) Nash	NP	slim tridens
Cyperaceae		**Sedge Family**
Carex planostachys Kunze	NP	cedar sedge
Cladium jamaicensis Crantz.	NP	Jamaica sawgrass
Dichromena nivea Boeckl.	NP	snowy whitetop
Eleocharis caribaea (Rottb.) Blake	NP	spikesedge
Eleocharis macrostachya Britton	NP	largespike spikesedge
Fuirena simplex Vahl.	NP	western unbrellasedge
Bromeliaceae		**Pine-apple Family**
Tillandsia recurvata L.	NP	ballmoss, gallitos
Juncaceae		**Rush Family**
Juncus dudleyi Wieg.	NP	Dudley rush
Juncus filipendulus Buckl.	NP	ringeseed rush
Juncus torreyi Cov.	NP	Torrey rush
Liliaceae		**Lily Family**
Asparagus offinalis L.	IP	garden asparagus
Dasylirion texanum Scheele	NP	Texas sotol
Nolina lindheimeri (Scheele) Wats.	NP	Lindheimer nolina
Smilax bona-nox L.	NP	saw greenbrier
Yucca arkansana Trel.	NP	Arkansas yucca
Yucca reverchonii Trel.*	NP	San Angelo yucca
Yucca torreyi Shafer	NP	Spanish dagger
Amaryllidaceae		**Amaryllis Family**
Cooperia drummondii Herb.	NP	rain lily, ceboleta
Iridaceae		**Iris Family**
Sisyrinchium ensigerum Bickn.	NP	swordleaf blue-eyed grass
Orchidaceae		**Orchid Family**
Epipactis gigantea Hook.	NP	giant helleborine
Salicaceae		**Willow Family**
Salix lasiolepis Benth. var. *bracelinae* Ball	NP	narrowleaf arroyo willow
Salix nigra Marsh. var. *nigra*	NP	black willow
Juglandaceae		**Walnut Family**
Carya illinoinensis (Wang.) K. Koch	NP	pecan, nogal morado
Juglans major (Torr.) Heller	NP	Arizona walnut
Juglans microcarpa Berl.	NP	little walnut
Fagaceae		**Beech Family**
Quercus fusiformis Small	NP	scrub live oak
Quercus glaucoides Mart. & Gal.	NP	Lacey oak
Quercus muehlenbergii Engelm.	NP	chinkapin oak
Quercus pungens Liebm. var. *vaseyana* (Buckl.) C.H. Mull.	NP	Vasey shin oak
Quercus texana Buckl.*	NP	Spanish oak

Ulmaceae		**Elm Family**
Celtis reticulata Torr.	NP	netleaf hackberry
Ulmus crassifolia Nutt.	NP	cedar elm, olmo
Moraceae		**Mulberry Family**
Morus microphylla Buckl.	NP	moutain mulberry
Urticaceae		**Nettle Family**
Boehmeria cylindrica (L.) Sw. var. *cylindrica*	NP	smallspike falsenettle
Parietaria obtusa Rydb.	NP	pellitory
Viscaceae		**Mistletoe Family**
Phoradendron tomentosum (DC.) Gray subsp. *tomentosum*	NP	injerto
Aristolochiaceae		**Birthwort Family**
Aristolochia coryi I.M. Johnst.	NP	Cory Dutchmanspipe
Nyctaginaceae		**Four-o'clock Family**
Boerhaavia linearifolia Gray	NP	narrowleaf spiderling
Mirabilis dumetorun Shinners	NP	four-o'clock
Mirabilis grayana (Standl.) Standl.*	NP	four-o'clock
Portulacaceae		**Purslane Family**
Portulaca mundula I.M. Johnst. var. *mundula*	NP	chisme, shaggy portulaca
Ceratophyllaceae		**Hornwort Family**
Ceratophyllum demersum L.	NP	common hornwort
Ranunculaceae		**Crowfoot Family**
Clematis drummondii T. & G.	NP	Texas virgins bower
Clematis texensis Buckl.*	NP	scarlet clematis
Berberidaceae		**Barberry Family**
Berberis trifoliolata Moric	NP	agarito, algerita
Menispermaceae		**Moonseed Family**
Cocculus carolinus (L.) DC.	NP	Carolina snailseed
Papaveraceae		**Poppy Family**
Argemone albiflora Hormen.	NA	white pricklypoppy
Argemone mexicana L.	NA	yellow pricklypoppy
Brassicaceae		**Mustard Family**
Lepidium virginicum L.	NA	Virginia pepperweed
Rorippa nasturtium-aquaticum (L.) Hayek	IP	watercress
Capparidaceae		**Caper Family**
Polanisia dodecandra (L.) DC. var. *trachysperma* (T. & G.) Iltis	NA	roughseed clammyweed
Platanaceae		**Plane-tree Family**
Platanus occidentalis L.	NP	sycamore, buttonwood
Rosaceae		**Rose Family**
Cercocarpus montanus Raf. var. *glaber* (Wats.) F.L. Martin	NP	smooth mountain mahogany
Crataegus traceyi Ashe*	NP	mountain hawthorne
Prunus serotina Ehrhart subsp. *eximia* (Small) McVaugh	NP	escarpment blackcherry
Rubus trivialis Michx.	NP	southern dewberry
Fabaceae		**Legume Family**
Acacia constricta Benth.	NP	mescat acacia
Acacia roemeriana Scheele	NP	catclaw
Acacia smallii Isley	NP	huisache
Cassia lindheimeriana Scheele	NP	Lindheimer senna
Cassia roemeriana Scheele	NP	twoleaf senna
Cassia wislizenii Gray	NP	Wislizenus senna

Cercis canadensis L. var. *texensis* (Wats.) Rose	NP	Texas redbud
Desmodium psilophyllum Schlecht.	NP	tickclover
Eysenhardtia texana Scheele	NP	Texas kidneywood
Galactia texana (Scheele) Gray*	NP	Texas milkpea
Gleditsia triacanthos L.	NP	honey locust
Indigofera lindheimeri Scheele	NP	Lindheimer indigo
Lespedeza violacea (L.) Pers.	NP	prairie clover
Leucaena retusa Gray	NP	littleleaf leadtree
Mimosa biuncifera Benth.	NP	catclaw mimosa
Parkinsonia aculeata L.	IP	retama, Mexican palo verde
Prosopis glandulosa Torr.	NP	mesquite
Rhynchosia texana Torr. & Gray	NP	Texas snoutbean
Sophora affinis Torr. & Gray	NP	Eve's necklace
Sophora secundiflora (Ort.) DC.	NP	Texas mountain laurel
Oxalidaceae		**Wood-sorrel Family**
Oxalis dillenii Jacq.	NP	yellow wood-sorrel
Linaceae		**Flax Family**
Linum rupestre Engelm.	NA	rock flax
Zygophyllaceae		**Caltrop Family**
Kallstroemia parviflora Norton	NA	warty caltrop
Tribulus terrestris L.	IA	puncturevine, goathead
Rutaceae		**Citrus Family**
Ptelea trifoliata L. subsp. *angustifolia* (Benth.) Bailey var. *persicifolia* (Greene) Bailey	NP	waferash, hoptree, skunk-bush, cola de zorrillo
Thamnosma texana (Gray) Torr.	NP	Dutchman's britches
Zanthoxylum hirsutum Buckl.	NP	tickle tongue
Meliaceae		**Mahogany Family**
Melia azedarach L.	IP	chinaberry, paraiso
Malpighiaceae		**Malpighia Family**
Thryallis angustifolia (Benth.) Kuntze	NP	narrowleaf thryallis
Polygalaceae		**Milkwort Family**
Polygala lindheimeri Gray	NP	shrubby milkwort
Euphorbiaceae		**Spurge Family**
Acalypha lindheimeri Muell. Arg.	NP	Lindheimer copperleaf
Argythamnia neomexicana Muell. Arg.	NP	New Mexico wildmercury
Bernardia myricifolia (Scheele) Wats.	NP	brush myrtlecroton, oreja de raton
Croton monanthogynus Michx.	NA	one-seeded croton
Euphorbia angusta Engelm.*	NA	blackfoot euphorbia
Euphorbia dentata Michx.	NA	toothed spurge
Euphorbia nutans Lag.	NA	eyebane, spotted euphorbia
Euphorbia prostrata Ait.	NA	prostrate euphorbia
Euphorbia serpens H.B.K.	NA	heirba de la golondrina
Euphorbia stictospora Engelm.	NA	slimseed euphorbia
Euphorbia villifera Scheele	NA	hairy euphorbia
Phyllanthus polygonoides Spreng.	NP	knotweed leafflower
Tragia ramosa Torr.	NP	noseburn
Anacardiaceae		**Sumac Family**
Rhus aromatica Ait. var. *flabelliformis* Shinners	NP	skunkbush, polecat bush
Rhus lanceolata (Gray) Britt.	NP	flameleaf sumac
Rhus toxicodendron L. var. *vulgaris* (Michx.) DC.	NP	poison ivy
Rhus virens Gray	NP	evergreen sumac
Hippocastanaceae		**Buckeye Family**
Aesculus pavia L. var. *flavescens* (Sarg.) Correll	NP	red buckeye, horse chesnut

Sapindaceae		**Soap-berry Family**
Sapindus saponaria L. var. *drummondii* (H. & A.) L. Benson	NP	western soapberry, jaboncillo
Ungnadia speciosa Endl.	NP	Mexican buckeye
Rhamnaceae		**Buckthorn Family**
Condalia hookeri M.C. Johnst.	NP	brasillo, capul negro
Rhamnus caroliniana Walt.	NP	Indian-cherry
Ziziphus obtusifolia (T. & G.) Gray	NP	lotebush, clepe, gumdrop tree
Vitaceae		**Grape Family**
Cissus incisa (Nutt.) Des Moulins	NP	cowitch, hierba de buey, ivy treebine
Parthenocissus quinquefolia (L.) Planch.	NP	Virginia creeper, hiedra, parra
Vitis berlandieri Planch.	NP	wintergrape
Malvaceae		**Mallow Family**
Abutilon incanum (Link.) Sweet	NP	indianmallow, pelotazo
Sida filicaulis T. & G.	NP	spreading sida
Passifloraceae		**Passion-flower Family**
Passiflora affinis Engelm.	NP	bracted passionflower
Passiflora tenuiloba Engelm.	NP	spreadlobe passionflower
Loasaceae		**Stick-leaf Family**
Mentzelia oligosperma Nutt.	NP	stickleaf, chickenthief
Cactaceae		**Cactus Family**
Echinocactus texensis Hopffer	NP	horse crippler, devil's head
Echinocereus triglochidiatus Engelm. var. *paucispinus* (Engelm.) L. Benson	NP	claret-cup
Opuntia leptocaulis DC.	NP	tasajillo
Opuntia lindheimeri Engelm.	NP	Texas pricklypear
Onagraceae		**Evening Primrose Family**
Ludwigia palustris (L.) Ell.	NP	marsh seedbox
Apiaceae		**Parsley Family**
Daucosma laciniatum Gray*	NA	meadow daucosma
Eryngium leavenworthii Torr. & Gray	NA	leavenworth eryngium
Hydrocotyle verticillata Thunb. var. *triradiata* (A. Rich.) Fern.	NP	water pennywort
Torilis arvensis (Huds.) Link	NA	hedge parsley
Cornaceae		**Dogwood Family**
Garrya lindheimeri Torr.*	NP	Lindheimer silktassel
Sapotaceae		**Sapodilla Family**
Bumelia lanuginosa (Michx.) Pers. var. *texana* (Buckl.) Cronquist	NP	ironwood, coma
Ebenaceae		**Persimmon Family**
Diospyros texana Scheele	NP	Mexican persimmon
Oleaceae		**Olive Family**
Forestiera pubescens Nutt.	NP	elbowbush, spring herald
Forestiera reticulata Torr.	NP	netleaf forestiera
Loganiaceae		**Logania Family**
Buddleja racemosa Torr.*	NP	wand butterfly bush
Gentianaceae		**Gentian Family**
Centaurium beyrichii (T. & G.) Robins. var. *beyrichii*	NA	mountain pink, centaury
Centaurium calycosum (Buckl.) Fern. var. *breviflorum* Shinners	NA	rosita, centaury
Asclepiadaceae		**Milkweed Family**
Matelea reticulata (Engelm.) Woods.	NP	milkvine
Convolvulaceae		**Morning Glory Family**
Evolvulus sericeus Sw.	NP	silky evolvulus

Boraginaceae		**Borage Family**
Heliotropium tenellum (Nutt.) Torr.	NA	pasture heliotrope, turnsole
Lithospermum parksii I.M. Johnst. var. *parksii*	NP	Park's gromwell, puccoon
Verbenaceae		**Vervain Family**
Phyla incisa Small	NP	sawtooth frogfruit
Verbena bipinnatifida Nutt.	NA	Dakota vervain
Verbena canescens H.B.K.	NP	Gray vervain
Lamiaceae		**Mint Family**
Hedeoma drummondii Benth. var. *drummondii*	NP	Drummond hedeoma, mock pennyroyal
Marrubium vulgare L.	IP	common horehound
Mentha piperita L.	IP	peppermint
Salvia coccinea Murr.	NP	tropical sage
Salvia farinacea Benth.	NP	mealy sage
Scutellaria drummondii Benth.	NP	Drummond skullcap
Teucrium canadense L. var. *canadense*	NP	American germander, wood sage
Solanaceae		**Nightshade Family**
Datura stramonium L.	IA	jimson weed, toloache
Datura wrightii Regal	NA	sacred datura
Nicotiana repanda Willd.	NA	fiddleleaf tobacco
Solanum carolinense L.	NP	Carolina horsenettle
Solanum elaeagnifolium Cav.	NP	silverleaf nightshade
Solanum rostratum Dunal	NA	buffalobur
Solanum triquetrum Cav.	NP	Texas nightshade
Scrophulariaceae		**Figwort Family**
Bacopa monnieri (L.) Wettst.	NP	coastal waterhyssop
Maurandya antirrhiniflora Willd.	NP	snapdragon vine
Mimulus glabratus H.B.K.	NP	roundleaf monkeyflower
Verbascum thapsus L.	IA	flannel mullein
Martyniaceae		**Unicorn-plant Family**
Proboscidea louisianica (Mill.) Thell.	NA	common devilsclaw, unicorn plant
Lentibulariaceae		**Bladderwort Family**
Utricularia gibba L.	NA	conespur bladderwort
Acanthaceae		**Acanthus Family**
Carlowrightia torreyana Wasshausen	NP	
Justicia americana (L.) Vahl.	NP	American water-willow
Ruellia metzae Tharp	NP	
Siphonoglossa pilosella (Nees) Torr.	NP	hairy tubetongue
Rubiaceae		**Madder Family**
Cephalanthus occidentalis L.	NP	old honeyballs
Hedyotis nigricans (Lam.) Fosb.	NP	bluets
Caprifoliaceae		**Honeysuckle Family**
Lonicera albiflora T. & G. var. *albiflora*	NP	white honeysuckle
Cucurbitaceae		**Gourd Family**
Cucurbita foetidissima H.B.K.	NP	buffalo gourd
Asteraceae		**Sunflower Family**
Ambrosia psilostachya DC.	NP	western ragweed
Aphanostephus ramossissimus DC.	NA	plains dozedaisy
Aphanostephus riddellii T. & G.	NP	Riddell dozedaisy
Baccharis neglecta Britton	NP	Roosevelt weed
Chaetopappa bellidifolia (Gray & Engelm.) Shinners*	NA	hairy leastdaisy
Cirsium texana Buckl.	NP	southern thistle
Erigeron modestus Gray	NP	plains fleabane
Eupatorium serotinum Michx.	NP	late flowering thoroughwort
Evax prolifera Nutt.	NA	bighead evax
Helenium quadridentatum Labill.	NA	longdisk sneezeweed, rosilla

Hymenoxys odorata DC.	NA	western bitterweed
Hymenoxys scaposa (DC.) Parker var. *scaposa*	NP	bitterweed
Lygodesmia texana (T. & G.) Greene	NP	Texas skeletonplant
Parthenium confertum Gray	NP	pissweed
Pectis angustifolia Torr.	NA	crownseed pectis
Perityle lindheimeri (Gray) Shinners var. *lindheimeri**	NP	Lindheimer rockdaisy
Ratibida columnaris (Sims) D. Don	NP	Mexican hat, upright prairie coneflower
Senecio obovatus Muhl.	NP	golden groundsel
Silphium asperrimum Hook.	NP	roughstem rosinweed
Tetragonotheca texana (Gray) Engelm. & Gray	NP	plateau nerveray
Thelesperma filifolium (Hook.) Gray	NP	greenthread
Verbesina encelioides (Cav.) Gray	NP	cowpen daisy
Verbesina lindheimeri Robins. & Greenm.*	NP	Lindheimer crownbeard
Verbesina virginica L.	NP	frostweed
Vernonia baldwinii Torr.	NP	western ironweed
Xanthocephalum texanum (DC.) Shinners	NA	Texas broomweed, snakeweed
Zexmenia hispida H.B.K.	NP	hairy zexmenia

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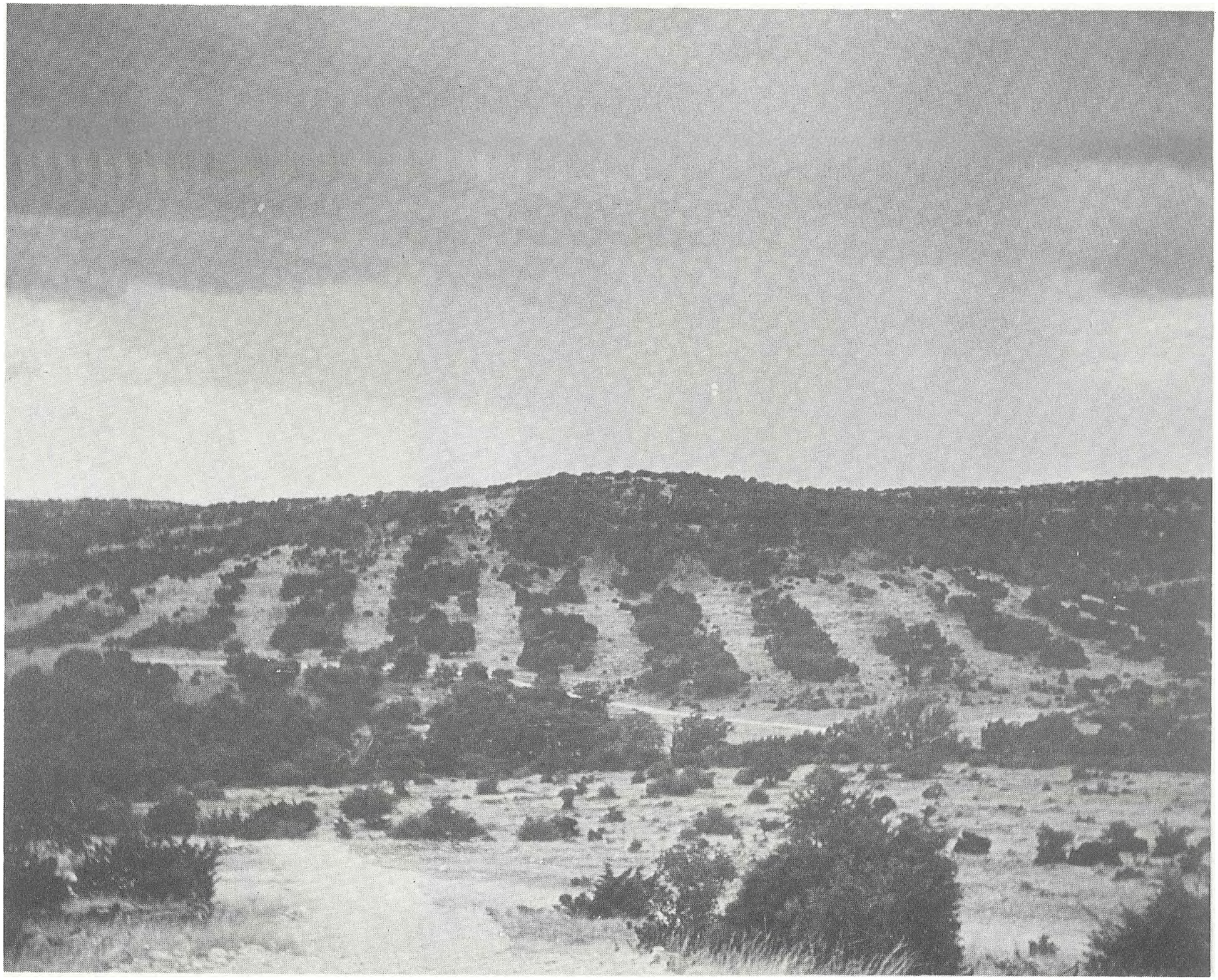


FIGURE 1
A mosaic of cleared and uncleared areas on the Eagle Ranch just north of the headquarters (Joy Hollow 7.5-minute quadrangle map).

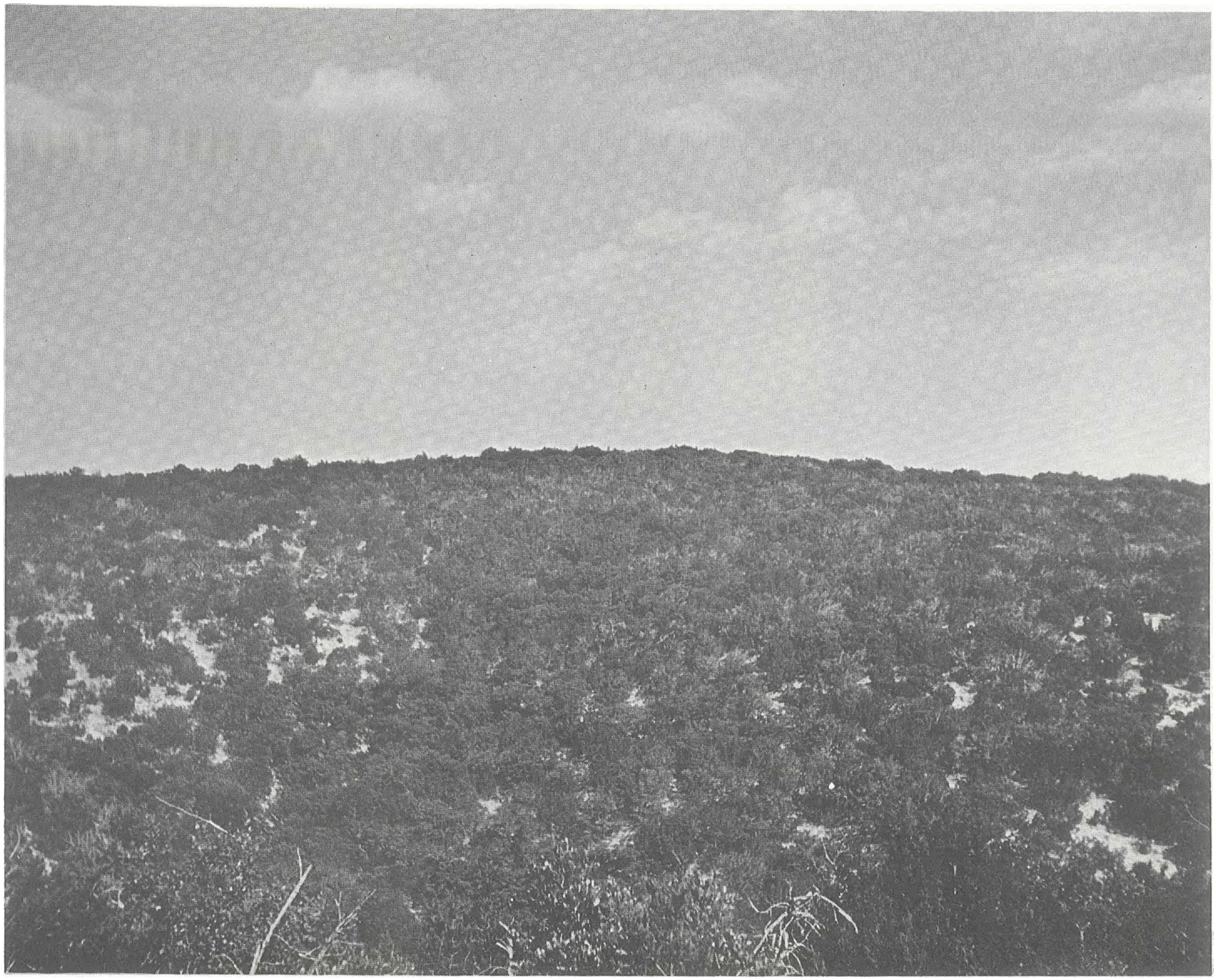


FIGURE 2

Line 1. West-facing slope ca. 0.4 miles southwest of windmill, ca. 2 miles northeast of Kalentine Hole along Hackberry Creek (Hackberry 7.5-minute 9-quadrangle map).

FIGURE 3
Line 3. Creek bottom beginning at the junction of two drainages ca. 0.5 miles southwest of windmill, ca. 2 miles northeast of Kalentine Hole along Hackberry Creek (Hackberry 7.5-minute quadrangle map).

FIGURE 4
Quadrat transect 1 and line 4. Ca. 50 meters southwest of the southern rim of the Devil's Sinkhole (Devil's Sinkhole 7.5-minute quadrangle map).

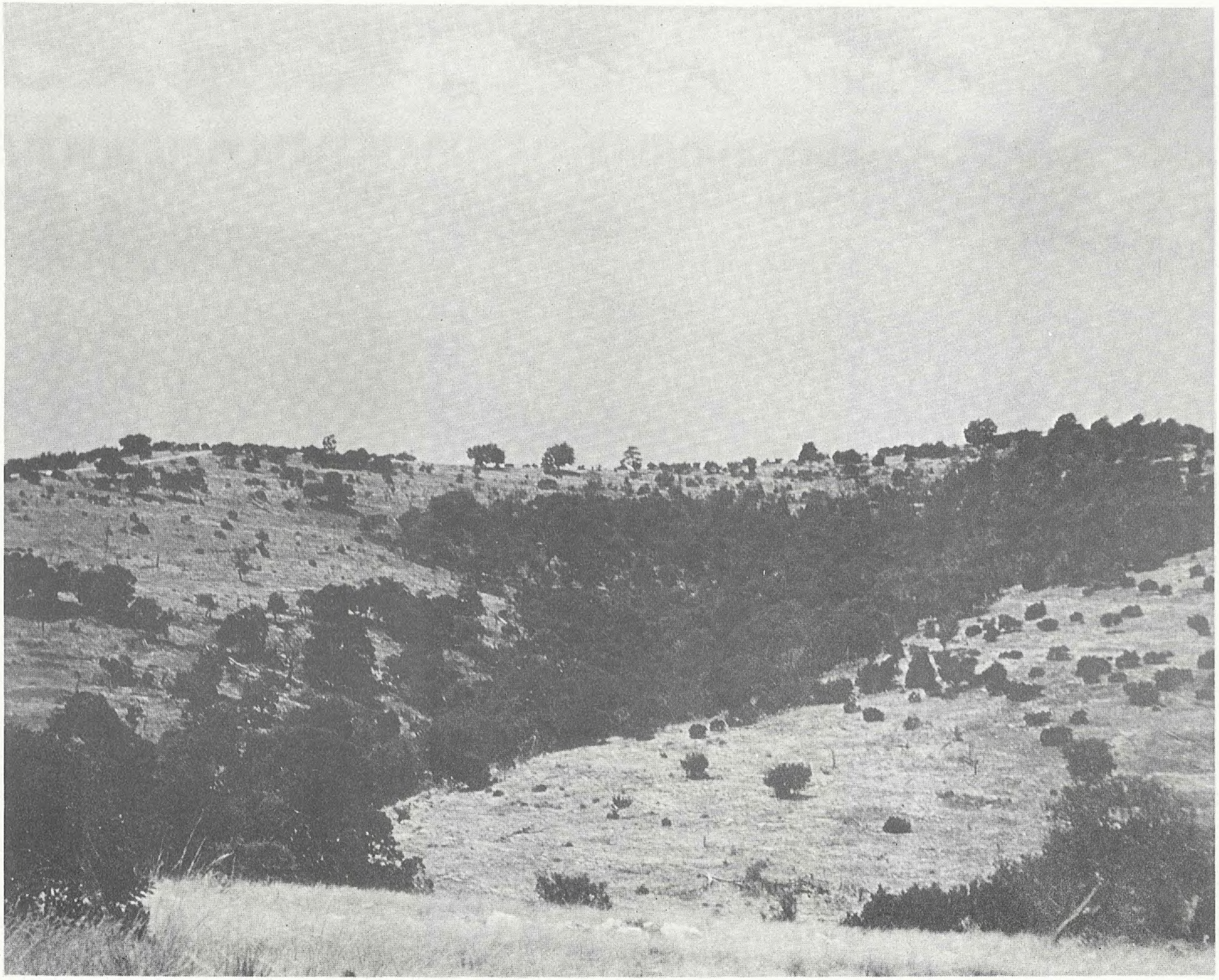


FIGURE 5
Line 5. South-facing slope above northern fork of Mullen Hollow, ca. 0.5 miles southwest of Eagle Ranch Headquarters (Joy Hollow 7.5-minute quadrangle map).

FIGURE 6
Quadrat transect 2. ca. 0.25 miles south of Texas Highway 41, ca. 2.1 miles north northwest of Devil's Sinkhole (Devil's Sinkhole 7.5-minute quadrangle map).

FIGURE 7
Line 6 and the area of the tree density count. Floodplain just east of Hackberry Creek, ca. 0.5 miles north northwest of the confluence of Hackberry Creek and East Prong of the Nueces River (Hackberry 7.5-minute quadrangle map).

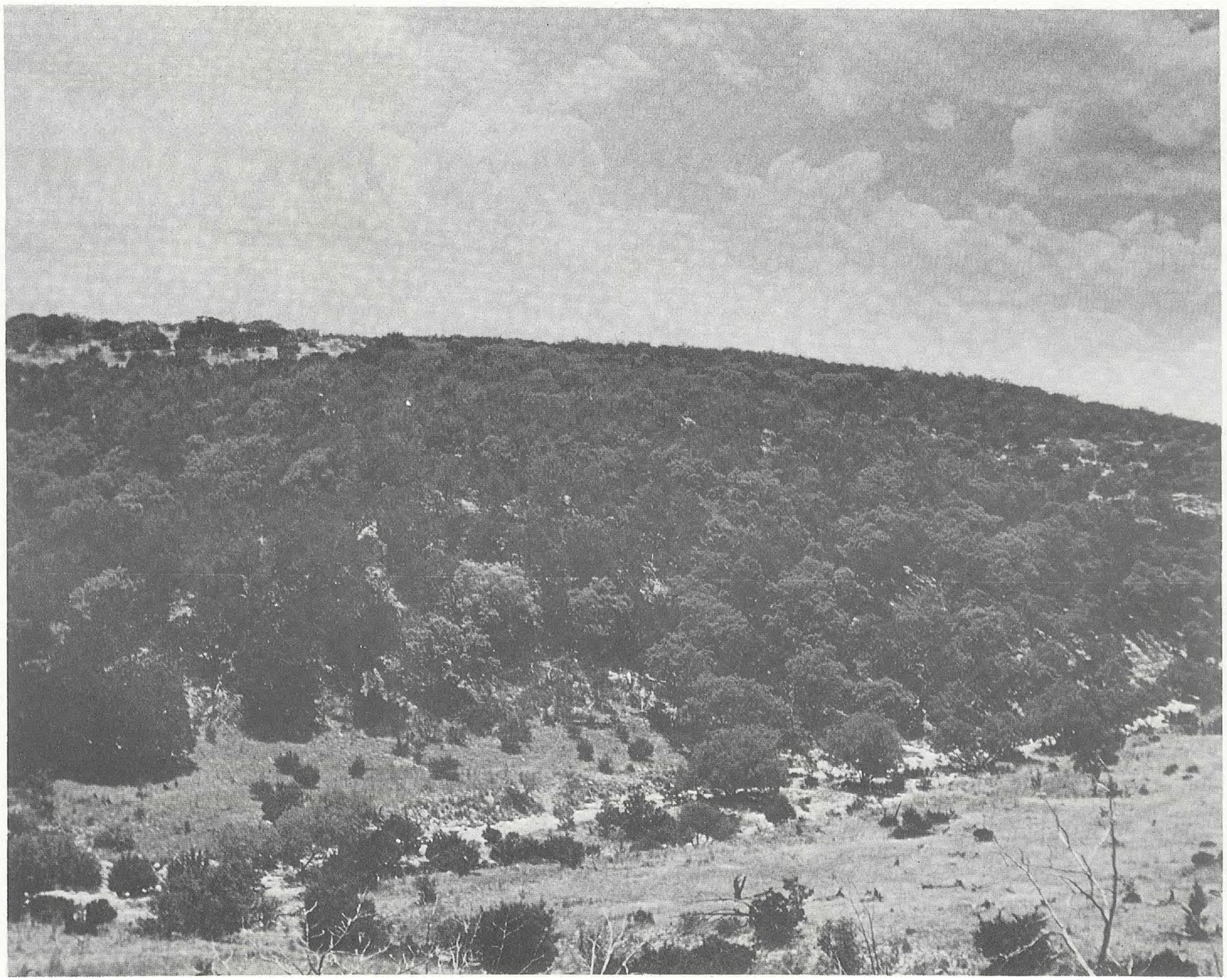


FIGURE 8
Line 7. North-facing slope, northwest branch of West Rose Draw, ca. 0.8 miles southwest of Red Arrow Cave (Joy Hollow 7.5-minute quadrangle map).

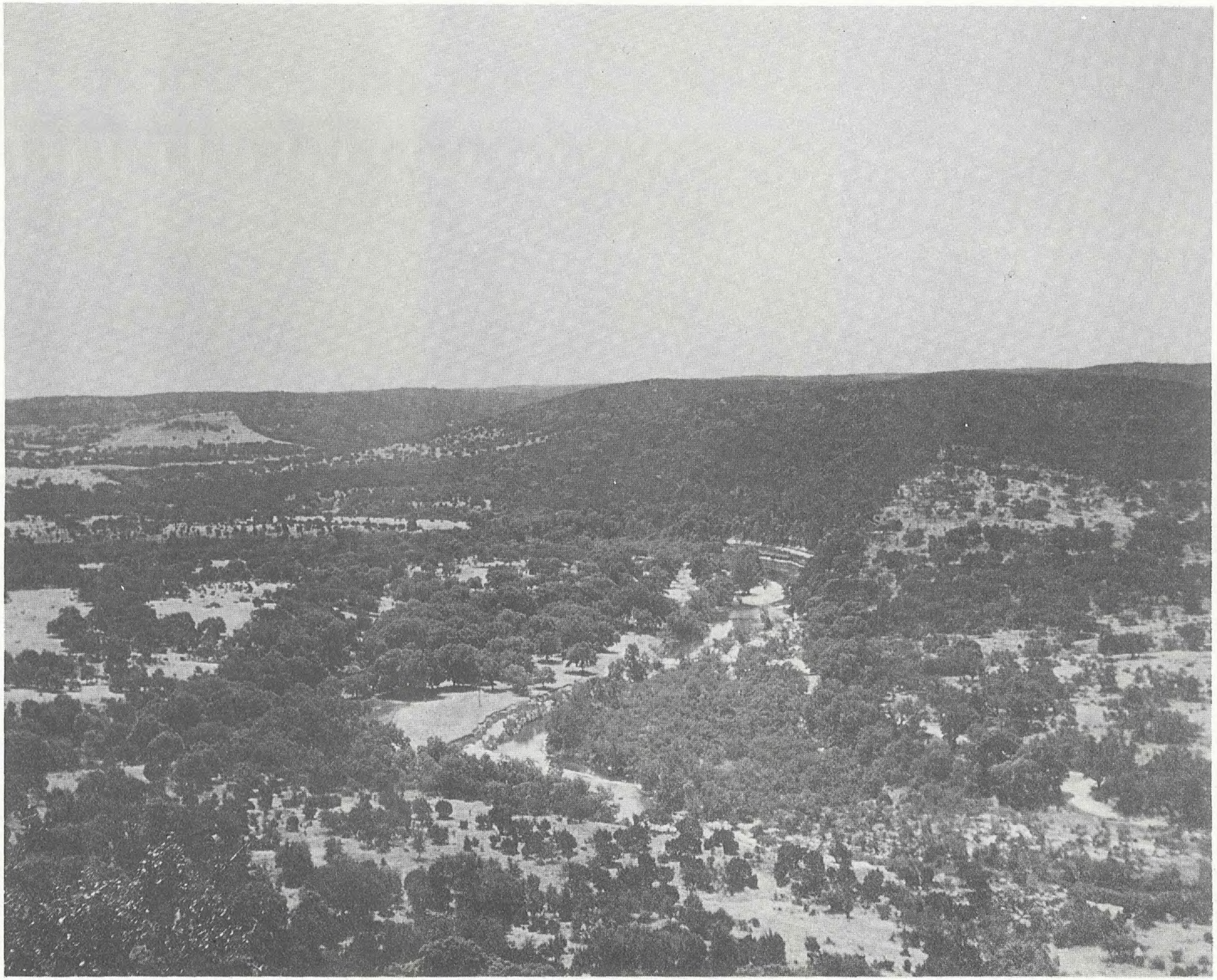


FIGURE 9

Quadrat transect 3 and line 8 on cleared slope. Quadrat transect 5 and line 9 on wooded slope. North-facing slope of Graveyard Mountain, ca. 0.25 miles west of Hackberry cemetery (Hackberry 7.5-minute quadrangle map).

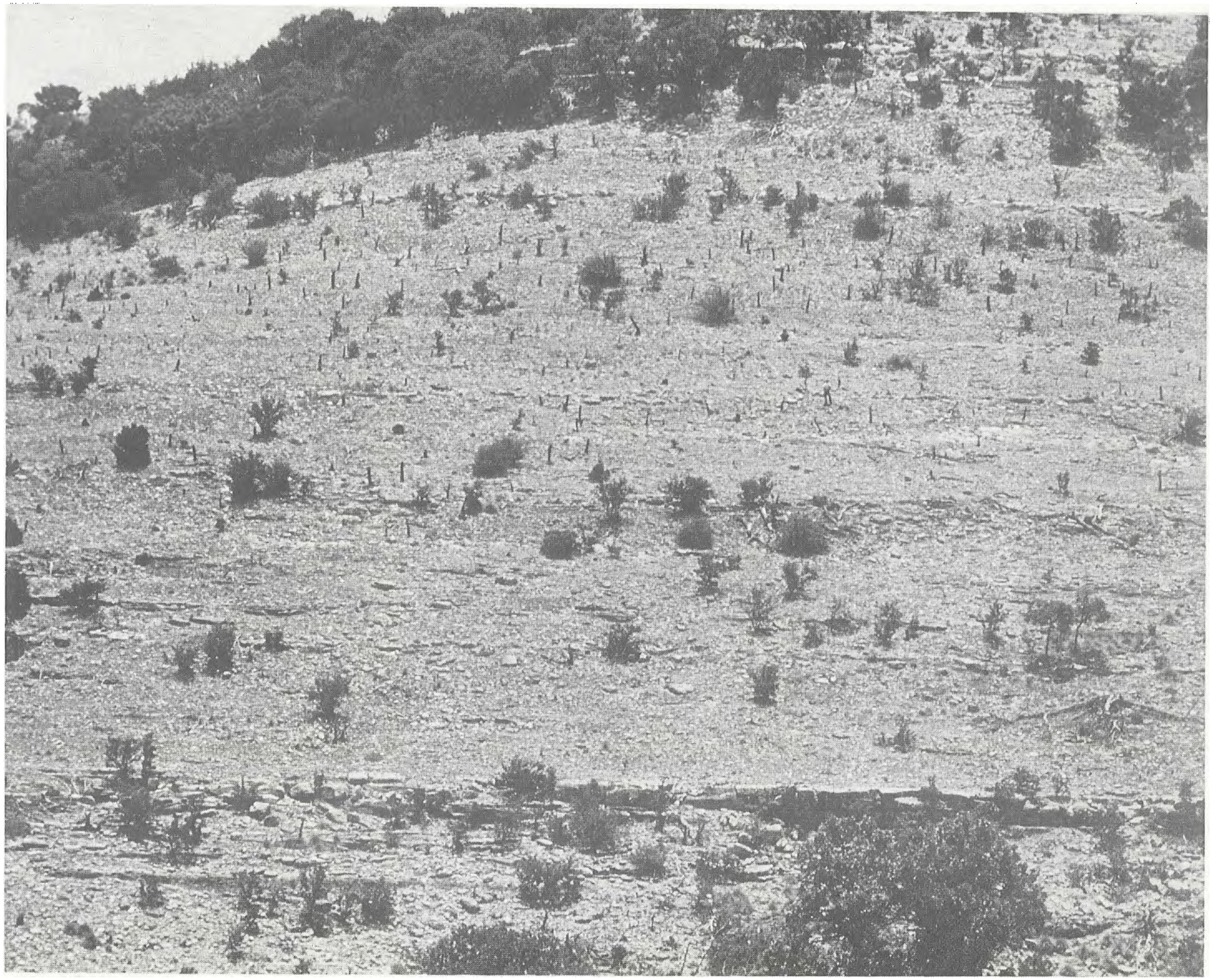


FIGURE 10

Quadrat transect 4. North-facing slope of Schoolhouse Mountain, ca. 0.1 miles south of Cade Spring (Hackberry 7.5-minute quadrangle map).

FIGURE 11
Mexican pinyon on Schoolhouse Ranch, ca. 2 mi. southwest of Eagle Ranch Headquarters (Joy Hollow 7.5-minute quadrangle).

CAVE RESOURCES OF THE DEVIL'S SINKHOLE – HACKBERRY CREEK AREA

Dwight Deal
Chihuahuan Desert Research Institute
and
National Speleological Society

Ronald G. Fieseler
Texas Speleological Association
and
Texas Speleological Survey

INTRODUCTION

Two major caves and several smaller ones are known to exist in the Devil's Sinkhole-Hackberry Creek area studied in July, 1974 by the Natural Areas Survey of the University of Texas at Austin. This report is prepared for the Division of Natural Resources and Environment for submission to the Texas Parks and Wildlife Department. The caves, large and small—when considered along with the springs and the history of ground-water flow in the area—provide the basis for what could be an outstanding interpretative program for future visitors to the area. As a result, we are preparing this special section in the hope that users of this report will consider the unique educational benefits that could be gained from an integrated development of both the surface and subsurface resources of the area.

There is some chance that other large caves must be found in this area in the future. Certainly many small ones will be discovered. This particular area is generally quite accessible and most of the caves have been known for many years. Much of the area has been actively searched for caves, but only a few recent discoveries have been reported. The chance discovery of some overlooked crack or the excavation of crevices or sinkholes could, however, result in the discovery of another significant cave in this area.

We are considering primarily the physical resources of the caves in this report. The biological aspects of Devil's Sinkhole are discussed separately by Elliott and Reddell (this volume).

PREVIOUS WORK

Although all caves discussed were visited during the time the Natural Areas Survey field party was in the area, the three larger caves–Devil's Sinkhole, Red Arrow Cave, and Vance Cave–have been visited by numerous individuals in the past. We are drawing heavily on their experiences and publications and are grateful both to the dedication of these cave explorers and for the information contained in the files of the National Speleological Society, the Texas Speleological Association, and the Texas Speleological Survey. Much of the descriptive information is taken directly from the files of the Texas Speleological Survey, some of which was published previously by Reddell and Smith (1965). The text of the description of Devil's Sinkhole is copyrighted material (Fieseler, in preparation) from a book on the commercial caves of Texas.

CAVE DESCRIPTIONS

DEVIL'S SINKHOLE (HELL HOLE)

(C) 1974 by Ronald G. Fieseler, Austin, Texas

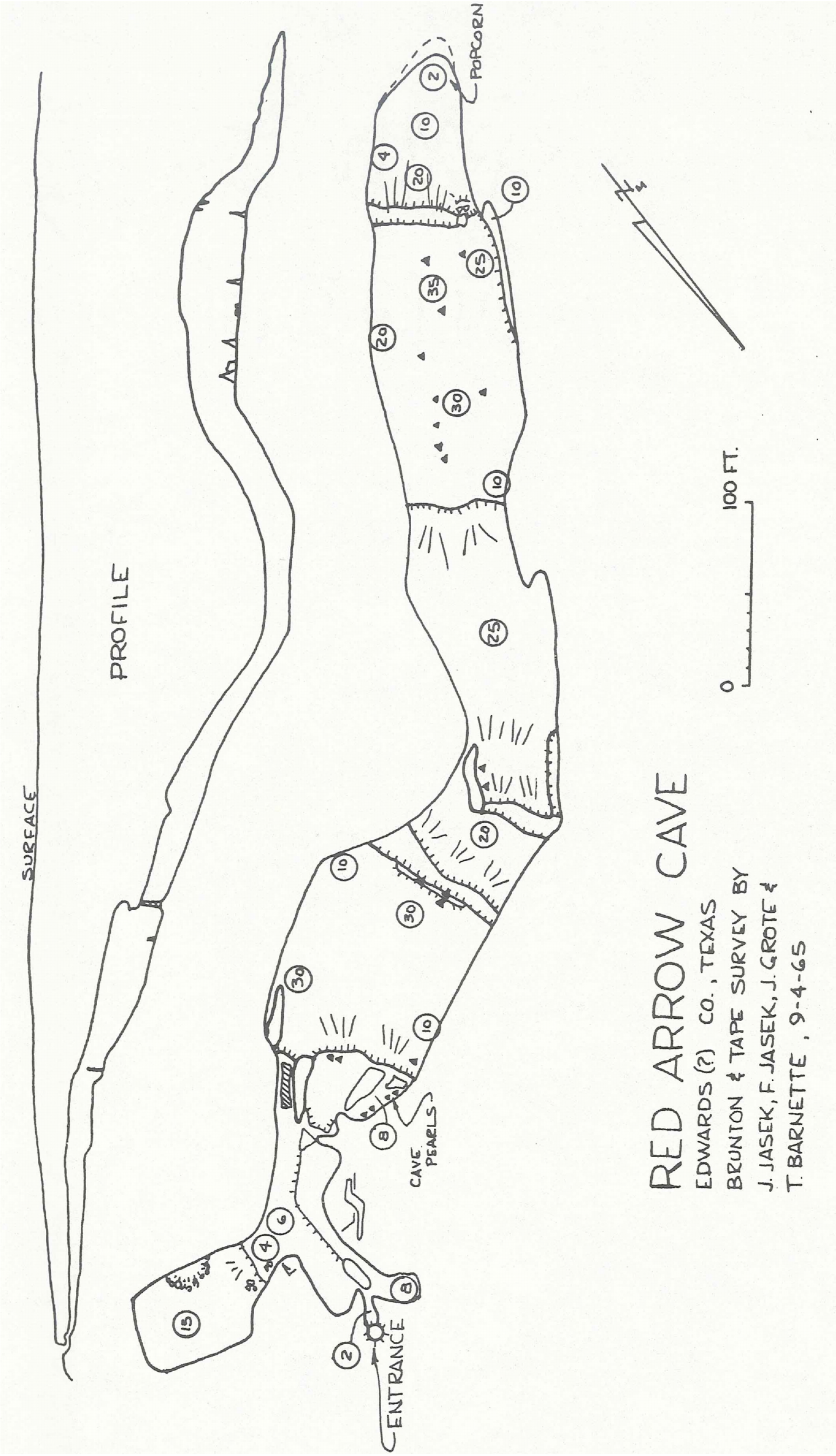
Location—Devil's Sinkhole 7½-minute Quadrangle, Edwards County

Owner—C. V. Whitworth, Jr.

Description—(C) by Ronald G. Fieseler, Austin, Texas

The entrance to the cave is located on top of a relatively flat ridge of almost bare limestone with scattered clumps of underbrush and stunted trees (fig. 1). With a diameter of about 60 feet, the entrance drops abruptly from the surrounding hillside for about 140 feet. The first few feet of the drop are against the ledge, but after this it is deeply undercut and is a free fall the rest of the way down. It is not possible to descend into the Sinkhole without the use of rope or cable ladders. On one side a short drop leads to a steeply sloping ledge which may be followed for a short way, but this soon ends in another sheer drop requiring rope.

The vertical nature of this cave has led to the entrapment and subsequent rescues of several inexperienced people. Common sense indicates that one should not attempt to enter this cave without prior vertical caving experience or without the presence of a vertically qualified leader. Proper training and experience, along with modern techniques and equipment, are absolute necessities for exploring this impressive pit.


RED ARROW CAVE
EDWARDS (?) CO., TEXAS
BRUNTON & TAPE SURVEY BY
J. JASEK, F. JASEK, J. GROTE &
T. BARNETTE, 9-4-65
PROFILE
SURFACE
ENTRANCE
CAVE PEARLS
POPCORN
0
100 FT.

At the bottom of the drop one finds himself on top of a large breakdown "mountain" with steep sides sloping downward to the walls. The blocks of breakdown comprising these slopes are covered with slick guano, making for very treacherous footing. At the bottom of this mountain it is possible to look back up toward the entrance for what is truly one of the most spectacular underground sights conceivable (fig. 2). The entrance, about 300 feet above, framed by terraced ledges hung with cave formations, moss, lichens, and other greenery and centered above a giant underground mountain, is a sight that few will forget. The overall dimensions of the high ceiling and breakdown mountain make it seem much larger.

Climbing under and through the breakdown at the bottom of the slope soon brings one to a series of deep lakes. Divers have explored these and have reached depths of 40 to 80 feet without reaching a bottom. These lakes were originally reported to be 409 feet below the entrance, but a recent accurate survey revealed the true depth to be 310 feet. It is in these deep, clear pools that species of blind amphipods and isopods live and are of great interest to biospeleologists.

There are no known side passages or rooms. One large room (of which the lake rooms are a part, being separated only by breakdown) comprises the entire cave.

History

It is not known who discovered the Sinkhole, but some accounts claim it was discovered as early as 1867, although it is located well beyond the frontier of that time. In 1876 Ammon Billings drove 400 hogs onto the plateau to feed on the heavy mast. While out hunting one day with several other men, they saw some Indians and fired at them. The Indians fell, and Billings started to rush them but was persuaded by Captain Wells that the Indians' disappearance might be a ruse. They came back the next day and found traces of blood on the ground where the Indians had fallen. While reconnoitering through the high grass, they walked up on the brink of the Sinkhole. Their wives were invited to see "a helluva hole in the ground." The women agreed that it was quite a hole but disliked the perhaps-warranted profanity. They suggested that "The Devil's Sinkhole" would do just as well (Meador, 1965).

The Sinkhole was often visited by cowboys. They did little more than drop rocks and larger boulders into the pit to watch in amazement as they shattered upon impact and listen to the tremendous boom echoing off the walls of the cave. Such activities usually stirred up the bat colony and sent them spiraling out of the cave and into the range of the cowboys' pistols and rocks. The cowboys were sorely tempted by large accumulations of honeycomb deposited by the vast swarms of honey bees inhabiting the cave. The honey was 10 to 20 feet below the entrance ledge, however, and no one would think of suspending himself from a lariat over such a deep void.

Who first entered the cave is unknown. One of the oldest names and dates carved on the rock at the bottom is H. S. Barber, October 19, 1889. Judge John W. Hill and party explored the cave in 1899. They reported finding a skeleton of a bear and many beautiful "water formations." Sometime in the early explorations of the cave Ira L. Wheat and Captain Frank James, while searching for the Odel boys (outlaws?), had occasion to enter the Sinkhole. These two men had shot down over a wagonload of honey from the ledges and rooms of the cave. Some unknown rancher with an enterprising mind laid his windmill pipes down the pit to Windmill Lake (Emerald Lake) to avoid expensive and often hit-or-miss drilling.

The Sinkhole was visited on August 19, 1934 by Frank E. Nicholson and a group of friends. Nicholson greatly exaggerated the observations made during his visit. He claims to have collected blind fish from the Emerald Lakes, although there is no record of blind fish from this cave. Despite countless collection trips by many biologists, no one else has sighted a fish, and it is very doubtful that there could be any. In addition, he claims the depth from the entrance to the lake level to be 646 feet with the dimensions of the room to be 1500 to 1800 feet in width.

The bats of the cave have played an important part in the history of Sinkhole. Machinery was installed in 1934 in an attempt to mine the vast guano deposits found in the cave. Dr. Nance and his associates in Dallas were in charge of this mining venture. At an unknown date operations were shut down.

During World War II Dr. Lytle S. Adams, a surgeon from Irwin, Pennsylvania, entered the Devil's Sinkhole by means of a ladder made of several hundred feet of barbed wire with brush rungs. He was investigating the bat colony for his famous bat bomb project. This project, labeled by the Navy as "Project X-Ray," involved using bats as carriers of tiny incendiary bombs to be dropped over Japanese targets. Tests indicated this to by a highly effective weapon. The program was abruptly cancelled in October of 1944, probably because an even more devastating weapon was nearing completion—the atomic bomb.

Perhaps the best known descent and exploration is that of Patrick J. White, Floyd Potter, Eddie Raney, and Ralph Velasco in January, 1947. They entered the pit using a bosun's chair attached to a cable and were raised and lowered by car. Their adventures

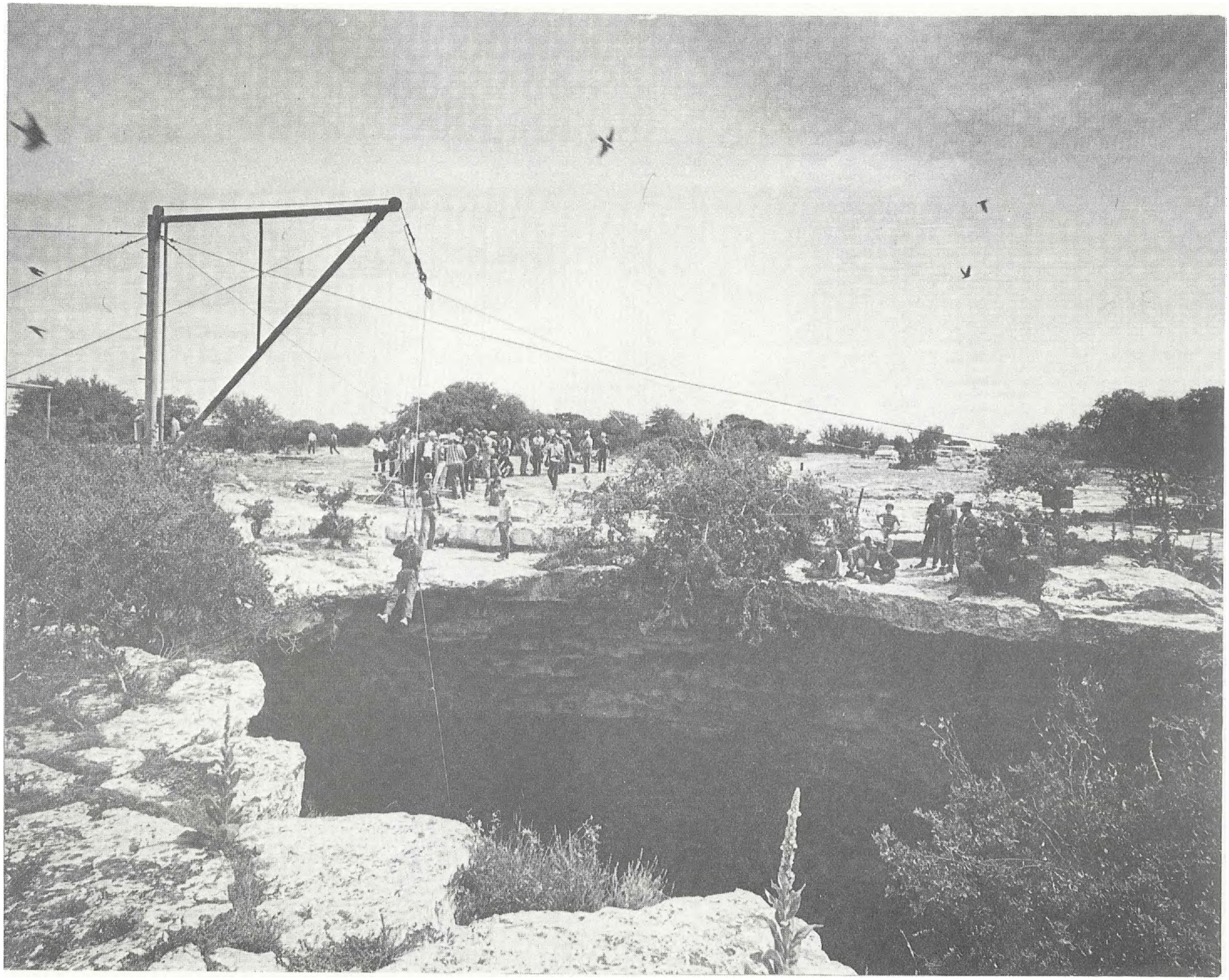


FIGURE 1

Entrance to the Devil's Sinkhole. Note the cave swallows flying in and out of the entrance and the boom that had been erected for a defunct guano-mining operation. This picture was taken in June, 1964 when more than 200 people attending the annual convention of the National Speleological Society were lowered into the cave. The car in the background raised and lowered the cavers by backing up and driving forward. Although the drop is only 140 feet, the car traveled 13 miles that day! Photograph by Carl Kunath.

while exploring the cave are vividly described by White in Bulletin 10 of the National Speleological Society. They calculated the depth of the cave to be 407 feet. The method used by this group to enter the cave was adopted by many visitors with occasional variations. One group visiting the cave in February, 1947 used a winch truck with a platform at the end of the cable. The discomfort and danger experienced by those early explorers due to the makeshift, cumbersome, and elaborate rigging they used almost makes a modern explorer's blood run cold.

In May, 1947 Foster Studios of Kerrville moved their equipment to the site, set up a generator, and began shooting a film. They continued working into October when they finished a 55-minute color film with sound, entitled "The Devil's Sinkhole."

In 1959 and 1960 the Sinkhole was commercialized for a short period by Sid Templeton and Alfred Stewart. They installed a small winch-powered elevator and charged $1.00 per person for the ride to the top of the breakdown mountain and return. Despite the impressiveness of the pit and the beautiful sights at the bottom, the enterprise soon folded.

Mr. R. B. Barlow of the Texas State Park Board visited the cave in early 1956 to investigate possibilities of developing the Sinkhole into a new state park. Unfortunately, there was a lack of necessary funds, and the proposal had to be abandoned.

The Emerald Lakes had always been an intriguing sight for explorers of the cave because of rumors of other rooms located a short dive away. January, 1956 saw an aqualung expedition being led by Bob Holder to check out this story. More than twenty cavers attended to help erect a monorail system to transport equipment and build a diving platform which was illuminated by power from generators brought into the cave. Fred Berner, Jamie Spence, and others reached depths of about fifty feet without finding anything of importance. The silt-covered breakdown and floor hindered exploration by turning the water into an almost impenetrable murkiness soon after entering. The entire project lasted 78 hours of which 66 were spent underground.

A group of cavers from the Corpus Christi Grotto visited the cave in October, 1956 and reported that the Sinkhole was once more being mined for its guano deposits. To gain access to the cave, the miners were using a 150-foot wooden ladder made of two-by-fours and secured with a rope to a platform built at the edge of the entrance. A "cable car" system was employed to remove large sacks of guano from the cave. The rotting remains of the old wooden ladder may still be seen scattered in disarray about the steep ledges in the upper part of the entrance.

In recent years a new mining operation at the Sinkhole was initiated. An extensive search was made for other "lost" rooms of guano by means of gravity meters and well drilling, all to no avail. A large boom was erected near the edge and swung far out over the entrance to facilitate the removal of the guano. This mining operation, like all the others, was soon abandoned, and presently no mining is being done at the cave.

The boom was left in place at the close of operations and was used for many years by cavers visiting the cave. When the Sinkhole was one of the field trips for the National Speleological Society convention held in New Braunfels in June, 1964, over 200 people were lowered into the cave by use of this boom (fig. 1). The lift car traveled an incredible 13 miles during the event. The University of Texas Grotto organized the trip and did an outstanding job of providing the crowd with a safe—yet exciting—visit to this magnificent cave. Thus, it came as a blow to many cavers to discover that in early 1970 the boom had been taken down. Cavers now enter the cave by the standard rappel and prusik methods (figs. 3 and 4). The cave is still one of the most popular in the state, with several trips made each year by various groups.

During its long history of exploration, the Sinkhole has had only two known fatalities, although numerous people and groups have been trapped in the cave due to lack of experience and proper equipment. In September, 1960 Abner Jefferson Totty, a Boy Scout from San Antonio, was killed in the lake room when the cable ladder he was climbing dislodged a rock which fell and crushed his skull. The most recent death occurred in April, 1972 when Angeline Palmer, a University of Texas student from Dallas, fell to her death while climbing out of the cave. A knot on her climbing gear came untied about 30 feet from the top, causing her to topple backward from the climbing rope and fall to the bottom 110 below. Because of incidents like these, and the possibility of others occurring, the owner requires a notarized release from all persons entering his land for the purpose of exploring caves.

In 1971 Secretary of the Interior Rogers C. B. Morton approved the Devil's Sinkhole for inclusion in the National Registry of Natural Landmarks, truly a fitting tribute to such a renowned cave.

Rumors and Legends

The large size of the Devil's Sinkhole has inspired many wild rumors about the cave. Tales of passages miles long, old skeletons, great rivers, and oaken doors can be heard from almost anyone who knows of the cave. Another tremendous room is purportedly just a short dive under water. All indications, combined with extensive exploration both above and

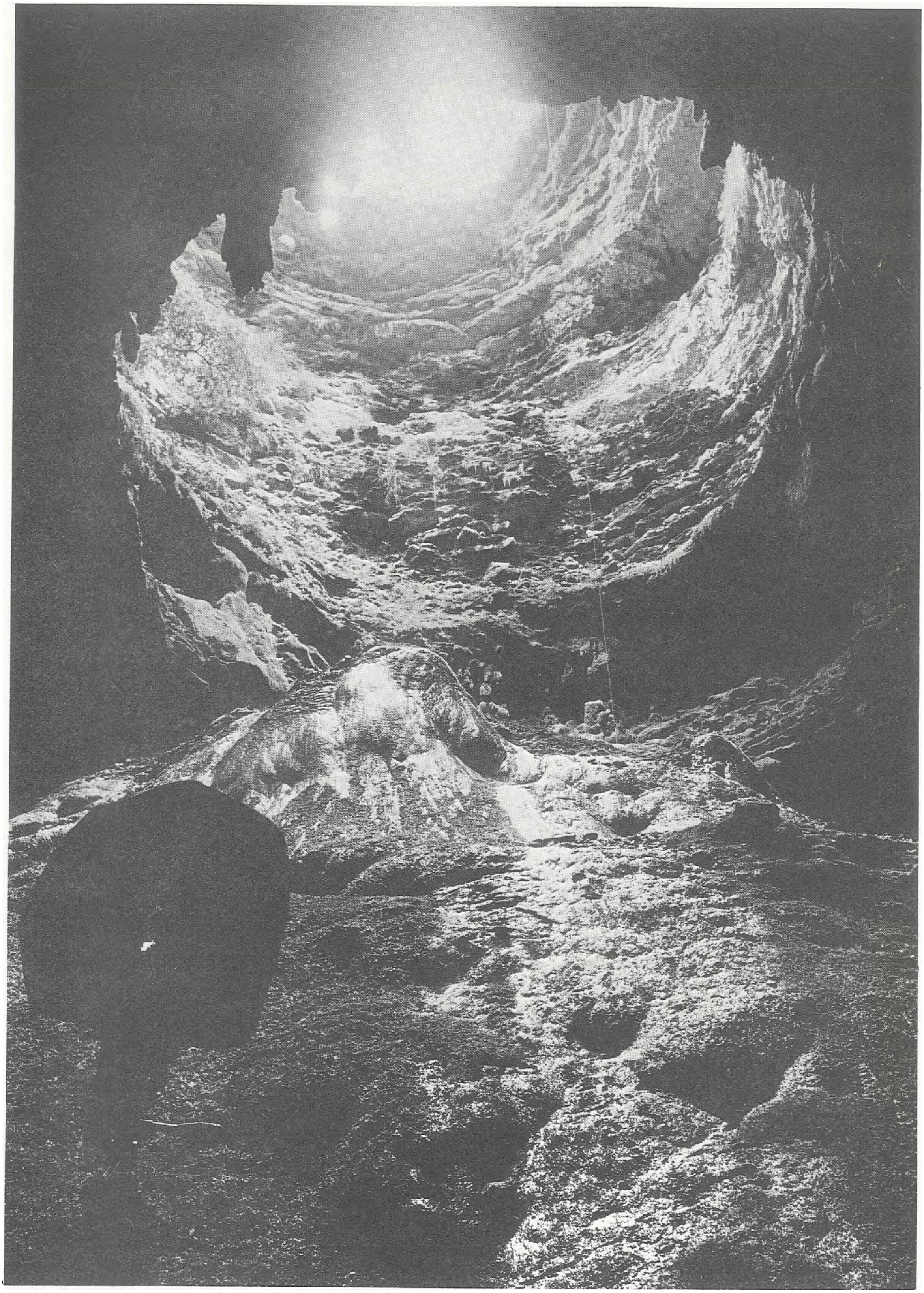


FIGURE 2
Devil's Sinkhole. View of the breakdown "mountain" and entrance shaft from inside the cave. Photo by Reagan Bradshaw.

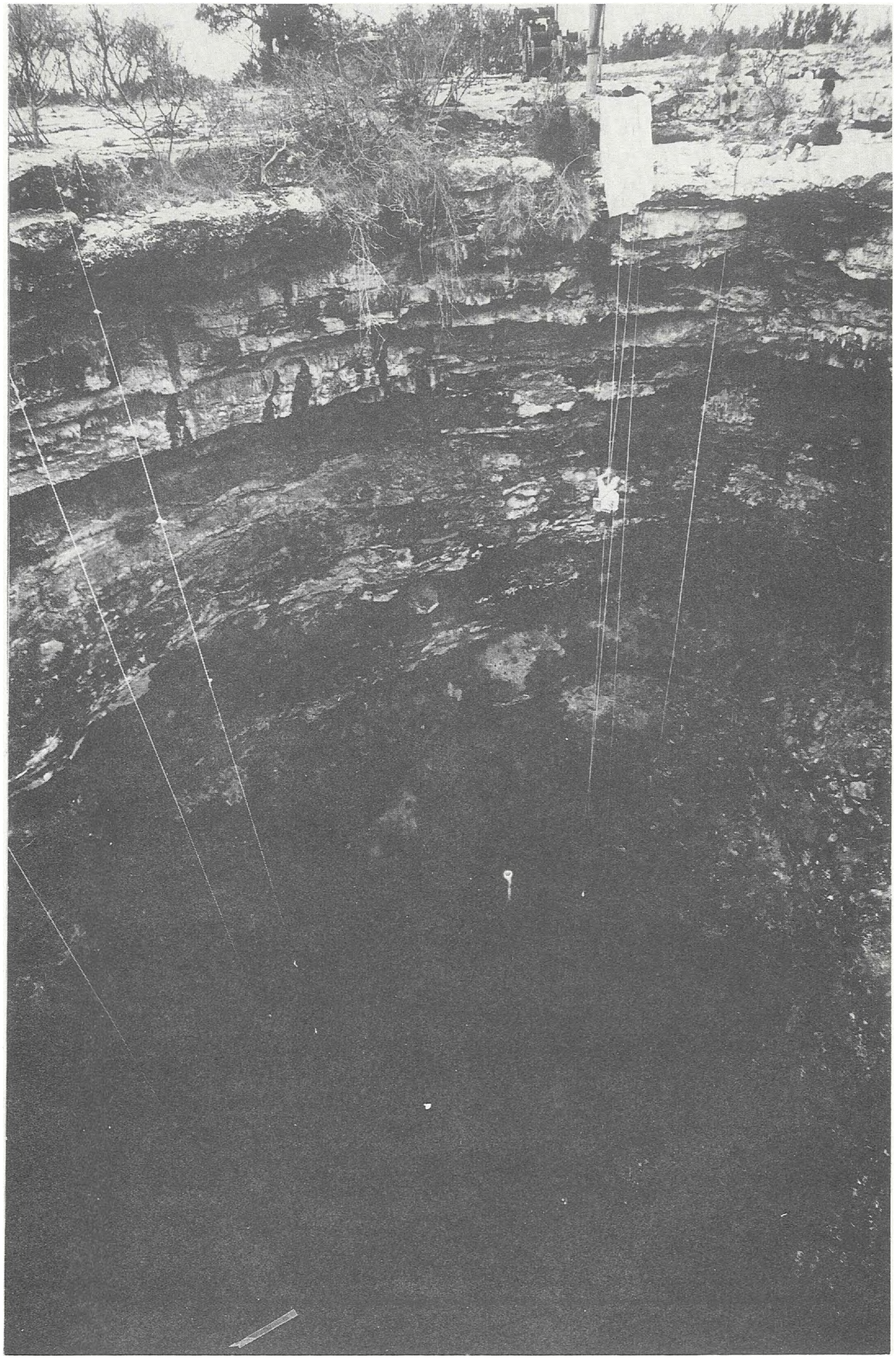


FIGURE 3
A caver descending into the Devil's Sinkhole on a fixed rope, using a rappel technique. The hoist in the background was an inoperable remnant of a former guano-mining operation and has been removed. Photograph by Carl Kunath.

below water, seem conclusive that there is only one large room with no major passages leading off. If others exist, they undoubtedly are buried beneath tons of breakdown.

Paleontology

The bones of a bear were reported found in the cave by Judge John W. Hill and party in 1899.

Hydrology

The "lakes" in the cave actually are a stream which flows very slowly from northwest to southeast across the bottom of the cave. A water sample was taken in the cave on March 4, 1939 and analyzed by the State Board of Water Engineers. The results of the analysis were was follows:

Total dissolved solids (calculated) 224 ppm (parts per million)	
Calcium (CA)	67
Magnesium (Mg)	13
Sodium and Potassium (Na+K)	2
Bicarbonate (HCO_3)	224
Sulphate (SO_4)	10
Chloride (Cl)	12
Nitrate (NO_3)	less than 20
Flouride (F)	0
Total hardness of $CaCO_3$	222

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RED ARROW CAVE

Location—Joy Hollow, 7½-minute Quadrangle, Real County, Texas

Owner—Eagle Ranch, Hap Johnston (?), Junction, Texas

Description

The entrance to the cave is a small sink leading into a low duckway frequently containing rattlesnakes. After about 50 feet the passage comes to a junction. To the left a dropoff leads into a room 15 feet high, about 50 feet wide, and 70 feet long, with a crevice along the right wall. To the right a 6-foot-high, 20-foot-wide passage leads to an area of massive flowstone (fig. 5), some formations, and a drop and steep flowstone slope. Somewhere near the top of the steep slope, on the right-hand (southeast) wall of the cave, Neil Morris and Barbara Vinson report the recent discovery of more than 1000 feet of virgin passage. This passage is not like the rest of the cave and is mostly crawlway sized. The crawlway has not been surveyed and is not shown on the accompanying map of the cave. The steep flowstone slope in the main passage extends down into a room about 100 feet wide and 100 feet long with a dropoff and steep slope at its end. This leads down a steep slope for a distance of about 100 feet where the deepest point in the cave is reached at about 120 feet, a depth in sharp contrast to the estimated 500 feet depth of Helmer (1955). The ceiling height of this deepest room is about 25 feet. After about 100 feet an upward slope leads to a large, relatively flat-floored room about 150 feet long, 100 feet wide, and 30 feet high (fig. 6). A room floored by cave "popcorn" is reached via a dropoff at the end of the previous room (fig. 7). No passage extends from the popcorn-floored room.

History

Red Arrow Cave has been known locally for some time. The dates, Christmas Day 1915 and 1930, have been found written in the cave and are the only known records of early exploration. The first known entry into the cave by organized explorers occurred in June, 1955 when the entrance was located by Bob Holder, Mel Huebel, Dan Austin, and Ed Smith. Their exploration was thwarted by a 5-foot diamondback

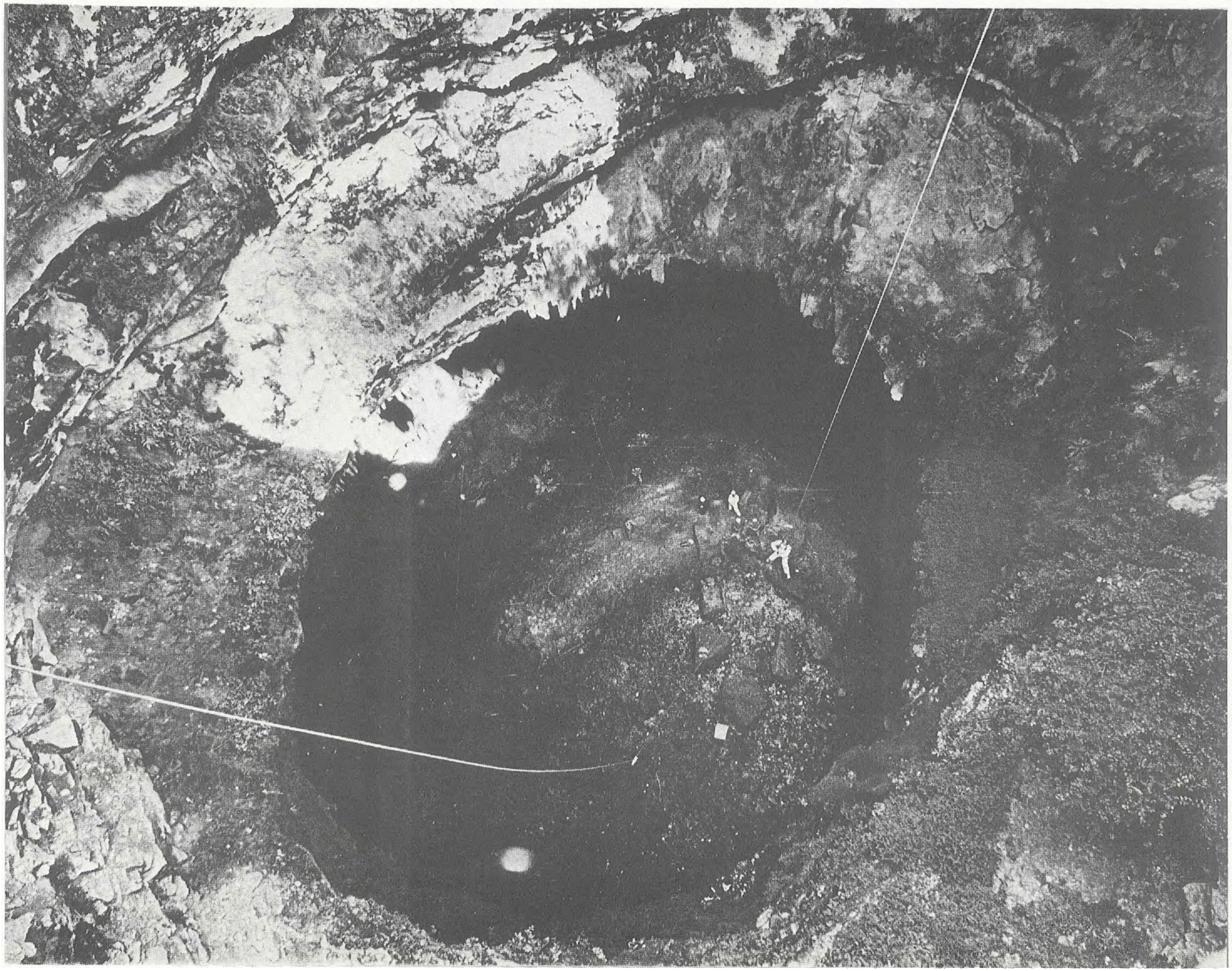
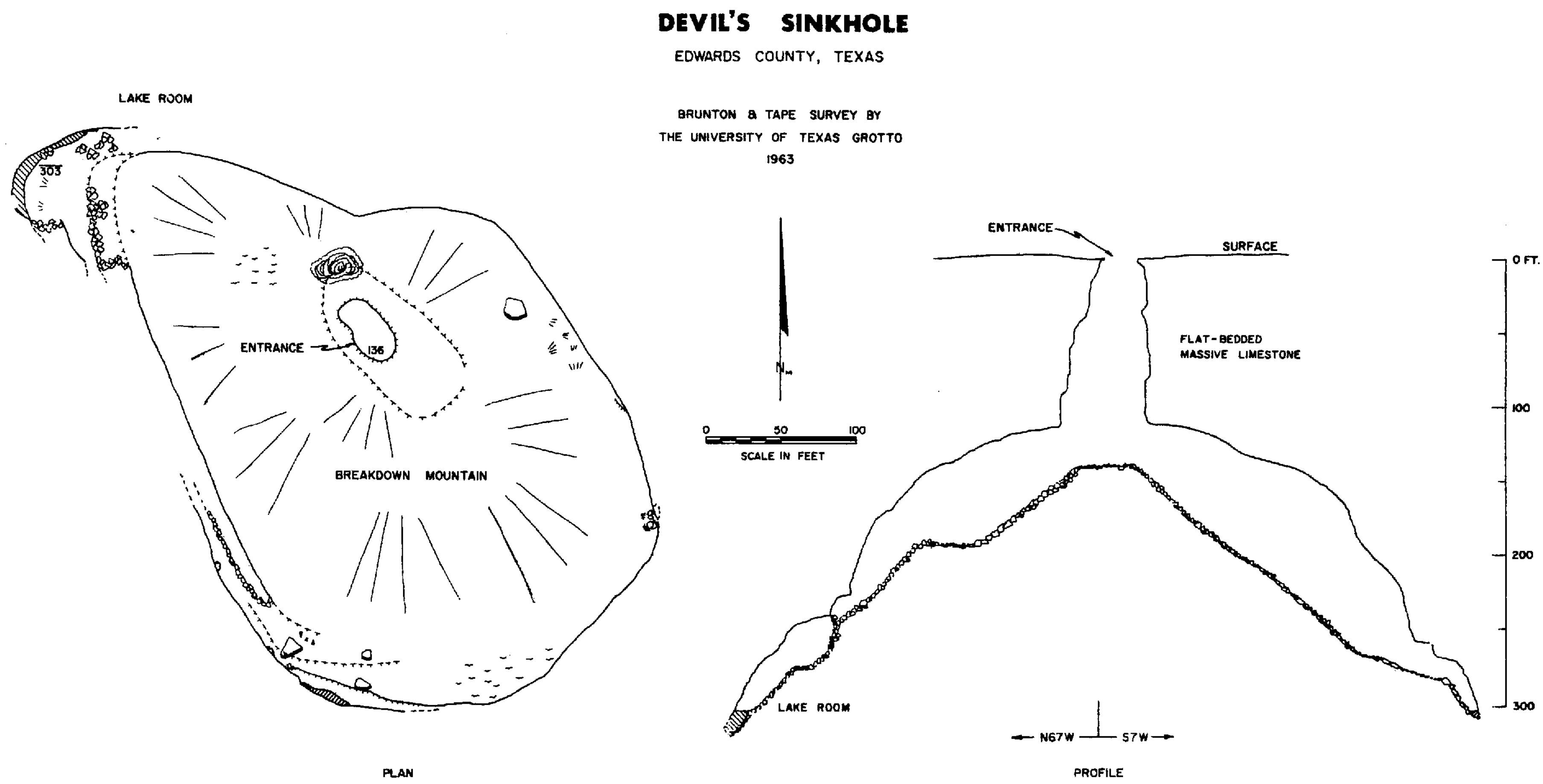


FIGURE 4

Looking down into the entrance of the Devil's Sinkhole. The cave floor 140 feet below looks flat but is really the top of a steep, guano-covered "mountain" of breakdown blocks which fell into the cave when the entrance was created (fig. 2). The cave explorer on the rope is only partway down the shaft. Photograph by Carl Kunath.


DEVIL'S SINKHOLE
EDWARDS COUNTY, TEXAS
BRUNTON & TAPE SURVEY BY
THE UNIVERSITY OF TEXAS GROTTO
1963
LAKE ROOM
303
ENTRANCE
136
BREAKDOWN MOUNTAIN
PLAN
N
0
50
100
SCALE IN FEET
ENTRANCE
SURFACE
FLAT-BEDDED
MASSIVE LIMESTONE
0 FT.
100
200
300
LAKE ROOM
N67W
S7W
PROFILE

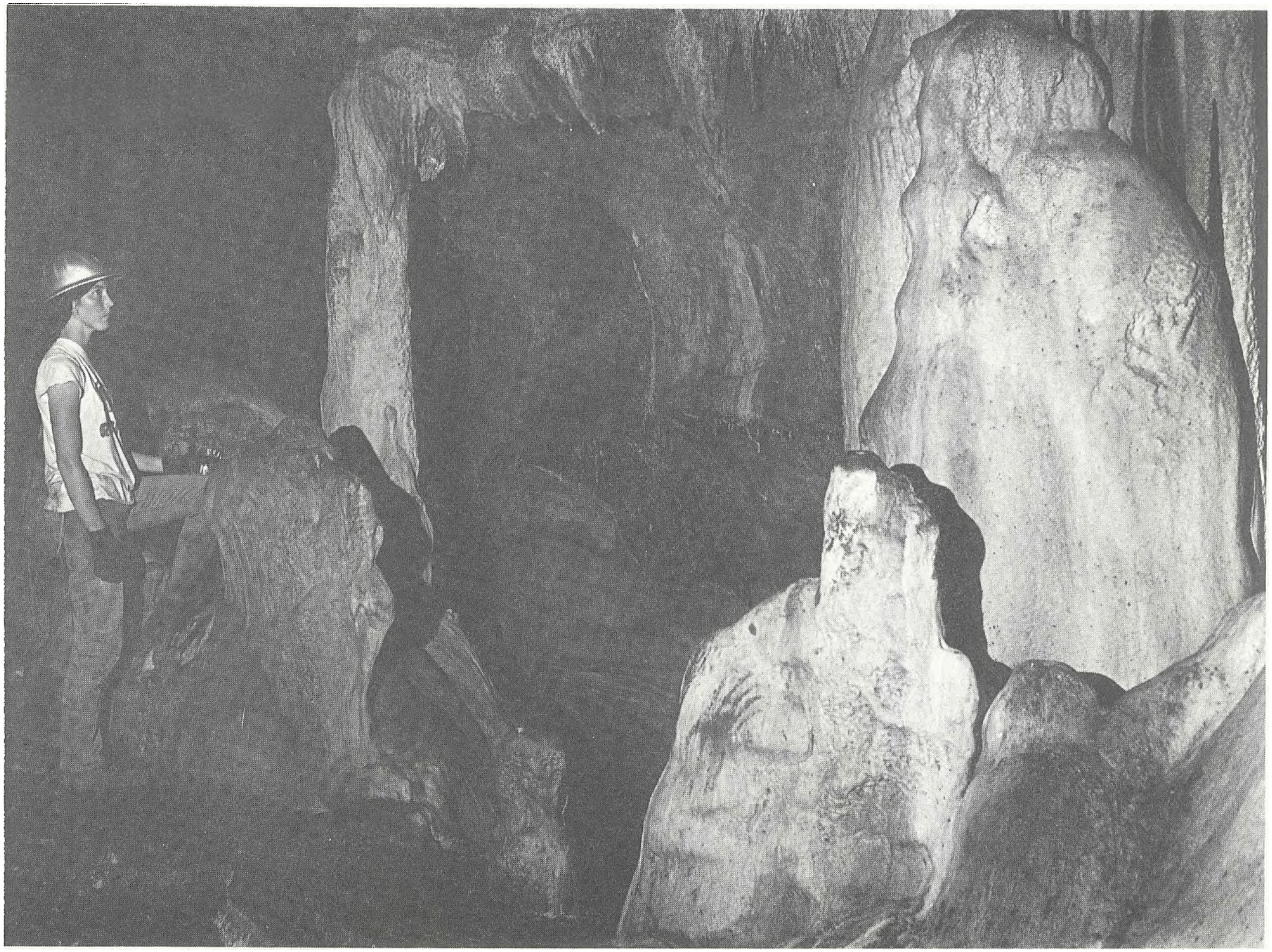


FIGURE 5
Massive speleothems near the entrance of Red Arrow Cave. Photograph by Ronald Fieseler.

rattlesnake just inside the narrow crawlway entrance. Three weeks later a second group, including Lynn Allman, Larry Littlefield, Dan Jones, Bill Helmer, Dave Hannah, and Benny Hendrix, entered and explored the cave. Other trips have included one in December, 1955 by Bill Helmer, Bob Jones, Don Goodson, Robert Kneip, and Bill Hettler. At that time they encountered 2 rattlesnakes. A trip was made early in March of 1956 by David Hannah, Fred Bermer, Glen Harper, and Dave Kyser. It was mapped by Bill Helmer, Dayton Wodrich, and Tom Winans on July 15, 1956. Members of the Corpus Christi Grotto, led by Harvey Jackson, visited the cave in October, 1956. Since that time and until about 1959 a number of trips were made to the cave. Discourtesies to the owner forced him to close the cave, and no trips were made to the cave until September 4, 1965 when Jim Jasek, Frank Jasek, Joe Grote, and Tom Barnette mapped it. This second map is more detailed and is included in this report.

Ownership of the cave has changed hands several times in the past few years, and a number of trips have been made to the cave by groups from Waco and Austin. The field part of the U.T. Natural Areas Survey (Reagan Bradshaw, Mary Butterwick, Tom Byrd, Dwight Deal, William Elliott, Ronald and Susan Fieseler, Roger Kruger, Martha McKenzie, Bill Marmaduke, James Moore, Gerald, Elizabeth, and Eric Raun, Jackie Smith, Ken Stinnett, Hayden Whitsett, and Mrs. Hap Johnston and several members of her family) entered the cave twice in July, 1974. Mrs. Johnston informed us that her husband was in the process of selling the property over the cave. On September 7, 1974 Craig Bittinger, Tom Byrd, Ed Fomby, Jim and Mike Moore, Neil Morris, and Barbara Vinson visited the cave and reported that the cave had been sold by Johnston to an unknown party. Morris and Vinson discovered more than a 1000 feet of virgin passage on that trip.

Biology and Paleontology

In addition to rattlesnakes and perhaps an occasional copperhead, the cave is inhabited by scorpions, harvestmen, cave crickets, and a few bats. The cave is quite moist, with several pools of water. Just inside the single large room, about thirty yards inside the entrance, a colony of mice was found scampering in and out of holes in a depression in the wall. Also of interest was the discovery of fossilized bones representing the remains of a Cretaceous dinosaur, probably a Plesiosaur (Reddell and Smith, 1965).

William R. Elliott and James R. Reddell (personal communication, September 18, 1974), Department of Biological Sciences, Texas Tech University, report that Red Arrow cave is seemingly rather sterile. Their records indicate that only two trogloxenes (animals that utilize caves but which feed outside) have been positively identified:

Phylum Chordata
Class Reptilia

Order Squamata
Family Crotalidae . . . . *Crotalus* sp. Rattlesnake
This is probably *Crotalus atrox*

Phylum Arthropoda
Class Insecta

Order Saltatoria
Family Rhaphidophoridae . . . . *Ceuthophilus* sp.
(observed by Elliott)

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VANCE CAVE

Location—Hackberry 7½-minute Quadrangle, Edwards County

Owner—State of Texas

Description

The entrance to the cave is a 3-foot by 4-foot hole in a road cut. The presence of guano in the cave, however, indicates that a now-destroyed natural entrance was located on the side of the hill that was removed during excavation of the road cut. From the entrance a 4-foot-high crawlway with a narrow floor slot extends for about 60 feet before becoming too small for human entry. It is possible, however, to squeeze into the slot along the left side of the upper level passage and enter a lower level one. For a few feet this is fairly large, about 10 feet wide and 4 feet high. It then becomes filled with silt, making it necessary to squeeze through a tight crevice-type passage to enter the main extension of the cave, developed in two principal levels. The upper level is a wide, low passage usually ranging from 1 to 2 feet in height and up to 15 feet in width. The lower level is a narrow slot which meanders in zig-zag fashion back and forth across the floor of the upper level. In a few places, they divide entirely, the upper level forming a shortcut over the lower level. In some locations it is impossible to follow the upper level because of silt plugs; in others it is impossible to follow the lower level because of narrowness. At several points it was necessary to move several inches of dirt in order to get through extremely low places. At no point did the passage enlarge. With digging, it is still possible to continue beyond the estimated 600 feet of known passage.

History

The first record of entry into the cave was on April 18, 1964 by James Reddell, David McKenzie, and Larry Manire. A trip was made to the cave by Richard Smith, Charles Loving, Terry Raines, Neal Prescott, and Ed Alexander on March 7, 1965. It was entered again by William R. Elliott and Marty McKenzie in July, 1974 during the time the U.T. Natural Areas Survey field team was in the area.

Biology

A small collection of invertebrates was made by Reddell, McKenzie, and Manire in 1964, and an additional collection was taken by Elliott and McKenzie in 1974. The records of these collections are at Texas Tech University. Elliott and Reddell (personal communication, September 18, 1974) have provided information on 7 species collected in the cave. Two species are "trogloxenes" (†, animals that utilize caves but which feed outside), 4 species are "troglophiles" (*, animals somewhat adapted to cave life, but which may be found in similar environments outside caves), and one is a "troglobite" (**, cave-limited species which are usually eyeless and depigmented).

Phylum Arthropoda
Class Diplopoda

Order Polydesmida
Family Trichopolydesmidae .... ***Speodesmus echinourus* Loomis
These millipeds are fairly abundant in the dark zone.

Class Arachnida

Order Araneae
Family Nesticidae .... **Nesticus pallidus* Emerton
This is a frequent cave species in the United States and Mexico.

Class Insecta

Order Collembola
Family Entomobryidae .... **Pseudosinella petterseni* Borner
This species is present in many Texas caves. Springtails are an important food source for cave spiders.

Order Saltatoria
Family Rhaphidophoridae .... *†Ceuthophilus (Geotettix) cunicularis* Hubbell
This is one of the commonest cave crickets in Texas.
†Ceuthophilus (Geotettix) cunicularis Hubbell

Order Coleoptera
Family Alleculidae .... **Lobopoda subcuneata* Casey
This species is abundant in the dark zone. It is also known from Sotano del Pozo, San Luis Potosi, Mexico.
Family Staphylinidae .... **Belonuchus* sp., nr. *moquinus* Casey
This is a widely distributed species usually found in organic debris or on raccoon feces.

Elliott (personal communication, September 18, 1974) comments: "Vance Cave has a fair representation of cave-adapted species. The cave is fairly damp, probably because of the small entrance. Immature blind phalangids and unidentified mites have also been taken in the cave. Although the cave is in a highway roadcut and the entrance area is littered with trash, the tightness of the crawlways in the cave probably prevent many people from visiting very far into the cave and it is probably fairly safe from public abuse."

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CADE HOLE CAVE

Location—Hackberry 7½-minute Quadrangle, Edwards County
Owner—Mrs. Schoolfield (Foreman: Milton Jones)
Description

The entrance is about halfway up the side of a low bluff and is about 6 feet wide and 4 to 5 feet high. The cave extends back about 10 feet over a dirt- and rock-strewn floor to a Y. Ceiling height is about 2 feet. The left-hand fork of the Y is a passage that extends for another 6 to 8 feet before becoming too small. Digging could extend it farther. To the right a similar but smaller passage leads off and also becomes too tight after about 6 feet. At the Y it is possible to stand up in a dome and enter a narrow crawl which extends over the right hand lower crawl. The upper and lower passages connect through small openings in several places. The upper crawl extends for about 12 feet before becoming too tight to traverse.

History

The cave was discovered and reported to Dwight Deal by Hayden Whitsett and Bill Marmaduke in mid-July, 1974 during an archaeological study of the area. The cave was not fully explored at that time due to lack of light. On July 28, 1974 it was entered and explored by Tom Byrd, Roger Kruger, Ronnie Fieseler, Susan Fieseler, Dwight Deal, Jim Moore, and Reagan Bradshaw. A sketch-map was made by Ronnie Fieseler, and the entrance was photographed.

BUCKEYE CAVE

Location—Hackberry Creek 7½-minute Quadrangle, Edwards County

Owner—Mrs. Schoolfield (Foreman: Milton Jones)

Description

The entrance is in one end of a small sink and is slightly under 3 feet square. A buckeye tree grows beside the sink which is in a brushy area on a ridge crest and difficult to locate. From the entrance a crawl leads off over a floor of dirt and small rocks with a ceiling height of 2 feet throughout the cave. At the 20-foot mark, a small constriction is reached where the cave makes a dogleg to the left. This passage averages 6 feet wide. A very low irregular area off to the right contains small speleothems, and the left wall of the passage has some inactive speleothems on it. After about 30 feet the passage abruptly ends. A very tiny hole leads off, but it would require blasting to open and is not very promising.

History

The cave originally was found by the foreman's son who entered it only a short distance, as he had no light. He reported it to Dwight Deal, who spent several hours looking for it in mid-July of 1974. On July 28, 1974 it was finally located and explored by Dwight Deal, Roger Kruger, Ronnie Fieseler, Susan Fieseler, Tom Byrd, and Jim Moore. A sketch-map was made by Ronnie Fieseler and the entrance photographed.

ORIGIN OF THE CAVES

The caves discussed in this report were formed by the slow solution of the limestone bedrock by slowly moving (feet per year rather than miles per hour) ground water. All the caves were formed at a time when the entire land surface was higher than it is today and when the volume of rock now containing them was completely saturated with ground water. Caves found high on the ridges (Devil's Sinkhole, Red Arrow Cave, and Buckeye Cave) formed before Hackberry Creek or the West Prong of the Nueces incised their valleys below the level of the caves. The same holds true for the caves found closer to the modern streams (Vance Cave and Cade Hole Cave), except that they probably are much younger, having been drained of water much more recently.

Caves can form under several different combinations of hydraulic head, rock type, porosity, permeability, and ground-water chemistry. These factors control how ground water moves through an area and how it reacts with the soluble country rock around it. The caves reflect this history and are fairly permanent records of past ground-water conditions.

Two strikingly different types of caves occur in the study area. The Devil's Sinkhole appears to have formed as a single, isolated, large chamber that probably formed at some depth below the local base level (the floor of adjacent valleys). Similar caves could form today only at some depth below the modern canyon bottoms, and then only if the rock were of a favorable type. These have been referred to as "deep-phreatic, isolated voids" in speleological literature. Devil's Sinkhole does not appear to have been part of any extensive underground drainage network and probably was not connected to other caves or conduits to form a significant part of the past underground "plumbing" of the area. The ancestral Hackberry Creek slowly incised its valley and finally cut downward below the elevation of the initial, large, water-filled void. As it did so, the intial chamber was slowly drained of water. Approximately 40 percent of the weight of any limestone blocks on the ceiling of the cave would have been supported by the bouyant effect of the water filling the chamber (Deal, 1962, p. 116). As the water drained, this bouyant effect was lost, and a large portion of the ceiling failed, initiating the deposition of the breakdown "mountain" now found in the cave. As the cave continued to drain, more failure occurred. Ceiling failure was most rapid during the time of draining but continued at a very, very slow rate to present times. Eventually, as the elevation of the ridge above the cave was lowered by erosion and the ceiling of the cave worked its way upward by continuing ceiling collapse, a fairly catastrophic event occurred as the keystone block fell into the chamber, opening the cave to the surface.

Other caves in the study area (Red Arrow, Vance, Cade Hole, and Buckeye) appear to have originated as portions of underground drainage conduits and probably are similar to caves forming today in the saturated volume of rock "upstream" from the many springs in the area. They are typically single-conduit passages that branch in an upstream direction. The elongation of the passages developed down the hydraulic gradient that existed during the time they were formed and did so near the top of the zone of continuous water saturation. These have been referred to as "shallow-phreatic, single-conduit caves" in the speleological literature. They can provide important keys to an understanding of past ground-water flow and climatic conditions in the area.

Red Arrow Cave contains some especially striking evidence of past variations in these conditions. All of these caves developed when the rock in which they are found was completely saturated with water, water that was chemically aggressive and could dissolve the calcium-carbonate in the limestone bedrock. After

the streams downcut farther and the caves drained, the filling of the cave passages by the deposition of calcium carbonate in the limestone bedrock. After "formations") began. Speleothems such as stalagmites, stalactites, and cave draperies can form only in air-filled cave passages, never below water (Moore and Nicholas, 1964; Hill, in press). Some past event caused Red Arrow Cave to be reflooded after sizeable subaerial speleothems had formed in the cave. It remained flooded with chemically aggressive waters for a long enough period of time to truncate and almost completely remove some of the speleothems by solution (fig. 8). The cave is now far above the level of the water table, and the permanent flooding required to cause this kind of re-solution is impossible under the climatic and topographic conditions existing today. It is not possible to adequately interpret the meaning of these events without detailed study of the Quaternary history of the area; it is certain, however, that the events did occur.

COMMERCIALIZATION AND DEVELOPMENT POTENTIAL

We feel that is it unlikely that successful attempts could be made to commerically develop either the Devil's Sinkhole or Red Arrow Cave as isolated tourist attractions. Abortive attempts have been made to commercialize the Devil's Sinkhole and probably failed because of two factors: one, the expense of the equipment and precautions necessary to safely lower visitors down the 140-foot shaft and two, because there is little to see at the bottom other than the spectacular view up the entrance shaft (fig. 2) and the steep, slippery mountain of breakdown covered with wet, black, bat guano.

Red Arrow Cave would be easy to open to the public, and once past the short entrance duckway, the cave is (by West Texas standards) unusually large and scenic. Some minor explosive work would be required to open the entrance passage, but once past the first 50 or 60 feet, trail construction could be easily accomplished. The major expense in development probably would be the installation of the concealed indirect lighting necessary to properly illuminate and enhance the beauty of the cave. The cave is short, however, and is far enough from main tourist routes to make the risk of development seem high. The cost of construction of adequate surface roads to the cave entrance probably would exceed the cost of the cave development itself.

Should there ever be any integrated development of the Hackberry Creek-West Prong of the Nueces area for recreation use, however, a "package" interpretative program involving a visit to the entrance of the Devil's Sinkhole, a trip through Red Arrow Cave, and visits to the sinks and springs along the rivers would provide visitors with a uniquely vivid understanding of how ground water flows and works in the western Edwards Plateau country.

During the time our field crew was in the area all the water in the West Prong of the Nueces River sank completely out of sight into a swallow hole in the river bed (fig. 9) near Eagle Cliff. That water flows through underground conduits, is certainly dissolving cave passages there today, and emerges from one major and several minor springs a few thousand feet downstream (fig. 10). A visit to this area should also be part of any such interpretative program.

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FIGURE 6
The main passage in Red Arrow Cave. Photograph by Ronald Fieseler.

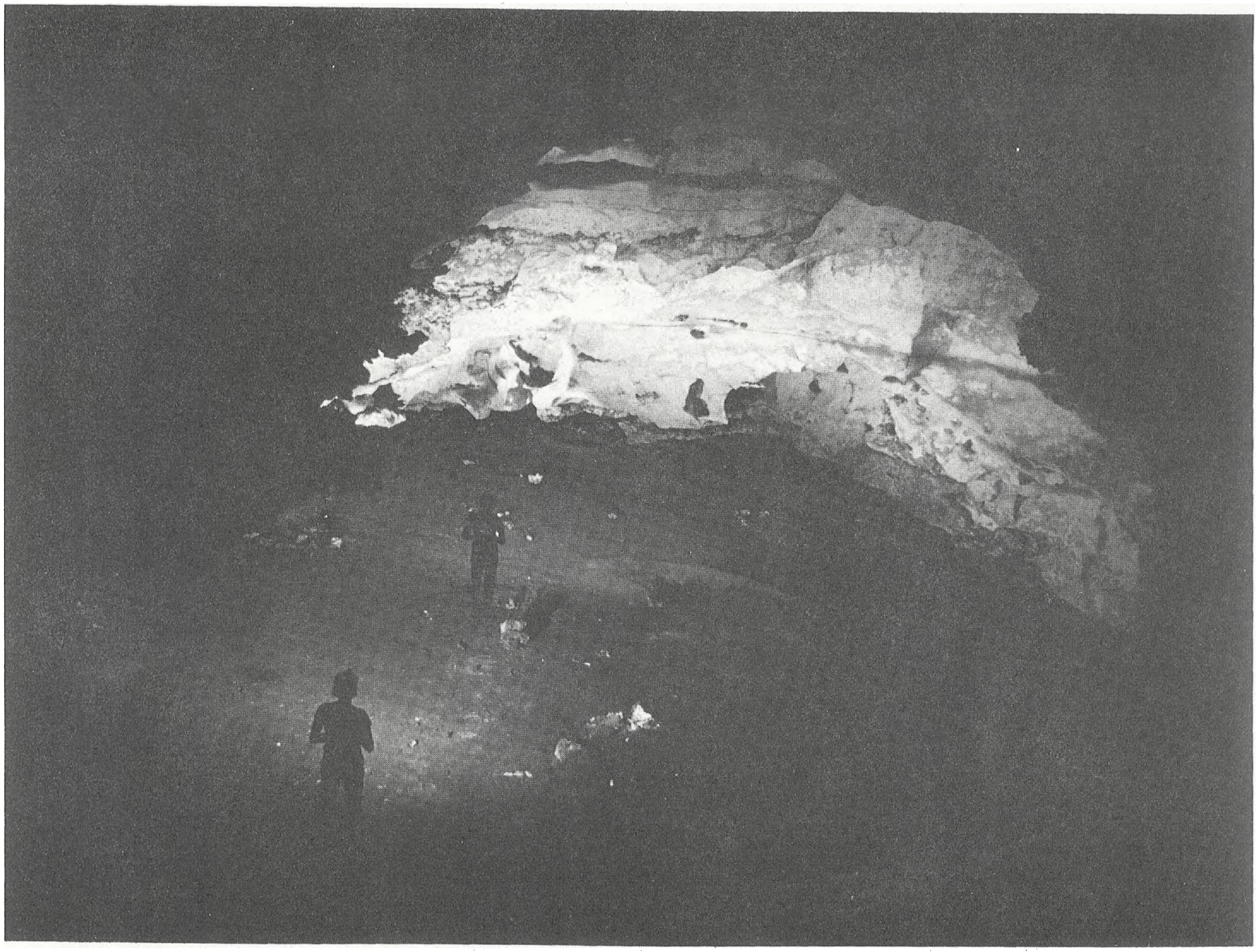
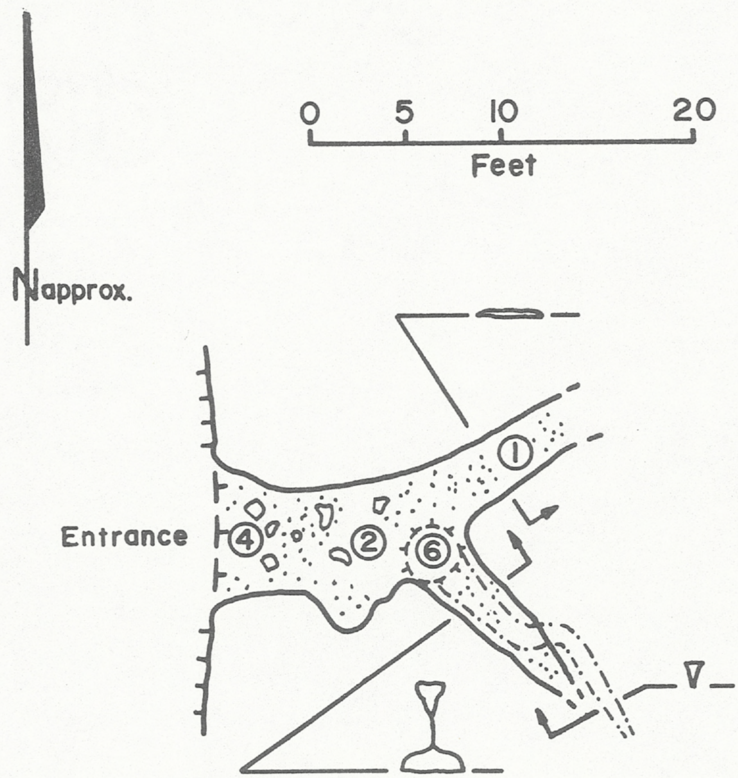


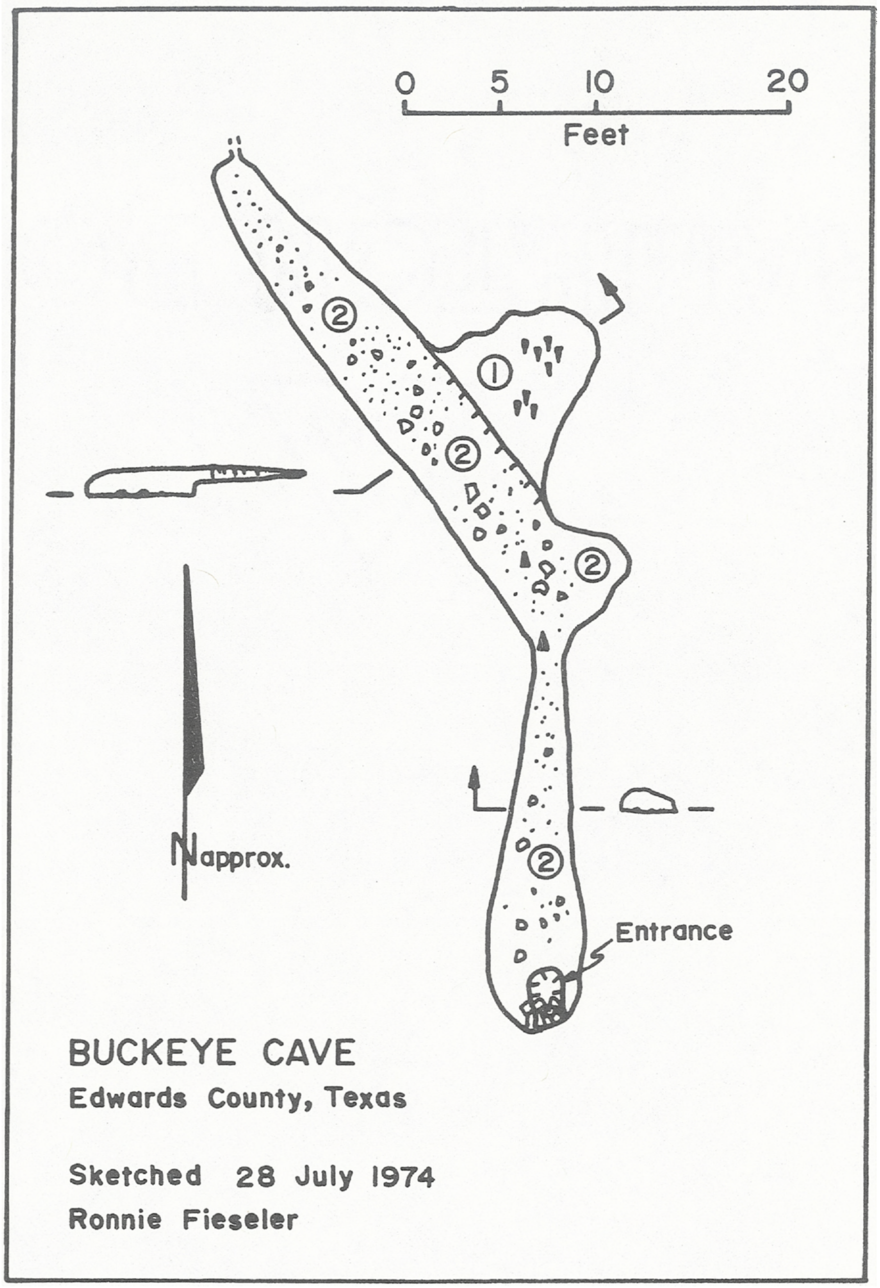
FIGURE 7

Looking down into the terminal room of Red Arrow Cave. Large passage continues another 50 feet beneath the brightly illuminated ledge. Photograph by Ronald Fieseler.



CADE HOLE CAVE
Edwards County, Texas

Sketched 28 July 1974
Ronnie Fieseler


0 5 10 20
Feet
N approx.
Entrance
BUCKEYE CAVE
Edwards County, Texas
Sketched 28 July 1974
Ronnie Fieseler

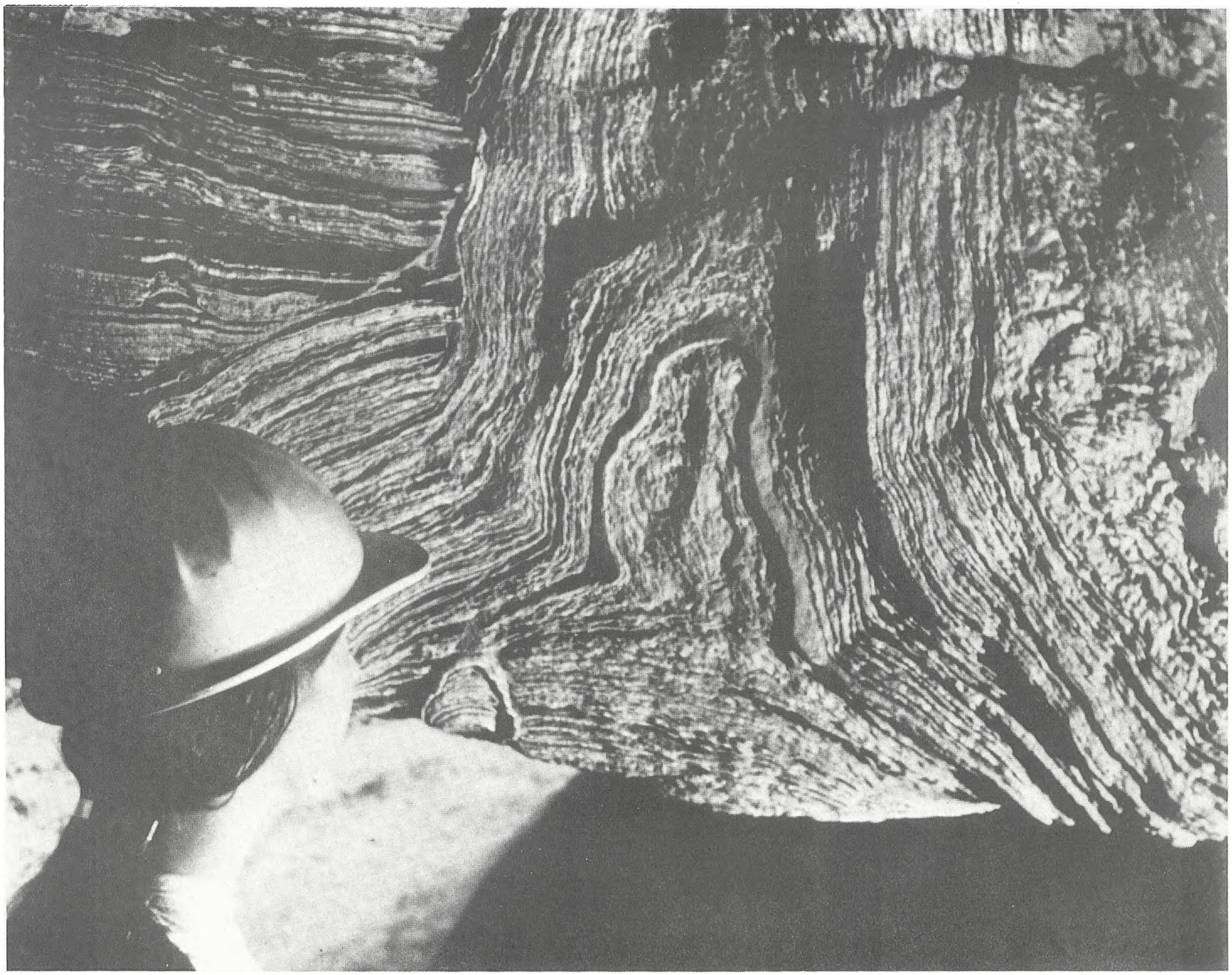


FIGURE 8

Red Arrow Cave. An ancient speleothem (cave "formation") has been truncated by a second period of cave solution. The convoluted banding is the internal structure of the speleothem and developed as growth bands, caused by alternating periods of rapid and slow growth. Photograph by Dwight Deal.

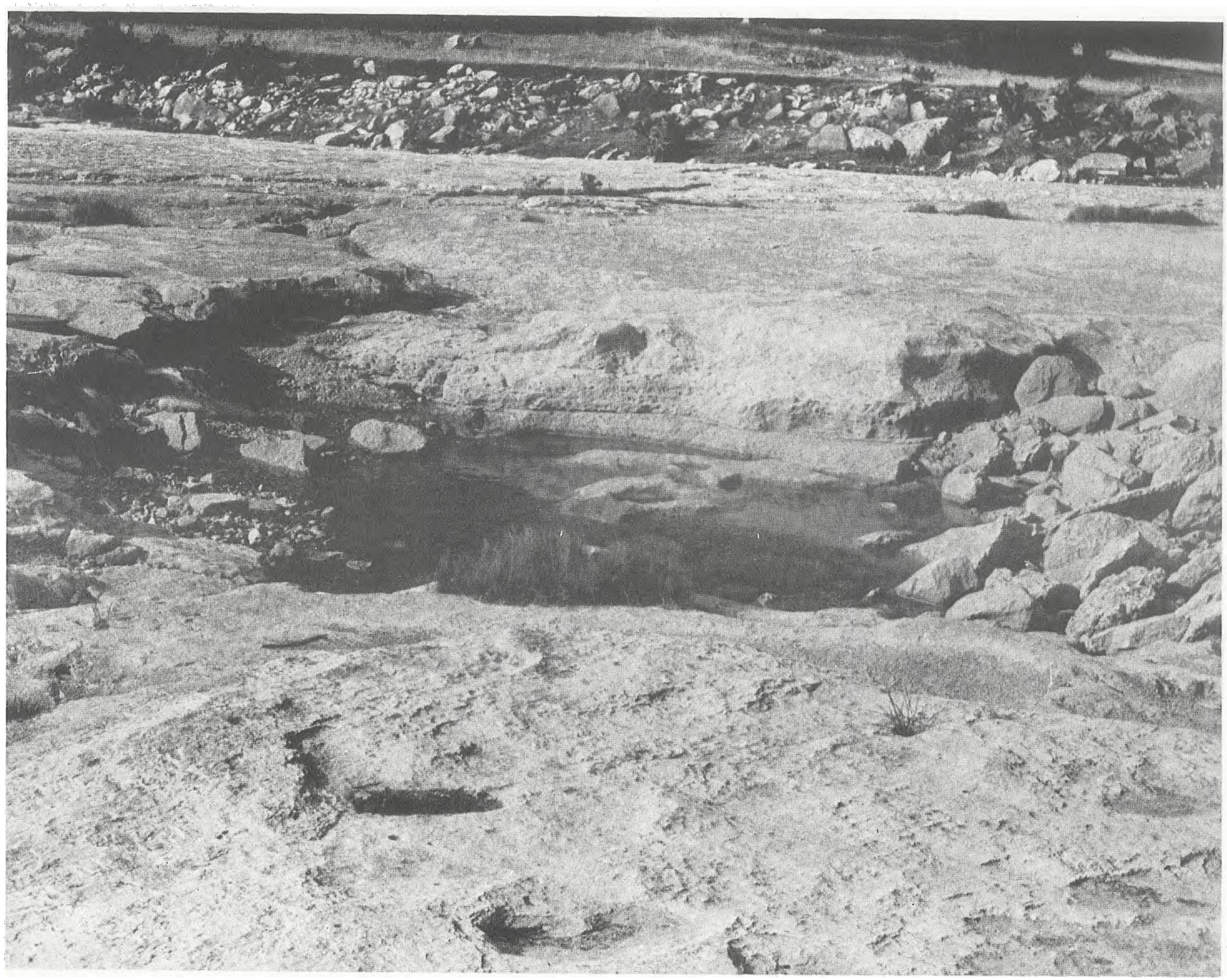


FIGURE 9
Swallow hole in the bed of the West Prong of the Nueces River near Eagle Cliff. In July, 1974 the entire flow of the river disappeared here. The river bed immediately downstream was dry. Photograph by Dwight Deal.

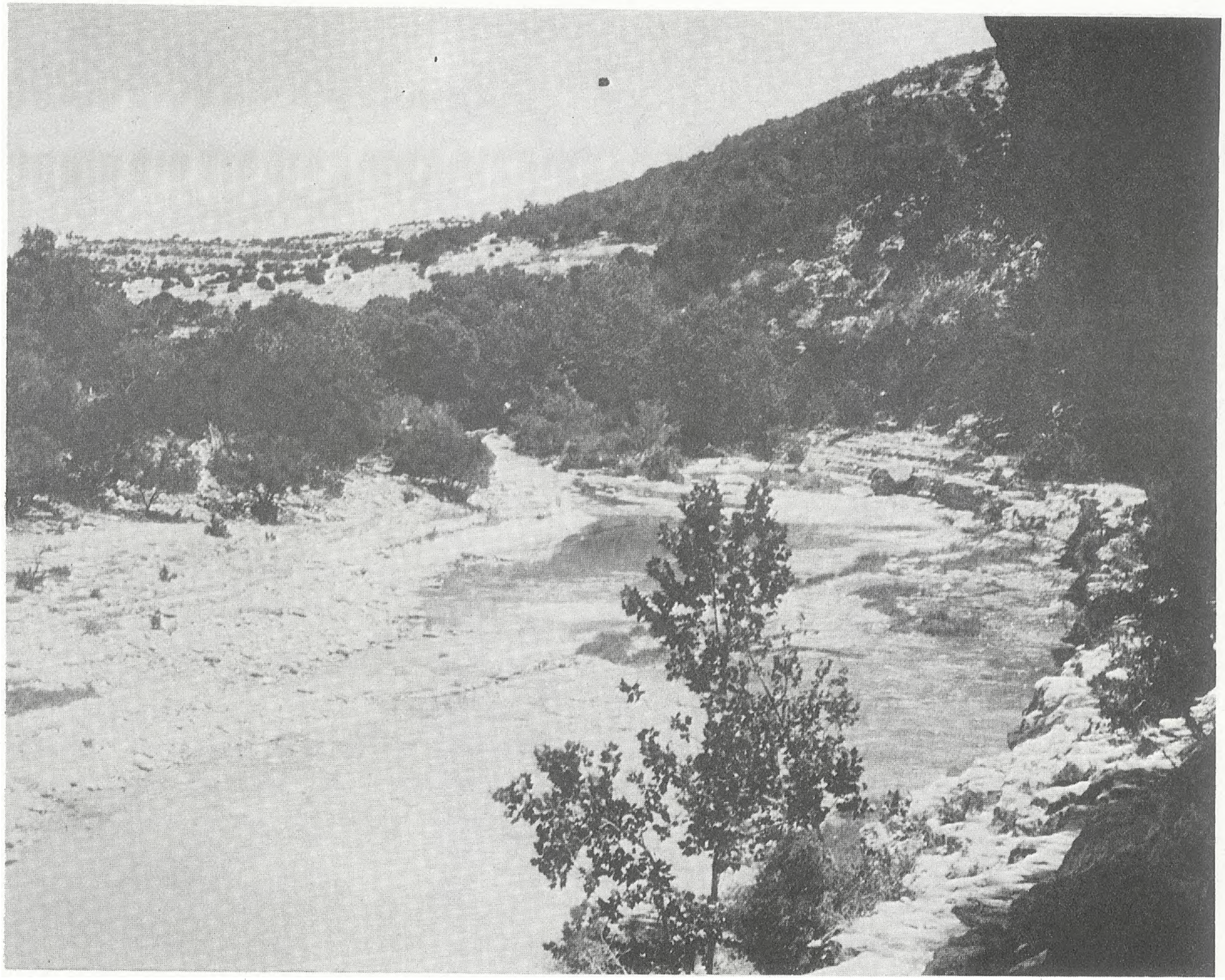


FIGURE 10
Spring area near the base of Eagle Cliff. Most of the water emerging from several springs in this area probably comes from the swallow hole shown in figure 9. Photograph by Dwight Deal.

THE FAUNA OF THE DEVIL'S SINKHOLE

William R. Elliott and James R. Reddell
Department of Biological Sciences
Texas Tech University
Lubbock

The Devil's Sinkhole is of great ecological value to Texas because it contains one of the state's largest colonies of the insectivorous Mexican free-tail bat, *Tadarida brasiliensis mexicana.* Earlier workers have estimated the size of the colony to be as high as 8,000,000 in the summer months, but Reddell and Smith (1965) suggest this may be too high an estimate. Although other bats are represented in the cave (see list below), the Mexican free-tail is of prime importance to the energy budget of the cave ecosystem. Food, in the form of bodies of dead bats and tons of guano, supports what must be a sizeable biomass of arthropods. These "guanophiles" and scavengers in turn support a number of arthropod predators, mostly spiders. The Devil's Sinkhole also acts as a natural trap, both because of the precipitous entrance drop and the high humidity and abundance of food within the cave. Repeated collections of animals in the area below the entrance have each time yielded "accidental" species not recorded before. In the twilight and dark zones, at the periphery of the "breakdown mountain," and in the lake rooms may be found truly cave-adapted forms. Of interest also is the large colony of cave swallows, estimated at 500 individuals (Selander and Baker, 1957).

Each of the ecological zones in the cave is represented by forms commonly found in Texas caves. Of the sixty-eight species recorded here, fifty-four are arthropods. Three species are of uncertain ecological status, sixteen are "accidentals" (designated here as ††), twenty-eight are "trogloxenes" (†, animals that utilize caves but which feed outside), seventeen are "troglophiles" (*, animals somewhat adapted for cave life, but which may be found in similar environments outside caves), and four are "troglobites" (**, cave-limited species which are usually eyeless and depigmented). Six of the trogloxenes and two of the troglophiles are considered "guanophiles," animals which utilize guano in their life cycles.

In the cave's dark zone are found four troglobite (cave-adapted) species. Two terrestrial forms may be found on moist rocks and flowstone: *Cicurina* sp., a small, eyeless spider (many species of blind *Cicurina* are known from Texas caves), and *Speodesmus echinourus*, a milliped. *Speodesmus* is known from numerous Texas caves and is being studied currently by one of us (W.R.E.). Besides having lost its eyes and pigment, *Speodesmus* seems to have lost its repugnatorial glands which most millipeds use defensively. In the two lakes one may find two troglobite crustaceans. *Stygonectes hadenoecus* is an eyeless amphipod found only in the Devil's Sinkhole. Other *Stygonectes* species are known from Texas caves, but this one is taxonomically problematical and has been placed in its own, unique species-group (Holsinger, 1967). These little shrimplike creatures are especially abundant in the open, guano-floored lake in the summer. *Cirolanides texensis* is an eyeless isopod found in many Edwards Plateau caves. It is a member of the family Cirolanidae, which is predominately marine in distribution. It is more abundant in the enclosed lake.

Elliott and Mitchell (1973) studied the temperature preference responses of both *S. hadenoecus* and *C. texensis* from the Devil's Sinkhole. They found that the former lacked any discernible temperature preferendum in either a 15°-30°C or a 10°-30°C gradient. The same results were obtained with another *Stygonectes* and an *Asellus* from Texas. The evolutionary loss of temperature discrimination might be expected in troglobites, especially aquatic ones which are "trapped" in the cave, because of the relative constancy of temperature in caves. Surprisingly, *C. texensis* had a strong preferendum for 20°-30°C, temperatures much higher than the 18°C of the lakes in the cave. This could be explained by the hypothesis that *C. texensis* is a recent cave species descended from a tropical ancestor.

Twenty-one new records are listed below. The bird records are drawn from Selander and Baker (1957) and the other records are drawn from the checklists of Reddell (1966, 1967, 1970a, 1970b). We are grateful to the following systematists for identifying material reported here for the first time: D. M. Anderson, beetles; G. W. Byers, flies; L. D. Delorme, ostracods; W. E. Duellman. frogs; T. L. Erwin, beetles; R. C. Froeschner, hemipterans; R. J. Gagné, flies; W. J. Gertsch, spiders; C. J. Goodnight, opilionids; J. M. Kingsolver, beetles; P. M. Marsh, wasps; A. S. Menke, wasps; C. W. Sabrosky, flies; and T. J. Spilman, beetles.

CHECKLIST OF SPECIES

Phylum Aschelminthes
Class Nematomorpha

Order Gordioidea
Undetermined species

This gordian worm was taken from soil; it probably is an internal parasite of cave crickets, *Ceuthophilus* sp. Adults have been seen, on occasion, in and near the large lake.

Phylum Arthropoda
Class Arachnida

Order Araneae

Family Agelenidae .... ***Cicurina* sp.

**Cicurina varians* Gertsch and Mulaik

This is the most common spider in Texas caves.

Family Argiopidae .... ††*Leucauge venusta* (Walckenaer) (det. W. J. Gertsch)

Family Gnaphosidae .... ††*Herpyllus* sp.

This specimen was taken along the breakdown slope below the entrance.

Family Linyphiidae .... ††*Eperigone maculata* Banks

This sepcies was found at the bottom of the entrance drop.

**Islandiana* sp.

This apparent new species was found under rocks in the twilight zone.

Family Lycosidae .... ††*Pirata* sp. (det. W. J. Gertsch)

††*Pirata sedentarius* Montgomery

This species was found among rocks at the bottom of the entrance drop.

Family Pholcidae .... †*Physocyclus* sp. (det. W. J. Gertsch)

Family Salticidae .... ††*Metaphidippus* sp. (det. W. J. Gertsch)

Family Scytodidae .... **Loxosceles* sp. (det. W. J. Gertsch)

Family Theridiidae .... **Achaearanea porteri* (Banks)

This is a common troglophile throughout the United States and Mexico; it usually is found hanging on walls.

Family Thomisidae .... ††*Misumenops* sp. (det. W. J. Gertsch)

Order Pseudoscorpionida

Family Cheiridiidae .... *Apocheiridium* sp.

The ecological status of this species is undetermined.

Family Chernetidae .... **Dinocheirus* sp.

Order Opiliones

Family Phalangiidae .... †*Leiobunum townsendi* (det. C. J. Goodnight)

†*Mesosoma texanum* Goodnight and Goodnight (det. C. J. Goodnight)

Order Acarina

Family Macronyssidae .... †*Steatonyssus (Steatonyssus) occidentalis* (Ewing)

This mite was taken from *Tadarida brasiliensis mexicana.*

Family Sarcoptidae .... †*Teinocoptes lasionycteris* (Boyd and Bernstein)

This mite was taken from *Tadarida brasiliensis mexicana.*

Class Crustacea

Order Podocopa

Family Darwinulidae .... **Darwinula* sp. (det. L. D. Delorme)

Order Isopoda
Family Cirolanidae .... ***Cirolanides texensis*** Benedict

Order Amphipoda
Family Gammaridae .... ***Stygonectes hadenoecus*** Holsinger

Class Diplopoda

Order Chordeumida
Family Lysiopetalidae .... ††*Abacion texense* (Loomis)
This species was found at the bottom of the entrance drop.

Order Julida
Family Paraiulidae .... ††*Gosiulus* sp.
A single female was found at the bottom of the entrance.

Order Polydesmida
Family Trichopolydesmidae .... ***Speodesmus echinourus*** Loomis
These usually are found on moist rocks at the perimeter of the breakdown mountain and, more rarely, in the larger lake room.

Class Insecta

Order Collembola
Family Entomobryidae .... **Pseudosinella violenta* (Folsom)
This is a common Texas troglophile.

Order Saltatoria
Family Rhaphidophoridae .... †*Ceuthophilus (Ceuthophilus)* sp.
†*Ceuthophilus (Ceuthophilus) ?secretus* Scudder
This is one of the most common and largest species of cave cricket found in Texas caves.
†*Ceuthophilus (Geotettix) cunicularis* Hubbell

Order Psocoptera
Family Psyllipsocidae .... **Psyllipsocus ramburii* Selys-Longchamps
This species was taken from guano in the dim twilight zone.

Order Hemiptera
Family Gerridae .... †*Gerris remigis* Say (det. R. C. Froeschner)
Family Reduviidae .... †Subfamily Emesinae gen. et sp.
A nymph of this subfamily was taken in the entrance area.

Order Coleoptera
Family Anthicidae .... †Unidentified genus and species (det. D. M. Anderson)
A larva of this family was collected below the entrance drop.
Family Carabidae .... ††*Amara littoralis* Mann. (det. T. L. Erwin)
**Bembidion (Peryphus) texanum* Chaudoir
**Rhadine howdeni* (Barr and Lawrence)
This is a widely distributed species frequently found in association with bat guano. Its activity is nocturnal.
Family Histeridae .... **Saprinus* sp. (det. J. M. Kingsolver)
Family Hydrophilidae .... **Cymbiodyta* sp.
Paracymbus sp.
The ecological status of this water beetle is undetermined.
Family Leiodidae .... **Ptomaphagus (Adelops) cavernicola* Schwarz
These beetles usually are found on dung or decaying animals.

Family Staphylinidae . . . . *Belonuchus* sp.

This is a widely distributed species found in organic debris or on raccoon feces.

**Philonthus* sp.

**Stilicolina condei* Jarrige

This species is also found in caves of Eddy County, New Mexico and in caves in Tamaulipas and San Luis Potosí, México. It is often found on raccoon feces.

Family Tenebrionidae . . . . †*Eleodes* sp.

Both adults and larvae of this species were taken from bat guano.

†*Eleodes fusiformis* LeConte (det. T. J. Spilman)

†*Eleodes goryi* Solier

This species was taken from bat guano.

†*Embaphion muricatum* n. subsp.

This species was taken from bat guano.

†*Noserus emarginatus* Horn (det. T. J. Spilman)

Order Hymenoptera

Family Braconidae . . . . ††*Apanteles* sp. (det. P. M. Marsh)

Family Pompilidae . . . . ††*Anoplius amethystinus atramentarius* (Dahlbom) (det. A. S. Menke)

Order Lepidoptera

Family Tineidae . . . . †*Amydria* sp.

Larvae of this genus of moth were found in the entrance area.

Order Diptera

Family Calliphoridae . . . . ††*Calliphora vicina* (R.-D.) (det. R. J. Gagné)

Family Milichiidae . . . . **Leptometopa latipes* (Mg.) (det. C. W. Sabrosky)

Family Tipulidae . . . . Unidentified genus and species (det. R. J. Gagné)

†*Tipula (Bellardina) schizomera* Alexander (det. G. W. Byers)

Phylum Chordata

Class Amphibia

Order Anura

Family Hylidae . . . . ††*Acris crepitans blanchardi* Baird – Northern Cricket Frog (det. W. E. Duellman)

Class Reptilia

Order Squamata

Family Crotalidae . . . . †*Crotalus atrox* Baird and Girard – Western Diamondback Rattlesnake

Class Aves

Order Strigiformes

Family Strigidae . . . . †*Bubo virginianus* (Gmelin) – Great Horned Owl

This owl has been observed nesting on ledges in the entrance pit.

Order Passeriformes

Family Hirundinidae . . . . †*Petrochelidon fulva pallida* Nelson – Cave Swallow

This is the only bird which inhabits caves to any extent in the United States; it ranges west into New Mexico and south into Mexico.

Family Paridae . . . . ††*Parus bicolor* Linnaeus – Tufted Titmouse

This bird was observed foraging over moss 100 feet below the surface at the cave entrance.

Family Troglodytidae .... †*Salpinctes mexicanus* (Swainson) – Canyon Wren
This bird was seen foraging on ledges 70 feet below the surface at the entrance; it presumably nests in the cave.

Family Fringillidae .... ††*Pipilo fuscus* Swainson – Brown Towhee
This species was observed foraging on moss at the lower ledge.

Class Mammalia

Order Chiroptera

Family Vespertilionidae .... ††*Myotis velifer incautus* (Allen) – Mexican Brown Bat
This bat is usually found occurring in colonies of no more than several thousand individuals and frequently in groups of less than one hundred.

†*Pipistrellus hesperus* (Allen) – Western Pipistrelle
This is a solitary bat and seldom more than one specimen is found in a single cave; it is known to hibernate in caves in Central and West Texas.

†*Pipistrellus subflavus subflavus* (Cuvier) – Eastern Pipistrelle
This bat is usually found hanging alone in small pockets in the ceiling. It probably will prove to be the most common pipistrelle in Texas caves.

†*Plecotus townsendii pallescens* (Miller) – Townsend's Big-eared Bat
This is the most eastern record for this species.

Family Molossidae .... †*Tadarida brasiliensis mexicana* (Saussure) – Mexican Freetail Bat

Order Carnivora

Family Procyonidae .... †*Procyon lotor* (Linnaeus) – Raccoon

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THE TERRESTRIAL VERTEBRATES OF THE DEVIL'S SINKHOLE – HACKBERRY CREEK AREA

James Kenneth Stinnett

The Devil's Sinkhole-Hackberry Creek area is situated in the eastern portion of Edwards County, near the western boundary of Real County. This area lies near the southwestern edge of the Edwards Plateau and is included in the Balconian Biotic Province (Blair, 1950). This Cretaceous limestone plateau is unique in that it provides suitable habitat for vertebrates with centers of origin in both the eastern and western United States. In addition, the Kansan and Tamaulipan Biotic provinces (Blair, op. cit.) contribute, to a lesser degree, vertebrates with grassland and neotropical affinities, respectively.

The area is characterized by thin-soiled plateaus and ridge tops, which support a liveoak savannah, and moderately soiled stream valleys where sycamores, pecans, walnuts, and Ashe juniper (*Juniperus ashei*) are dominant. The hillsides and slopes above the creek beds support a liveoak-Ashe juniper association. Brush eradication in the area has contributed greatly to the removal of topsoil on the ridge tops and hillsides. The riparian areas are relatively undisturbed, except for the construction of dams along the major drainages. Elevations in the area range from 1800 to 2400 feet above sea level.

The Devil's Sinkhole, a vertical cave about 320 feet deep, lies near the headwaters of Hackberry Creek. This cave is probably best known for its colony of Mexican Free-Tail Bats, *Tadarida brasiliensis mexicana.* This colony is one of the largest in Texas, and earlier investigators estimated that 8,000,000 Free-tails reside in the cave during summer months. Reddell and Smith (1965 and this study), however, have suggested that this estimate might be high. South of the Sinkhole several small, spring-fed tributaries of Hackberry Creek are found, but are seldom flowing, forming isolated pools along the valleys. About 3½ miles southeast of the Devil's Sinkhole, the main portion of Hackberry Creek begins and flows in a southeastward direction to join with the East Prong of the Nueces River to form the Nueces River. The limestone bluffs along the valley are dotted with numerous springs, and several small tributaries empty into Hackberry Creek.

In this report, the terrestrial vertebrates of the Devil's Sinkhole-Hackberry Creek area are listed. An annotated list of species includes those vertebrates collected or seen, and those whose presence in the area was confirmed by local residents. A checklist of terrestrial vertebrates known from the area is included, and a discussion of their zoogeographic affinities is presented. The avifauna of the area is excluded from this report and will be presented in a separate paper.

METHODS AND MATERIALS

Field observations and collecting were conducted during the last two weeks of July, 1974. Various collecting methods were employed, including: rat shot fired from a .22 caliber pistol, a modified potato rake used as a snake stick and for turning rocks and debris, large rubber bands for stunning potential specimens, bat nets, Sherman collapsible traps, Museum Special snap traps, and hand collecting. All traps were baited with rolled oats. Fish were collected, using an 8 foot one-quarter inch seine and an 18 x 12 inch dip net. Reptile and amphibian specimens were injected and fixed in a 10% formalin solution and later transferred to 40% isopropanol for storage. Standard measurements were made, using vernier calipers, and all data were recorded in a field handbook. Information from local residents was recorded, and road collecting and observations on local ranch roads yielded much information.

No attempt to measure the relative abundance of any species was undertaken. Reptiles were extremely scarce, and except for the bats captured in the nets, no mammals were collected. Literature information concerning the presence and abundance of vertebrates in the area has been included as a supplement to the collecting efforts.

ANNOTATED LIST OF SPECIES

A total of 75 specimens were collected during the period July 20 to July 30, 1974. Of this total, 24 specimens were bats, representing 3 species. The remaining 51 specimens represent 16 species of reptiles and amphibians. Sight records accounted for 5 species of reptiles and amphibians and 10 species of mammals. One mammal was identified to genus only. The remainder of those vertebrates included in the annotated list have been seen by local residents (Miles, pers. comm.; Fuchs, pers. comm.) within the last three years.

AMPHIBIANS

Acris crepitans—Cricket Frog

Cricket frogs were collected from several localities along Hackberry Creek, the East Prong of the Nueces, and in association with many small, spring-fed pools. Observations and nightly choruses indicated that this species is quite abundant.

Bufo punctatus—Red-Spotted Toad

One individual was collected along a local ranch road; another was collected in an Ashe juniper-liveoak association, and a third specimen was found in the Devil's Sinkhole. Such a variety in habitat indicates an almost certain abundance in the area.

Bufo valliceps—Gulf Coast Toad

One individual was collected in Devil's Sinkhole. An additional individual was collected along Hackberry Creek.

Rana catesbiana—Bullfrog

Bullfrogs are abundant in the area along all streams and springs. Several specimens were collected along Hackberry Creek.

Rana pipiens—Leopard Frog

Leopard frogs are common in the area. A total of six individuals were collected near Hackberry Creek and in two small spring pools.

Chrysemys scripta—Red-Eared Turtle

One red-eared turtle was seen in Hackberry Creek. This species probably inhabits all of the major bodies of water in the area.

Trionyx spinifer—Soft-Shell Turtle

One large soft-shell turtle was seen sunning along Hackberry Creek.

LIZARDS

Cophosaurus texanus—Earless Lizard

Several localized colonies were observed in the area. Hatchlings were seen frequently. Individuals were collected along Hackberry Creek and in rock piles on the ridge tops.

Crotaphytus collaris—Collared Lizard

Collared lizards were not seen during the survey period. Local residents attest to their presence.

Phrynosoma cornutum—Texas Horned Lizard

Although horned lizards were not seen during this survey period, local residents confirmed their presence.

Sceloporus olivaceous—Texas Spiny Lizard

Two spiny lizards were collected along dry stream beds in the area. Both individuals were found sleeping in liveoak trees.

Sceloporus poinsetti—Crevice Spiny Lizard

Crevice lizards were the most visually abundant lizard in the area. All individuals were collected along rocky limestone bluffs above stream beds.

Sceloporus undulatus—Southern Prairie Lizard

One prairie lizard was collected in a liveoak savannah near the Devil's Sinkhole.

Urosaurus ornatus—Tree Lizard

Tree lizards are common in all associations in the area. Two individuals were collected near the Devil's Sinkhole, while the majority of those specimens collected were found near Hackberry Creek.

Eumeces brevilineatus—Great Plains Skink

A single individual was collected near a small spring-fed pool, under a rotting log.

Lygosoma laterale—Ground Skink

Several ground skinks were collected and all specimens were found in debris piles. One ground skink was found under an aborted deer fawn near Hackberry Creek.

Cnemidophorus gularis—Texas Spotted Whiptail Lizard

Whiptail lizards are abundant in the area. Nine individuals were collected during the study period.

Gerrhonotus liocephalis—Alligator Lizard

Despite extensive searching for this unusual lizard, none were seen. Two local residents, one well versed in herpetology, confirm the presence of alligator lizards in the area. In some instances, these lizards were found sunning on concrete porches of permanent dwellings.

SNAKES

Diadophis punctatus—Texas Ring-Necked Snake

According to local residents, ring-necked snakes are abundant in the area. During the study period, however, none were seen.

Elaphe guttata—Rat Snake

No rat snakes were seen during the study period. Local residents confirm the presence of rat snakes, and county records for Edwards and Real Counties indicate the presence of rat snakes in the area.

Masticophis flagellum—Western Coachwhip

One coachwhip was collected in a liveoak-juniper association.

Natrix erythrogaster—Plain-Bellied Water Snake

Several of these water snakes were seen along Hackberry Creek and in several small spring-fed pools.

Natrix rhombifera—Diamond-Backed Water Snake

One diamond-backed water snake was seen sunning near the Nueces River.

Pituophis melanoleucus—Bullsnake

Local residents confirm the presence of bullsnakes in the area. None were seen during the study period.

Thamnophis cyrtopsis—Eastern Black-Necked Garter Snake

One black-necked garter snake was collected near Hackberry Creek. Several additional individuals were seen swimming in local creeks.

Thamnophis proximus—Ribbon Snake

Two ribbon snakes were collected during the study period. One large specimen regurgitated an adult *Rana pipiens* after being captured.

Thamnophis marcianus—Checkered Garter Snake

The presence of garter snakes in the area was confirmed by local residents.

Micrurus fulvius—Coral Snake

According to several local residents, coral snakes occur commonly along stream beds in the area. None were seen during the study period.

Agkistrodon contortrix–Copperhead

A single copperhead was collected during the study period. Local residents report that copperheads are abundant along all stream beds in the area.

Crotalus atrox–Western Diamond-Backed Rattlesnake

One local resident has seen only thirty diamond-backed rattlesnakes in the last three years, most of which were killed. None were seen during the study period.

Crotalus lepidus–Rock Rattlesnake

The above-mentioned local resident has seen only one rock rattlesnake in the last three years. County records indicate their presence in Val Verde, Edwards, and Real Counties.

Crotalus molossus–Black-tailed Rattlesnake

The Vertebrate Research Collection at Angelo State University contains one black-tailed rattlesnake collected in northern Real County in 1973. A local resident has seen three of these uncommon rattlesnakes in the last three years.

MAMMALS

Didelphis marsupialis–Opossum

Opossums were seen infrequently during the study period. One individual was found dead along Ranch Road 335 near the confluence of Hackberry Creek and the East Prong River.

Myotis velifer–Mexican Brown Bat

Two males and three female Mexican brown bats were found in bat nets positioned along Hackberry Creek.

Lasiurus borealis–Red Bat

Four males and two female red bats were caught in the same vicinity as the Mexican brown bats. This species probably roosts in the large trees in the riparian associations.

Tadarida brasiliensis–Mexican Free-tail Bat

Free-tail bats are the most abundant bat in this area. The largest colony in this area inhabits the Devil's Sinkhole. Two main flights of free-tails were observed: the first flight starting about one hour before sunset and the second, and largest, starting immediately before sunset. A total of nine bats were netted along Hackberry Creek, and five others were taken at the Devil's Sinkhole. All of the free-tail collected were males, which might indicate that females were occupied with young in nursery colonies.

Dasypus novemcinctus–Nine-banded Armadillo

Many armadillos were seen in the area. Several dead armadillos were seen along Ranch Road 335.

Lepus californicus–Black-tailed Jackrabbit

Several jackrabbits were seen along the ridge tops and tablelands in thick brush as well as open savannahs.

Sylvilagus spp.–Cottontails

Many cottontails were seen in all associations, but the majority were seen along the stream valleys. The ranges of two species, *Sylvilagus floridanus,* (the Eastern cottontail) and *Sylvilagus auduboni,* (the Western cottontail) are known to overlap in the general area. No individuals were collected for positive identification.

Sciurus niger–Eastern Fox Squirrel

A common rodent in this area, fox squirrels were seen predominantly in pecan and walnut trees in the valleys. One individual was seen and photographed in a liveoak tree on the ridge tops.

Spermophilus variegatus–Rock Squirrel

Rock squirrels were the most abundant rodent observed in the study area. They occupy a variety of habitats, although most were seen along the stream beds.

Peromyscus spp.–White-footed Mouse

One small mouse was found by a local resident in the stomach of a Western diamond-backed rattlesnake. The snake was caught and killed near the entrance of Red Arrow Cave. In addition to the mouse, four free-tail bats had been injested by the rattlesnake.

Mus musculus–House Mouse

An introduced species, this house mouse was collected from the bed of a pickup truck parked near Devil's Sinkhole. This individual probably came from an outside area via the truck.

Erethizon dorsatum–Porcupine

Evidence of recent feeding on the bark of several trees in the area indicated the presence of porcupines in the area. Pinyon pines, *Pinus cembroides* Zucc., var. *remota* Little, seemed to be favorite food in this area. All evidence of porcupines was found on ridge tops and hillsides.

Myocastor coypus–Nutria

Although no nutria were seen during the study period, local residents have seen these rodents along all streams and in stock tanks in the area. An introduced species, nutria are widespread in Texas and can be found invariably wherever water is present.

Canis latrans–Coyote

According to local residents, coyotes are found in this area only in the flat, hilltop areas north of the Devil's Sinkhole. One rancher reports no coyote sightings or kills in the last three years.

Urocyon cineroargenteus–Gray Fox

Gray foxes have been seen throughout the study area by local residents. They have indicated that the relative numbers of gray foxes in the area have decreased drastically in the last several years.

Procyon lotor–Raccoon

Only one raccoon was seen during the study period, and that individual was found dead on the road. According to one local resident, a large number of raccoons were killed by a distemper outbreak last year (1973), but frequent observations of raccoon and ringtail droppings indicate that densities are still fairly high.

Bassariscus astutus–Ringtail

One ringtail was seen along a rocky bluff above Hackberry Creek. A second individual was found dead along Ranch Road 335.

Taxidea taxus–Badger

Two local residents attest to the presence of badgers in the area. Several individuals have been seen along local roads.

Spilogale putorius–Eastern Spotted Skunk

One local resident has seen several hog-nosed skunks in the area. These skunks probably are uncommon in the area.

Felis concolor—Mountain Lion

One local resident found mountain lion tracks and a fresh kill in the fall of 1973. An adjacent neighbor reported hearing a lion last year about the same time.

Lynx rufus—Bobcat

No bobcats were seen during the study period. Local residents attest again to the presence of bobcats in the area.

Tayassu tajacu—Collared Peccary

Collared peccaries were not seen during the study period. Two peccary skulls were found on ridge tops, and local residents report seeing peccaries frequently.

Odocoileus virginianus—White-tailed Deer

White-tailed deer are abundant in the area. Many were seen in all associations.

Bison bison—Buffalo

Although this area was once within the geographical range of the buffalo, original populations have been extirpated. One herd of 24 individuals was seen, and residents report that this herd was imported five years ago.

In addition to those animals included in the annotated list of species, several other imported mammals were seen. These "exotic" mammals have been imported as game animals and have been stocked by several commercial hunting ranches in the area. Although these animals are a part of the vertebrate assemblage, their geographic origin excludes them from the natural fauna of the study area. The following "exotics" were seen in the study area:

Axis deer—*Axis axis*
Fallow deer—*Dama dama*
Mouflon-Barbados—*Ovis* spp.
Barbary Sheep-Aoudad—*Ammotragus lervia*
Black Buck Antelope—*Antelope cervicapra*

Other "exotics," not seen in the area but known to have been imported (Fuchs, pers. comm.), are:

Elk—*Cervus canadensis*
Red deer—*Cervus elaphus*
Sika deer—*Cervus nippon*

Data obtained on aquatic vertebrates in the area are minimal. Netting procedures yielded specimens of the following fish from area waters:

Mosquitofish—*Gambusia affinis*
Greenthroat darter—*Etheostoma lepidum*
Sunfish—*Lepomis* spp.
Shiner—*Notropis* spp.

Largemouth bass, *Micropterus salmoides* and channel catfish, *Ictalurus punctatus,* were also seen in the area.

CHECKLIST OF THE TERRESTRIAL VERTEBRATES OF THE DEVIL'S SINKHOLE-HACKBERRY CREEK AREA

This checklist includes all terrestrial vertebrates collected during the study period and all species previously recorded in the literature from Edwards and Real Counties.

Also included are those species whose presently known distribution indicates that they may be present in the Devil's Sinkhole-Hackberry Creek Area.

Distributional data on these vertebrates listed are based on literature and specimen records from the following publications: Blair, 1950; Blair, *et al.,* 1968; Brown, 1950; Dalquest, *et al.,* 1969; Dalquest and Kilpatrick, 1973; Davis, 1960; Hall and Kelson, 1959; Raun, 1962; Raun and Gehlbach, 1972; Reddell and Smith, 1964; Reddell, 1970; Roth, 1972; Schmidley, 1973; and Semken, 1967.

CLASS AMPHIBIA

Superorder Lepospondyli
Order Urodela
Suborder Salamandroidea
Family Plethodontidae .... *Eurycea neotenes* Bishop and Wright – Texas Salamander
Plethodon glutinosus (Green) – Slimy Salamander

Superorder Salientia
Order Anura
Suborder Anomocoela
Family Pelobatidae .... *Scaphiopus couchi* Baird – Couch's Spadefoot
Suborder Proceola
Family Leptodactylidae .... *Hylactophryne augusti* (Dugés) – Barking Frog
Syrrhophus marnocki Cope – Texas Cliff Frog
Family Bufonide .... *Bufo debilis* Girard – Green Toad
Bufo punctatus Baird and Girard – Red-Spotted Toad
Bufo speciousus Girard – Texas Toad
Bufo valliceps Wiegmann – Gulf Coast Toad
Family Hylidae .... *Acris crepitans* Baird – Cricket Frog
Hyla versicolor-chrysoscelis – Gray Tree Frog

Suborder Diplasiocoela
Family Ranidae . . . . *Rana catesbiana* Shaw – Bullfrog
Rana pipiens Schreber – Leopard Frog
Family Microhylidae . . . . *Gastrophyrne olivacea* (Hallowell) Great Plains Narrow-mouthed Toad

CLASS REPTILIA

Order Testudinata
Family Kinosternidae . . . . *Kinosternon flavescens* (Agassiz) – Yellow Mud Turtle
Family Emydidae . . . . *Terrapene ornata* (Le Conte) – Western Box Turtle
Graptemys versa Stejneger – Texas Map Turtle
Chrysemys scripta (Schoepff) – Pond Slider
Chrysemys concinna (Le Conte) – River Cooter
Family Trionychildae . . . . *Trionyx spinifer* Le Sueur – Spiny Softshell

Order Squamata
Suborder Lacertilia
Family Gekkonidae . . . . *Coleonyx brevis* Stejneger – Texas Banded Gecko
Family Anguidae . . . . *Gerrhonotus leocephalis* Wiegmann – Texas Alligator Lizard
Family Teidae . . . . *Cnemidophorus gularis* Barid and Girard – Eastern Spotted Whiptail
Family Iguanidae . . . . *Cophosaurus texanus* Troschel – Greater Earless Lizard
Crotaphytus collaris (Say) – Collared Lizard
Phrynosoma cornutum (Harlan) – Texas Horned Lizard
Sceloporus olivaceous Smith – Texas Spiny Lizard
S. poinsetti Baird and Girard – Crevice Spiny Lizard
S. undulatus (Latreille) – Eastern Fence Turtle
Urosaurus ornatus Baird and Girard – Tree Lizard
Family Scincidae . . . . *Eumeces brevilineatus* Cope – Short Lined Skink
E. obsoletus (Baird and Girard) – Great Plains Skink
Lygosoma laterale Say – Grand Skink

Suborder Serpentes
Family Leptotyphlopidae . . . . *Leptotyphlops dulcis* (Baird and Girard) – Texas Blind Snake
Family Colubridae . . . . *Heterodon nasicus* Blair and Girard – Western Hognose Snake
Heterodon platyrhinos Latreille – Eastern Hognose Snake
Opheodrys aestivus (Linnaeus) – Rough Green Snake
Natrix rhombifera (Hollowell) – Diamond-backed Water Snake
Natrix erythrogaster (Forster) – Plain-bellied Water Snake
Elaphe guttata (Linnaeus) – Corn Snake
E. obsoleta (Say) – Rat Snake
E. subocularis (Brown) – Trans-Pecos Rat Snake
Pituophis melanoleucus (Daudin) – Bull Snake
Thamnophis cyrtopsis (Kennicott) – Black-necked Garter Snake
T. marcianus (Baird and Girard) – Checkered Garter Snake
T. proximus (Say) – Western Ribbon Snake
Rhinocheilus lecontei Baird and Girard – Longnosed Snake
Lampropeltis getulus Linnaeus – Common Kingsnake
Salvadora grahamiae Baird and Girard – Mountain Patch-nosed Snake
Masticophis flagellum (Shaw) – Coachwhip
Masticophis taeniatus (Hollowell) – Striped Whipsnake
Sonora episcopa Kennicott – Ground Snake
Diadophis punctatus (Linnaeus) – Eastern Ringneck Snake
Tantilla atriceps (Gunther) – Mexican Black-headed Snake
T. gracilis Blair and Girard – Flat-headed Snake
Hypsiglena torquata Cope – Night Snake
Tropidoclonian lineatum (Hollowell) – Lined Snake
Family Elapidae . . . . *Micrurus fulvius* Linnaeus – Coral Snake
Family Viperidae . . . . *Agkistrodon contortrix* (Linnaeus) – Copperhead

CLASS MAMMALIA

Subclass Theria
Infraclass Metatheria
Order Marsupialia
Family Didelphidae .... *Didelphis marsupialis* Linnaeus – Opossum

Infraclass Eutheria
Order Insectivora
Family Soricidae .... *Notiosorex crawfordi* (Baird) – Desert Shrew

Order Chiroptera
Family Vespertilionidae .... *Myotis velifer* (Allen) – Mexican Brown Bat
Pipistrellus hesperus (Allen) – Western Pipistrelle
P. subflavus (Cuvier) – Eastern Pipistrelle
Lasiurus borealis (Miller) – Red Bat
L. cinereus (Beauvois) – Hoary Bat
Plecotus townsendii (Cooper) – Western Big-Eared Bat
Antrozous pallidus (Le Conte) – Pallid Bat
Family Mosossidae .... *Tadarida brasiliensis* (Saint-Hilaire) – Mexican Free-Tail Bat

Order Edentata
Family Dasypodidae .... *Dasypus novemcinctus* Linnaeus – Nine-banded Armadillo

Order Lagomorpha
Family Leporidae .... *Lepus californicus* Gray – Black-tailed Jackrabbit
Sylvilagus auduboni (Baird) – Desert Cottontail
Sylvilagus floridanus (Allen) – Eastern Cottontail

Order Rodentia
Suborder Sciuromorpha
Family Sciuridae .... *Sciurus niger* Linnaeus – Eastern Fox Squirrel
Cynomys ludovicianus (Ord) – Black-tailed Prairie Dog
Spermophilus mexicanus (Erxleben) – Mexican Ground Squirrel
Spermophilus variegatus (Erxleben) – Rock Squirrel
Family Geomyidae .... *Geomys bursarius* (Shaw) – Prairie Pocket Gopher
Thomomys bottae (Eydous and Gervais) – Valley Pocket Gopher
Family Castoridae .... *Castor canadensis* Kuhl – Beaver
Family Heteromyidae .... *Perognathus merriami* Allen – Merriam's Pocket Mouse
P. hispidus Baird – Hispid Pocket Mouse
Suborder Myomorpha
Family Cricitidae .... *Reithrodontomys montanus* (Baird) – Plain's Harvest Mouse
R. fulvescens (Allen) – Fulvous Harvest Moon
Peromyscus leucopus (Rafinesque) – White-footed Mouse
P. attwateri Allen – Brush Mouse
P. pectoralis Osgood – Encinal Mouse
Baiomys taylori (Thomas) – Pigmy Mouse
Onychomys leucogaster (Wied-Neuwied) – Grasshopper Mouse
Sigmodon hispidus Say and Ord – Cotton Rat
Neotoma floridana (Ord) – Eastern Wood Rat
N. micropus Baird – Southern Plains Wood Rat
N. albigula Hartley – White-throated Wood Rat
Family Muridae .... *Rattus* spp. – introduced rats
Mus musculus Linnaeus – House Mouse (introduced)

Suborder Hystricomorpha
Family Erethisontidae .... *Erethizon dorsatum* (Linnaeus) – Porcupine
Family Myocastoridae .... *Myocastor coypus* (Molina)

Order Carnivora
Suborder Fissipeda
Family Canidae .... *Canis latrans* Say – Coyote
Urocyon cinereoargenteus (Schreber) – Gray Fox
Vulpes fulva (Desmaret) – Red Fox

Family Procyonidae . . . . *Procyon lotor* (Linnaeus) – Raccoon
Bassariscus astutus (Lichtenstein) – Ringtail
Family Mustelidae . . . . *Mustela frenata* (Lichtenstein) – Long-tailed Weasel
Taxidea taxus (Schreber) – Badger
Spilogale putorius (Linnaeus) – Eastern Spotted Skunk
Mephitis mephitis (Schreber) – Striped Skunk
Conepatus mesoleucus (Lichtenstein) – Hog-nosed Skunk
Family Felidae . . . . *Felis concolor* Linnaeus – Mountain Lion
Lynx rufus (Schreber) – Bobcat

Order Artiodactyla
Suborder Suiformes
Family Tayassuidae . . . . *Tayassu tajacu* Linnaeus – Collared Peccary
Suborder Ruminantia
Family Cervidae . . . . *Odocoileus virginianus* (Zimmermann) – White-tailed Deer
Family Bovidae . . . . *Bison bison* (Linnaeus) – Buffalo, Bison

DISCUSSION

The Devil's Sinkhole-Hackberry Creek area is characteristic of that part of the Edwards Plateau where numerous southeastward-flowing streams and rivers provide corridors of dispersal for those animals which require more mesic conditions than exist in the western portion of the Plateau. Reptiles and amphibians known from the area were assigned to one of five categories, based on that species' apparent center of origin or dispersal. The five faunal categories are: Austroriparian (eastern United States), Chihuahuan (southwestern United States and the tablelands of Mexico), Tamaulipan (the neotropical fauna of Central America and the eastern coast of Mexico), widespread and grassland forms, and endemic and Balconian (restricted to the Balconian portions of the state). Based on a total of 63 species, 29% are included in the Austroriparian fauna, 48% are of Chihuahuan origin, 3% are classed as Tamaulipan, 9% are widespread or are grassland forms, and the remaining 11% are Balconian in origin or range westward from the Balconian biotic province. The percentage of Austroriparian forms would be expected to decrease farther west on the Plateau. The high percentage of these eastern forms in the Devil's Sinkhole-Hackberry Creek area indicates an extreme efficiency in these corridors of dispersal from the east. Although collecting efforts in the area indicated low densities of many species, edaphic and physiographic factors in this transition area of Texas are limiting factors in the distribution of species, and low densities would be expected.

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SUMMER RESIDENT BIRDS OF THE DEVIL'S SINKHOLE – HACKBERRY CREEK AREA

Terry C. Maxwell

INTRODUCTION

The Devil's Sinkhole-Hackberry Creek area lies in the northeast corner of Edwards County, Texas. The area is near the southwest limit of the Edwards Plateau, a Cretaceous limestone plateau deeply cut and eroded by rivers flowing generally southeastward toward the Gulf of Mexico. The Devil's Sinkhole, a deep, vertical cave, is near the head of Hackberry Creek, a tributary of the Nueces River. The stream valleys are characterized by moderately deep soils that support a dense riparian vegetation dominated by pecan, sycamore, river walnut, and walnut trees. The slopes above the streams are covered with dense stands of ashe juniper (*Juniperus ashei*), where not eradicated, and liveoak. The ridge tops and tablelands are thin-soiled and support a liveoak savannah.

Ornithologically, the region is interesting for two reasons. The geographic location and ecology of the area provide for a blending of bird species from the east, west, and south. The Nueces River and Hackberry Creek valleys provide habitats for eastern woodland birds. Wooded river valleys are known to be corridors for dispersion of eastern animals into dryer western habitats. The proximity of semitropical habitats of South Texas and the eastern slope of Mexico accounts for a significant element of southern birds whose centers of distribution lie in tropical zones. Secondly, the area is thinly populated with people. Although overgrazing by sheep and goats has affected soil cover and vegetation on the ridges and slopes, the stream valleys have been only moderately altered from natural conditions.

This report lists the summer resident birds of the Devil's Sinkhole-Hackberry Creek area of the Edwards Plateau. An analysis is given of the zoogeographic affinities of the bird life.

MATERIALS AND METHODS

Field investigations were conducted for five days in the last two weeks of July, 1974 and two days in the second week of August, 1974. Investigations consisted of field observations and collection of specimens in and around the Devil's Sinkhole, Hackberry Creek, and the confluence of Hackberry Creek and the Nueces River. Specimens are deposited in the Vertebrate Research Collection at Angelo State University, San Angelo, Texas.

The limited time available for field work restricts the conclusions possible, not only as to the complete complement of the summer birds but also as to the abundance of the species noted.

ANNOTATED LIST OF THE SUMMER RESIDENT BIRDS OF THE DEVIL'S SINKHOLE-HACKBERRY CREEK

Sixty-six species of birds were observed. Two species were identified only to genus, and 64 were identified to species. Appendix A lists 45 species that were not observed but could possibly occur as summer residents in the area. The list in Appendix A was compiled from the records of Beuchner (1946) from Kerr County and the bird distributions given for Texas by Wolfe (1956). The following annotated list includes only the 66 species observed during this investigation.

Ardea herodias—Great Blue Heron

Individual Great Blue Herons were observed infrequently along Hackberry Creek. Behavior noted in other areas indicates that this heron probably occurs about stock tanks in the liveoak savannah as well.

Butorides virescens—Green Heron

Green Herons were seen frequently along Hackberry Creek, and three juveniles seen on July 21 indicated breeding in the area.

Cathartes aura—Turkey Vulture

Numerous Turkey Vultures were observed above all habitats in the area, and black-headed immatures indicated nesting.

Coragyps atratus—Black Vulture

Two Black Vultures were seen above Hackberry Creek, indicating this species to be less frequent than in Kerr County to the east where Beuchner found them to be common.

Buteo jamaicensis—Red-tailed Hawk

Red-tailed Hawks were seen three times in the valley and on the ridge, a normal breeding season density.

Buteo lineatus—Red-shouldered Hawk

This hawk is close to its western limit in southwestern Edwards County, and only two sightings of probably the same individual indicated it to be infrequent in the Hackberry Creek valley.

Parabuteo unicinctus—Harris' Hawk

One Harris' Hawk was seen above Hackberry Creek. Wolfe placed northern limit for resident Harris' Hawks in Central Texas in the southwestern Edwards Plateau. Beuchner found the species to be only occasional in Kerr County, and the Hackberry Creek area is probably close to the northern limit for this species in the plateau.

Falco sparverius—American Kestrel

One dead kestrel was found near Hackberry Creek.

Colinus virginianus—Bobwhite

Bobwhites were seen but once in the liveoak savannah, but more complete investigations are needed to determine the status of this secretive species.

Meleagris gallopavo—Turkey

Turkeys were seen commonly in the valleys. Area residents describe turkeys as locally abundant where they are fed by people.

Charadrius vociferous—Killdeer

Individual Killdeers were seen infrequently on gravel bars and rocky shores of Hackberry Creek.

Actitis macularia—Spotted Sandpiper

One Spotted Sandpiper was seen on the shore of Hackberry Creek. Whether this species nests in the area is uncertain since neither Beuchner nor Wolfe believed it to be a nester in the western Edwards Plateau.

Zenaida macroura—Mourning Dove

Mourning Doves were observed commonly in all habitats, and they were abundant near agricultural crops.

Scardafella inca—Inca Dove

This small dove was seen in low numbers close to human dwellings in the Hackberry Creek valley, and they probably occur in similar situations on the liveoak savannah.

Coccyzus americanus—Yellow-billed Cuckoo

Yellow-billed Cuckoos were seen infrequently in riparian tree groves along Hackberry Creek.

Geococcyx californianus—Roadrunner

One Roadrunner was seen in the Hackberry Creek valley. This secretive bird is probably as common here as in any part of its Texas distribution.

Otus asio—Screech Owl

This small owl was heard frequently in pecan and walnut groves along Hackberry Creek. The nocturnal field work in the liveoak savannah was insufficient to determine the presence of this species.

Bubo virginianus—Great Horned Owl

One dead Great Horned Owl was found beside the road in the Hackberry Creek valley. Reddell and Smith (1965) reported this owl nesting on ledges near the surface of the Devil's Sinkhole, and W. A. Thornton (pers. comm.) reported seeing a Great Horned Owl fly into the sink and under the entrance lip of limestone on August 15, 1974.

Phalaenoptilus nuttallii—Poor-will

One Poor-will was heard in the Nueces River valley.

Chordeiles minor—Common Nighthawk

This species was seen commonly in all habitats.

Archilochus sp.—Hummingbird

Female hummingbirds of the genus *Archilochus* were seen occasionally along Hackberry Creek. Beuchner recorded both the Black-chinned Hummingbird (*A. alexandri*) and the Ruby-throated Hummingbird (*A. colubris*) in the summer in Kerr County, and both species probably occur in the Upper Nueces area.

Megaceryle alcyon—Belted Kingfisher

One Belted Kingfisher was seen along Hackberry Creek on August 10. This kingfisher is probably a rare permanent resident of the Upper Nueces area.

Chloroceryle americana—Green Kingfisher

At least six Green Kingfishers were seen along the upper one-half of Hackberry Creek. This species is a common summer resident of the area permanent streams, and probably a permanent resident at this latitude. Two individuals were collected.

Centurus aurifrons—Golden-fronted Woodpecker

This woodpecker was seen infrequently about large trees in all habitats.

Dendrocopus scalaris—Ladder-backed Woodpecker

Ladder-backed Woodpeckers were seen commonly in all habitats.

Tyrannus verticalis—Western Kingbird

Four Western Kingbirds were seen together once near Rocksprings, about five miles west of the Devil's Sinkhole in liveoak savannah similar to that found around the sinkhole. Beuchner considered this kingbird to be only a migrant in Kerr County, and Simmons (1925) considered it to be a very rare migrant in the Austin area fifty years ago. Wolfe listed it as a summer resident of the Edwards Plateau, and today it occurs commonly in the summer at least as far east as Austin (Travis Audubon Society, 1972). A comparison of the modern and historical records indicates that this species has expanded its distribution eastward in recent times.

Muscivora forficata—Scissor-tailed Flycatcher

This flycatcher was seen infrequently in the liveoak savannah and does not appear to be as abundant here as it is farther west in the mesquite prairie.

Myiarchus cinerascens—Ash-throated Flycatcher

The Ash-throated Flycatcher was seen infrequently in the liveoak savannah.

Sayornis phoebe—Eastern Phoebe

One adult and two immatures of this phoebe were seen along Hackberry Creek. Wolfe's description of the distribution of this species indicates that the Upper Nueces is close to the southwestern limit of its range in Texas.

Sayornis nigricans—Black Phoebe

At least two Black Phoebes were seen regularly along Hackberry Creek.

Empidonax sp.—Flycatcher

One adult flycatcher of the genus *Empidonax* was seen feeding a fledgling in riparian growth along Hackberry Creek. Beuchner recorded the Acadian Flycatcher (*E. virescens*) in the summer in Kerr County, and Wolfe included the Willow Flycatcher (*E. traillii*) in the breeding birds of the southern Edwards Plateau. Either species could have been the bird observed.

Contopus virens—Eastern Wood Pewee

The Eastern Wood Pewee is a common species in the wooded areas of the stream valleys.

Pyrocephalus rubinus—Vermilion Flycatcher

Vermilion Flycatchers were seen uncommonly near human dwellings in the Hackberry Creek valley, and they probably occur near stock tanks in the liveoak savannah.

Eremophila alpestris—Horned Lark

Two Horned Larks were seen in an open grassy area near the Devil's Sinkhole. Beuchner considered the Horned Lark to be a rare vagrant in Kerr County, but it is an uncommon summer resident 60 miles north of Rocksprings in Schleicher County (Maxwell and Wiedenfeld, 1972). This species may be expanding its summer distribution into eastern Edwards County, but probably this area represents the eastern limit of its historical distribution in the southwestern Edwards Plateau.

Petrochelidon pyrrhonota—Cliff Swallow

An inactive nest colony of this species was found on a bluff above Hackberry Creek. Approximately 130 nests were sufficiently intact to suggest recent occupation.

Petrochelidon fulva—Cave Swallow

Cave Swallows in Texas are restricted largely to Edwards and Kerr Counties (Wolfe, op. cit.) and constitute one of the unique elements of the bird fauna of the state. Reddell and Smith identified eight swallow caves in Edwards County. Baker and Selander (1957) reported on the cave swallows of this area. They described the nesting colony in the Devil's Sinkhole: "Swallows nest on the slanting roof of the lower chamber 110 feet or more below ground level and high above the sides of the rock mound. A source of mud for the nests is provided by water which seeps from the sides of the sink, wetting soil that has accumulated on the narrow limestone ledges. . ." During the present study, the Cave Swallow colony was examined in the sinkhole. No accurate estimate was made of the population present in the summer of 1974, but probably about 400 swallows were present. Cave Swallows also were noted feeding above the Hackberry Creek valley and watering in the creek.

Aphelocoma coerulescens—Scrub Jay

Scrub Jays are uncommon but widespread in the juniper and liveoak savannah. They were noted less frequently in the Hackberry Creek valley.

Corvus cryptoleucus—White-necked Raven

One individual of this species was seen flying above the Hackberry Creek valley. Beuchner considered this raven to be accidental in Kerr County.

Parus carolinensis—Carolina Chickadee

Chickadees were seen commonly along Hackberry Creek.

Parus atricristatus—Black-crested Titmouse

Titmice were seen commonly along Hackberry Creek.

Psaltriparus minimus—Bushtit

Bushtits were seen in small flocks on the juniper-liveoak slopes and in the Hackberry Creek valley.

Thryomanes bewickii—Bewick's Wren

This species was seen commonly in all habitats.

Thryothorus ludovicianus—Carolina Wren

Carolina Wrens were seen and heard commonly in riparian growth along Hackberry Creek.

Salpinctes mexicanus—Canyon Wren

Canyon Wrens are common on near-vertical bluffs above Hackberry Creek. Four individuals were seen about the entrance to the Devil's Sinkhole and on several occasions were noted flying into the sink. Reddell and Smith reported seeing Canyon Wrens to a depth of 70 feet in the sink. Since the sink walls are the only vertical rock surfaces near the area, this species undoubtedly nests within the Devil's Sinkhole.

Mimus polyglottos—Mockingbird

This species is an uncommon summer resident of all habitats.

Lanius ludovicianus—Loggerhead Shrike

Shrikes were seen infrequently in the liveoak savannah. Beuchner did not record them in summer in Kerr County, but Wolfe listed them as summer residents of this part of Texas.

Vireo atricapillus—Black-capped Vireo

Two Black-capped Vireos were noted near the confluence of Hackberry Creek and the Nueces River in dense shrubs.

Vireo griseus—White-eyed Vireo

This species was seen commonly in riparian growth along Hackberry Creek.

Mniotilta varia—Black-and-White Warbler

Two Black-and-White Warblers were seen in juniper-river walnut thickets along Hackberry Creek.

Dendroica chrysoparia—Golden-cheeked Warbler

Two Golden-cheeked Warblers were seen feeding in juniper-river walnut thickets along Hackberry Creek on July 26 and again on August 10. The species is reported to nest (George Miles, pers. comm.) in Beef Hollow on the Frost Ranch. At least one other suitable nesting area was seen on the Schoolhouse Ranch. This species requires mature stands of Ashe Juniper for nesting and oaks and other broad-leaved trees for caterpillars on which they seem to prefer feeding. The presence of nesting habitat for this uniquely Texas warbler, a species whose survival is of much concern, in the Hackberry Creek area is worthy of attention.

Icteria virens—Yellow-breasted Chat

This secretive warbler was seen once in a thicket along Hackberry Creek.

Passer domesticus—House Sparrow

The House Sparrow is a common resident of the area, particularly about human dwellings.

Icterus spurius—Orchard Oriole

Orchard Orioles were seen infrequently along Hackberry Creek.

Molothrus ater—Brown-headed Cowbird

Small flocks of cowbirds were seen in all habitats.

Piranga rubra—Summer Tanager

Summer Tanagers were seen commonly along Hackberry Creek.

Cardinalis cardinalis—Cardinal

This species is common in thickets along Hackberry Creek.

Guiraca caerulea—Blue Grosbeck

Blue Grosbeaks were seen frequently near Hackberry Creek.

Passerina cyanea–Indigo Bunting
These buntings were seen infrequently near Hackberry Creek and in fallow fields in the valley.

Passerina ciris–Painted Bunting
Painted Buntings were seen more frequently than the previous species and in the same habitats.

Carpodacus mexicanus–House Finch
House Finches were seen commonly in all habitats.

Spinus psaltria–Lesser Goldfinch
This small goldfinch is an abundant resident of the pecan-walnut groves along Hackberry Creek.

Pipilo fuscus–Brown Towhee
Brown Towhees were noted commonly in all habitats in northeastern Edwards County.

Chondestes grammacus–Lark Sparrow
This sparrow possibly is the most abundant summer resident bird in this part of Texas. It was seen in the valleys and liveoak savannah.

Aimophila ruficeps–Rufous-crowned Sparrow
This secretive sparrow was seen commonly on rocky slopes with juniper and liveoak cover.

Spizella passerina–Chipping Sparrow
Chipping Sparrows were seen in all habitats except the dense riparian growth.

Spizella pusilla–Field Sparrow
One Field Sparrow was seen at the edge of a fallow field in the Hackberry Creek valley.

ZOOGEOGRAPHIC RELATIONS OF THE BIRD FAUNA

The distribution of a species is limited by ecological requirements for existence of that species. An aggregate of animal species identifiable with a geographical area wherein they encounter a broadly similar set of ecological conditions is defined as a fauna. For the purpose of identifying the bird faunas that contribute to the summer resident birds of the Devil's Sinkhole-Hackberry Creek area, the many described faunas are condensed into broad zoogeographic categories. The categories are: eastern birds (North America east of the Great Plains), western birds (North America from the Great Plains west and southwest to the Mexican Plateau), southern birds (South Texas south through tropical Central and South America), Edwards Plateau birds (endemics and those whose center of distribution lies in the plateau), and widespread birds (either entire North America or in both American continents).

Sixty-four of the 66 species identified in the study were assigned to one of the zoogeographic categories listed above. The two birds identified only to genus (*Empidonax* sp. and *Archilochus* sp.) were not included in the analysis. The 45 possible but not observed species (Appendix A) also were not included in the analysis. Further field work will have to be carried out to determine their occurrence in the area.

Of the 64 identified species in the Devil's Sinkhole-Hackberry Creek area, 23 species (36%) are widespread in distribution. Table I lists the species that are primarily eastern, western, or southern. Fifteen species (23%) are eastern, 13 species (20%) are western, and 10 species (16%) are southern. The remaining 3 species (5%) are of the Edwards Plateau fauna. Blair (1950) characterized the Balconian Biotic Province (including the Edwards Plateau) of Texas as an "intermixture of faunal elements characteristic of other, major, provinces." Although Blair did not consider birds in his diagnosis of the biotic provinces of Texas, he did compare the distributions of the other vertebrate classes. The presence of endemic salamanders justified the recognition of the Edwards Plateau as a distinct biotic province. Udvardy (1962) recognized an Edwards Plateau fauna as a subunit of

TABLE I

Faunal association of the summer resident birds of the Devil's Sinkhole-Hackberry Creek area of the Edwards Plateau.

EASTERN BIRDS	WESTERN BIRDS	SOUTHERN BIRDS
Green Heron	Roadrunner	Black Vulture
Red-shouldered Hawk	Ladder-backed Woodpecker	Harris' Hawk
Bobwhite	Western Kingbird	Inca Dove
Killdeer	Scrub Jay	Green Kingfisher
Eastern Phoebe	White-necked Raven	Golden-fronted Woodpecker
Carolina Chickadee	Common Bushtit	Black Phoebe
Carolina Wren	Canyon Wren	Vermilion Flycatcher
White-eyed Vireo	House Finch	Cave Swallow
Black-and-White Warbler	Brown Towhee	Black-crested Titmouse
Orchard Oriole	Lark Sparrow	Lesser Goldfinch
Cardinal	Rufous-crowned Sparrow	
Indigo Bunting	Ash-throated Flycatcher	
Painted Bunting	Poor-Will	
Field Sparrow		

the chaparral and desert scrub of the Southwest. Based on the center of distribution of the species, he included four species in his Edwards Plateau fauna: Scissor-tailed Flycatcher, Black-capped Vireo, Golden-cheeked Warbler, and Cassin's Sparrow. The first three listed species were found in the Devil's Sinkhole-Hackberry Creek area, and the Cassin's Sparrow probably occurs there as well.

Thornton (1951), in a study of the birds of the Stockton Plateau 120 miles to the west of the Devil's Sinkhole, described the summer resident bird faunal elements as follows: 38.3% widespread, 23.3% southern, 23.3% western, 11.6% eastern, and 3.3 Great Plains. Reassigning two of the Stockton Plateau species. (Ladder-backed Woodpecker and Rufous-crowned Sparrow) from southern to western, and placing the Great Plains species (Scissor-tailed Flycatcher and Black-capped Vireo) in the Edwards Plateau fauna, makes the data comparable to the present study. Table II gives the revised faunal percentages of the Stockton Plateau in comparison with the Devil's Sinkhole-Hackberry Creek faunal elements.

A comparison of the two areas is preliminary at this time due to the minimal field work in the Devil's Sinkhole-Hackberry Creek area, but some conclusions are obvious. A greater percentage of eastern birds, associated with the Nueces River valley, correlates in the present study area with a greater percentage of western birds in the more xeric and less wooded Stockton Plateau. The presence of the dryer liveoak savannah with its western birds beside the wetter stream valley of the Upper Nueces with its eastern birds provides for a rich summer resident bird fauna. In the 120 miles from the Stockton Plateau, environmental conditions change sufficiently to account for at least a 10% shift toward eastern birds in the Devil's Sinkhole-Hackberry Creek area.

TABLE II

Faunal comparison between the Stockton Plateau and the Devil's Sinkhole-Hackberry Creek area of the Edwards Plateau.

	FAUNAS				
Location	**Widespread**	**Eastern**	**Western**	**Southern**	**Edwards Plateau**
Devil's Sinkhole-Hackberry Creek	36%	23%	20%	16%	5%
Stockton Plateau	38.3%	11.6%	26.7%	20%	3.3%

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APPENDIX A

Species unobserved but of possible occurrence as summer residents in the Devil's Sinkhole-Hackberry Creek area of the Edwards Plateau.

Anas discors–Blue-winged Teal
Anas cyanoptera–Cinnamon Teal
Anas clypeata–Shoveller
Aix sponsa–Wood Duck
Accipiter striatus–Sharp-shinned Hawk
Accipiter cooperii–Cooper's Hawk
Buteo albonotatus–Zone-tailed Hawk
Callipepla squamata–Scaled Quail
Cyrtonyx montezumae–Montezuma's Quail
Fulica americana–American Coot
Columbina passerina–Ground Dove
Tyto alba–Barn Owl
Strix varia–Barred Owl
Archilochus colubris–Ruby-throated Hummingbird
Archilochus alexandri–Black-chinned Hummingbird
Myiarchus crinitus–Great Crested Flycatcher
Empidonax traillii–Willow Flycatcher
Contopus sordidulus–Western Wood Pewee
Progne subis–Purple Martin
Corvus brachyrhynchos–Common Crow
Auriparus flaviceps–Verdin
Sitta carolinensis–White-breasted Nuthatch
Campylorhynchus brunniecapillus–Cactus Wren
Salpinctes obsoletus–Rock Wren
Toxostoma curvirostre–Curve-billed Thrasher
Siala sialis–Eastern Bluebird
Polioptila caerulea–Blue-gray Gnatcatcher
Sturnus vulgaris–Starling
Vireo bellii–Bell's Vireo
Vireo flavifrons–Yellow-throated Vireo
Vireo olivaceus–Red-eyed Vireo
Parula americana–Parula Warbler
Dendroica petechia–Yellow Warbler
Dendroica dominica–Yellow-throated Warbler
Oporornis formosus–Kentucky Warbler
Geothlypis trichas–Yellowthroat
Agelaius phoeniceus–Red-winged Blackbird
Icterus galbula–Northern Oriole
Quiscalus quiscula–Common Grackle
Tangavius aeneus–Bronzed Cowbird
Spiza americana–Dickcissel
Aimophila cassinii–Cassin's Sparrow
Ammodramus savannarum–Grasshopper Sparrow
Amphispiza bilineata–Black-throated Sparrow

AN ARCHAEOLOGICAL RECONNAISSANCE IN THE VICINITY OF THE DEVIL'S SINKHOLE

William S. Marmaduke and Hayden Whitsett

INTRODUCTION

The Devil's Sinkhole lies on the western edge of the Central Texas hill country, a part of the Edwards Plateau that has been cut and sculpted by numerous clear-flowing, spring-fed rivers and streams. The highland surfaces, preserved in their pristine condition in only a few places, are stoney grasslands dotted with isolated clumps of juniper and some pinyon pine or mottes of scrub oaks. Where the hand of man the pastoralist has been felt heavily, denser stands of juniper are apparent. The major drainages within the study area, Hackberry Creek and the Nueces River, wind their ways through deep limestone canyons; at the bottoms, the streams flow over shallow, cobble-strewn beds which often, where the discharge is irregular, are choked with verdant tangles of Mexican Walnut. At every turn, the sides of the canyons are lined with earthen terraces covered with imposing, dark Pecan or magisterial Sycamore trees.

Today the area is populated with scattered ranches; in the past, before European man laid claim to it, the land was thinly settled for thousands of years with the small, smokey camps of Indians. Evidence of these people's passage can still be seen today, and their remains are a part of our Texan and American heritage as surely as the buildings where later men died for their rights.

But today this link with a people long gone is being threatened at an ever increasing rate by the burgeoning population of an affluent society that seems to measure its progress by a yardstick of destruction. Each year, a little more of the land is bulldozed for new urban growth, or opened for recreation, and with each instance, another small part of our heritage disappears.

This study is concieved as a effort to salvage some of the legacy; we do not wish to reverse the social trends of the last quarter century, for we doubt that the forces which cause them can be resisted. Our aims in this study are to provide a document which will educate, so that public policy may flow from a position of enlightenment, as well as record the treasures of prehistory which we possess now but may be able only to read about in the future. If archaeological materials are anything, they are fragile; and once they have been destroyed, they are gone forever, irrevocably, irredeemably.

METHODOLOGY

Theoretical Strategy

The authors envision this reconnaissance as the first step in a multistage research program proposed by Redman (1973). The purpose of Redman's first stage—an unstructured reconnaissance coupled with paleoenvironmental studies—is to provide preliminary information on patterns of site locations as well as temporal and cultural trends in the study area, from which a statistical "universe" can be defined. Ideally, sampling designs based on probability can then be formulated and further, more definitive studies performed.

Due to the brief time (ten days) allowed in the study area and a correspondingly brief amount of time for research before going into the study area, the authors' approach differs in several ways from the steps outlined by Redman. An attempt toward constructing a subjective sampling design was made, using both field observation and map analysis. Since the authors presently do not contemplate being able to conduct further research in the study area, some sort of sampling design had to be combined with some aspects of unstructured reconnaissance to ensure the collection of reasonably complete data about the prehistoric resources in the area. Following this plan, the authors feel that an adequate sample was in fact obtained and is capable of providing guidelines for future research.

This study also differs from the Redman model in its organization of paleoenvironmental data. The literature about the climates, flora, and fauna of the post-Pleistocene past in Central Texas is often difficult to locate, organize, or use. Botanical and zoological studies seem to be conceived narrowly as curiously static analyses of dynamic systems. Additionally, little effort seems to be spent integrating the results of field identification into a complex structure of microenvironmental zonation involving acute recognitions of soil, radiation, moisture, temperature levels, and status in relation to competing biota.

Field Strategy

In actual practice, the choice of areas to be surveyed was determined partially by the availability of landowner permission. Still, all of the grossly recognized physiographic contexts existing in the study vicinity were sampled.

The valley of Hackberry Creek was surveyed from the vicinity of the Devil's Sinkhole to Kalentine hole. Additionally, the area of the Devil's Sinkhole was surveyed, along with two tributary channels which drain the sinkhole environs and flow south into Hackberry Creek. Wherever possible, other tributaries to Hackberry Creek and their catchment areas were surveyed. The Nueces River bed was surveyed also, from its juncture with Hackberry Creek to the Eagle Ranch and when feasible adjacent uplands and tributaries were examined. There were, however, permission problems in the survey of the portion of the Nueces River, resulting in a survey of one side only in many cases, or a survey peering out the window of a pickup truck while driving down a county road which parallels the river. The authors make no pretense to have located and recorded all of the sites in these areas; nevertheless, a significant and valuable number (if not a majority) of the sites were located.

Collections from each site were limited severly to artifacts that could give an indication of site age, cultural affiliation, or function. The quality of these collections varies greatly and depends mostly on how much surface collecting had been done by amateurs before the investigators reached the area. Remoteness, the landowner's policy toward amateurs and the amount of time spent on the site by the authors were all factors in the quality of the collections. We feel justified in not attempting to collect intensively because the brief nature of our study simply would not permit the useful analysis of large amounts of non-diagnostic materials, and, in addition, any collection is an act of destruction which cannot be reversed. Thus we felt compelled to leave as much of the sites intact for later research as was possible while at the same time achieving the goals of this study.

ARCHAEOLOGICAL BACKGROUND

The area surrounding the Devil's Sinkhole, Hackberry Creek, and the Upper Nueces drainage lies near the western edge of the Central Texas archaeological province. This region is one of the largest defined in Texas, extending northward to the Dallas-Fort Worth vicinity, eastward to the Trinity River, and southward to the edge of the Coastal Plains (Suhm et al., 1954).

CULTURE CHRONOLOGY

Three broad traditions or stages of technological development are recognized in Central Texas: the "Paleo-Indian" or "Big Game Hunting" Tradition, the Archaic Tradition, and the Neo-American Stage.

The earliest of these, the Paleo-Indian stage, is thought to be the remains of a nomadic people who pursued a hunting and gathering economy based primarily on the exploitation of now-extinct late Pleistocene megafaunas. Dating roughly from 12,000 B.C. to 5,000-4,000 B.C., the characteristic site of these cultures associates stone tools of human manufacture with the remains of Mammoth, extinct Bison, Tapir, Brocket, Horse, and Camel. The Paleo-Indian stage has been divided into three chronological units on the basis of artifact typology, animals hunted, and methods of hunting. In Central Texas, the two earlier cultures, Llano and Folsom, are represented principally by surface collections of diagnostic tool forms or by woefully scant material in the lowest levels of some deeply stratified sites. The later culture, Plano, has a better representation, with two sites, Kincaid (Suhm, 1958) in Uvalde County and Levi Rockshelter (Alexander, 1962) in Travis County, producing adequate material for study. Diagnostic artifacts of the Plano culture in Central Texas are several distinctive, thinned biface designs, popularly known as projectile point types, which have been assigned the names *Plainview, Plainview Golondrina, Lerma,* and *Angostura.* The Paleo-Indian stage was terminated by changing climatic conditions associated with the retreat of Wisconson glaciation and a consequent extinction of the larger forms of animal life.

Following on the heels of the big-game hunting tradition and perhaps developing out of it was the Archaic tradition, known in central Texas as the Edwards Plateau Aspect (Kelly, 1974; Suhm, et al., 1954). Long-lived, it begins in central Texas around 4,000 B.C. (a date of 3455 ± 300 B.C. was obtained from the early levels of the Wunderlich site) (Johnson, Suhm, and Tunnell, 1962) and persisted until A.D. 500 or possibly later.

Aside from obvious differences of time and projectile point morphology, the big-game hunting tradition differs from the Archaic in the critical area of subsistence. As has been explained previously, the economy of the nomadic big-game hunting tradition was based on the pursuit of now extinct megafauna. Such a stratagem dictates the covering of comparatively large amounts of land to locate and then hunt these animals, a pattern similar in some aspects to the lifeway of the historic footbound hunters of the Great Plains. In contrast, the Archaic shows a shift to small bands living in a defined area, having a technology adapted to the resources occurring there. Rather than nomadic wanderings seeking game animals, these bands moved in an annual migratory pattern controlled by their knowledge of area resources and their seasonal availability.

The material culture was a simple one, reflecting the way of life practiced during the Archaic. Basic weaponry consisted of the dart and atlatl (or spear and throwing stick), and hunting was probably the domain of the males. Grinding stones and implements of bone such as awls and spatulas may have been the result of extensive wild plant gathering and of clothes making by women. Because of the relatively moist climate in Central Texas, perishable artifice such as clothing and basketry is not found commonly in Archaic age sites.

Following the Archaic or, perhaps more accurately, a late substage of it, is the Neo-American stage or Central Texas Aspect. It is separable from the material Archaic by the presence of the bow and arrow and of pottery, but the subsistence patterns continued unchanged, and there is some evidence that the Central Texas Aspect represents the descendants of the Edwards Plateau Aspect populations (Jelks, 1962).

The Central Texas Aspect is divided into two foci, Austin and Toyah. The Austin focus is characterized by the presence of *Scallorn* and *Granbury* style arrowpoints and dart points of the *Godley, Darl, Ensor, Yarborough,* and *Wells* designs. No pottery has been recovered. Dates for this focus fall between A.D. 500 and A.D. 1000. The following Toyah focus is recognized by the presence of *Perdiz* and *Clifton* arrowpoints and an absence of dart points. An indigenous pottery called *Leon Plain* and some Caddoan pottery which probably was obtained by trade are present also. Dates for this focus fall between A.D. 1000 and A.D. 1500 (Jelks, 1962).

The Toyah focus terminates before the beginning of the Historic period and the arrival of first the Spanish explorers and, later, Anglo settlers. Within this study area, both the Lipan Apache and a group called "Jumano" in Spanish records were encountered during early exploration. The Spanish established two missions, Candeleria and San Lorenzo de la Cruz, near the study area in 1762 to minister to the Lipan Apaches. Each was only occupied for a few years before its missionaries were withdrawn.

To aid in understanding the dating of the sites found during this reconnaissance, a chronology of projectile point design based on the excavations at Canyon Reservoir (Johnston, Suhm, and Tunnell, 1962) and other Central Texas sites is presented below.

CENTRAL TEXAS CHRONOLOGY

Central Texas Aspect	Toyah Focus–*Perdiz, Clifton* Austin Focus–*Scallorn, Granbury*
Transitional Archaic	*Darl*, Provisional Type III
Late Archaic	*Ensor, Montell, Frio, Marcos*
Middle Archaic	Pedernales
Early Archaic	*Travis, Nolan, Bulverde*

PREVIOUS INVESTIGATIONS NEAR THE STUDY AREA

Little archaeological investigation has been conducted in Edwards and Real Counties. Hester (1966) has reported on the excavation of a burned rock midden in Real County by a crew from the Carrizo Springs High School. The sites contained components of both the Edwards Plateau Aspect and the Austin Focus of the Central Texas Aspect.

Central Texas Sites

The types of sites found in Central Texas reflect in some ways the patterns of subsistence practiced by its Edwards Plateau and Central Texas Aspect inhabitants. These sites or either open habitation sites or rockshelters and nearly always located close to a reliable source of water.

> Many of the open campsites (burnt rock middens) are distinguished by sizable accumulations of burned and cracked limestone mixed with charcoal and ash-stained soil, as well as cultural debris. Burnt rock middens are an unusual kind of site, having been reported to date only in the Edwards Plateau and Trans-Pecos regions of Texas. They vary greatly in size, sometimes reaching over an acre in extent and six or more feet in thickness. In cross section the middens appear as low knolls, while in outline they are circular or oval. Since it is uniformly agreed that the burnt rock middens grew by accretions incidental to occupation, they are not usually referred to as mounds, the latter term being reserved for intentional structures such as burial or temple mounds.
>
> The discoloration and angularity of the rock fragments comprizing the midden deposits are a result of contact with fire and thermal fracturing, and indicate that the burnt rock middens are largely accumulations of hearthstones. . . The most complex variety was made by lining a small oval or circular depression with stone slabs. Simpler types of hearths were made by placing stones in a circle or oval on an undisturbed surface, or by scooping out a shallow concavity and placing large stones around it.
>
> The repeated occupation of a site disturbed earlier hearths, creating a more or less homogeneous deposit. . . .
>
> Other open sites in Central Texas consist almost exclusively of refuse buried in alluvial terraces or of thinly scattered refuse deposits found on the surface of uplans (Suhm, 1958).

Burned rock middens obtained the largest part or all of their bulk from Edwards Plateau Aspect occupation, but occasionally Paleo-Indian or Central Texas Aspect indicators are found.

Paleoenvironment

Little environmental or ethnobotanical data exist for Central Texas. Palynological (fossil pollen) analysis has been attempted at several sites in the region but with poor results. Only the Kyle site (Jelks, 1962) has yielded significant amounts of plant remains. These were sunflower, wild onion, acorns, pecans, cocklebur, wild gourd, and maize (one cob).

Faunal remains are somewhat more common and have been analyzed more completely. A good representative list was obtained from the Kyle site and these are, in rank order, deer, snake, pine vole, cotton rat, birds, pocket mouse, cottontail, turtle, frog, fish, gopher, beaver, coyote, pack rat, bison, grasshopper mouse, badger, antelope, and soft-shelled turtle (Jelks, 1962:111-112).

THE SITES

The type designations given in the following sections are based on those defined in *A Handbook of Texas Archeology: Type Descriptions* by Dee Ann Suhm and Edward B. Jelks (1962). These labels should be considered, however, with a sizeable amount of caution; the cultural and temporal implications of projectile points have been determined from large collections obtained from site excavations rather than from single finds. Many types may well be characteristic of a particular time and place, yet transcend, in small numbers, the boundaries assigned to the area or period. Moreover, the distinctions between many types are drawn exceedingly fine in the literature of Texas archaeology, often introducing the personal biases of the investigator into the analysis and making "precision typing" of small collections a dubious occupation at best. Contributing to the problem in this study, the specimens gathered during survey were fragmentary more often than not, and quite difficult to identify with complete assurance. Nevertheless, we believe that the types recognized in the following section do bear some gross relationship to time and cultural affiliation and they will be treated as such. Having issued fair warning, we will not be chastened if further research modifies or alters completely our assignations of date and affinity to particular sites.

SITE DESCRIPTIONS

41 Ed 23

A large, curving open terrace site about 800 x 50 meters in size. Most of the site is currently in a fenced hay field or beneath ranch buildings. Plowing and other disturbances have brought a great deal of lithic debris and burned rock to the surface with the largest concentration appearing closest to Hackberry Creek.

Location: Terrace the Gilmore ranch house is located on.

Materials collected: 4 *Perdiz,* 1 *Scallorn,* 1 *Frio,* 1 *Bulverde,* 1 *Pedernales,* 1 *Ensor,* 1 mano fragment, 3 unifaces, 1 end scraper, 12 biface fragments, 9 untyped point fragments, 1 bottle fragment, 7 pieces bone, 1 piece clamshell.

41 Ed 24

A small rockshelter about 2.5 meters deep, 3.5 meters wide and now 1 meter high. Fill seemed mostly soil and burned rock with some ash. Flake was very sparse.

Location: Due south of 41 Ed 23 and about 40 meters east of Ranch Road 335.

Materials collected: No collection.

41 Ed 25

A ridgelike natural levee or terrace remnant on the west side of Hackberry Creek. A road cut in a portion of the site showed a depth of deposit of 40 cm. Lithic debris were noted in the cut and along the surface. A partially buried circular fire hearth was also noted.

Location: Immediately east of 41 Ed 24 and along the road from the Gilmore ranch house to Hackberry Creek.

Materials collected: Small bone fragments.

41 Ed 26

A burned rock midden remnant on a terrace formed by the intersection of Hackberry Creek and a spring-fed tributary. Only one edge of the midden and a slight scatter of lithic debris remains. Site area is partially under some livestock pens and is about 25 by 25 meters in size.

Location: Opposite tributary from 41 Ed 25 and about 25 meters east of Ranch Road 335.

Materials collected: No collection.

41 Ed 27

A long terrace of Hackberry Creek about 1 kilometer long and several hundred meters in width. Occupation debris extend over entire terrace but are concentrated at the north end, where there is scattered lithics and burned rock and at the south end, where a tributary exposes three small burned rock middens and additional deposits of lithics and burned rock extending about 1 meter in depth. Part of the site has been plowed but not deeply. The middens and surrounding area are untouched.

Location: On east side of Hackberry Creek. Site is cut by road from Gilmore Ranch to the Schoolfield Ranch.

Materials collected: 1 *Ensor,* 1 *Montell,* 1 *Scallorn,* 1 *Marshall,* 1 uniface ovate knife, 1 biface fragment.

41 Ed 28

A large terrace about 250 meters long and of undetermined width on the north side of Hackberry Creek. Two burned rock middens are located on the highest terrace, one with a pothole showing roughly 80 cm. in depth. On the terrace below are several individual fire hearths. Burned rock and lithics are scattered over the entire site.

Location: Opposite site 41 Ed 23 on Hackberry Creek. The site is split by Ranch Road 335.

Materials collected: 3 biface fragments.

41 Ed 29

A terrace of Hackberry Creek showing some lithic debris and occasional burned rock. Size is estimated as 45 x 100 meters. Deposit is probably very shallow.

Location: Upstream from 41 Ed 28, site is divided by a ranch road.

Materials collected: No collection.

41 Ed 30

Small scatter of flake and burned rock on a hill slope next to a tributary of Hackberry Creek. Size could not be estimated and depth is probably very shallow.

Location: On the south side of the tributary and only a few meters due west of Ranch Road 335; 0.9 airline miles south of Gilmore ranch house.

Materials collected: No collection.

41 Ed 31

A small burned rock midden on a low terrace of the tributary of Hackberry Creek. The midden is about 5 meters long and 2 meters wide and parallels the streambed. Very little lithic debris.

Location: Upstream of 41 ED 30 about 0.2 miles on the south side of the tributary.

Materials collected: No collection.

41 Ed 32

Small flake scatter on a terrace on the south side of the tributary and at the point where a side channel enters the streambed. Site size is about 40 x 40 meters.

Location: 0.1 mile upstream of 41 Ed 31.

Materials collected: No collection.

41 Ed 33

Description and location essentially similar to 41 Ed 32 except site is located on the opposite bank of the side channel.

Materials collected: No collection.

41 Ed 34

Scatter of lithic debris and a slight amount of burned rock on a terrace located on the south side of the Hackberry Creek tributary. Two biface fragments were noted but not collected.

Location: 0.15 miles upstream from 41 Ed 32, 33.

Materials collected: No collection.

41 Ed 35

Scattered lithic debris in an area about 10 meters in diameter on a terrace of the tributary of Hackberry Creek. A small side channel enters the streambed just north of the site creating a triangular shaped terrace.

Location: 0.2 miles upstream of 41 Ed 34 on the south side of the tributary.

Materials collected: No collection.

41 Ed 36

A scatter of lithic debris and a slight amount of burned rock on a terrace on the south side of the tributary of Hackberry Creek. Area of site is 35 by 11 meters.

Location: 0.4 miles upstream of 41 Ed 35.

Materials collected: No collection.

41 Ed 37

A scatter of lithic debris and a slight amount of burned rock on a terrace of the tributary. Size is about 30 x 10 meters.

Location: Slightly upstream of 41 Ed 33 but on northern bank.

Materials collected: No collection.

41 Ed 38

A U-shaped terrace at the head of the tributary of Hackberry Creek. Some scattered lithic debris present and one biface fragment noted.

Location: At the head of the tributary.

Materials collected: No collection.

41 Ed 39

Two burned rock middens on a ridge top, one on the highest point of the ridge, the other lower in elevation but on the bluff edge. One is about 5 x 2 meters, the latter 35 x 10 meters.

Location: Next to a windmill and tank just off a dirt road on the Schoolfield Ranch.

Materials collected: 1 *Pedernales*, 12 biface fragments.

41 Ed 40

A scatter of burned rock and flake in a pass that creates a slight divide in a ridge. A dirt road bisects the site and the westernmost edge seems to be a fence line. Size was not determined.

Location: Below 41 Ed 39 and about 150 meters down the road from the windmill.

Materials collected: No collection.

41 Ed 41

A quarry site of brownish flint eroding out of a ridge top in a cobble form. Many large flakes and cores were noted, particularly around some small depressions that may have been holes dug in the thin topsoil to expose the cobbles below. Area of site is roughly 70 meters in diameter.

Location: 70 meters down road from 41 Ed 40.

Materials collected: No collection.

41 Ed 42

A slight flake scatter located in the flat area below 41 Ed 41. No burned rock was noted and area could not be determined.

Location: Fiat below 41 Ed 41.

Materials collected: No collection.

41 Ed 43

A large burned rock midden about 20 meters in diameter and more than a meter thick. Most of the midden has been destroyed for road fill. Surrounding the site is a lithic scatter about 65 meters in diameter.

Location: Just east of the dirt road passing through site 41 Ed 41.

Materials collected: 1 biface fragment.

41 Ed 44

A large burned rock midden about 5 meters in diameter located on a small soil cap on a ridge top. Most of the midden has been destroyed for road fill but portions are still intact.

Location: On same road as 41 Ed 43.

Materials collected: 1 *Darl*, 1 *Marshall*, 2 biface fragments, 1 distal point fragment.

41 Ed 45

Two closely associated, small (100 m^2), .6 m high, middens. Numerous small pits and accompanying disturbed material suggest that pot hunters have been active at the site. Very little artifactual material could be seen.

Location: On a high terrace to the south of Cade Springs on the west side of Hackberry Creek.

Material Collected: No collection.

41 Ed 46

A quarry site on a ridge top where flint is weathering out in a cobble form. In some places cores, flakes, and cobbles almost form a pavement. About 100 meters in diameter and confined to surface.

Location: Site is bisected by same road as 41 Ed 43.

Materials collected: 1 biface, 1 blade, 2 flakes.

41 Ed 47

A small burned rock midden—10 x 3 meters—on a flat ridge that parallels a tributary of Hackberry Creek. Around the midden is a scatter of lithic debris.

Materials collected: No collection.

41 Ed 48

A small burned rock midden about 5 meters in diameter with ashy soil and lithic debris around it.

Location: On the east side of a small creek 400 m east from Hackberry Creek and 200 m north of 41 ED 47.

Materials collected: 20 bifaces and fragments, 6 uniface fragments.

41 Ed 49

Small burned rock midden about three meters in diameter on a small terrace above an old channel of Hackberry Creek. Lithic debris are included in the burned rock of the midden. This site is probably larger than indicated, it appears to be buried by alluvium with only the top of the midden visible.

Location: Near old stream channel of Hackberry Creek east of Ranch Road 335.

Material Collected: No collection.

41 Ed 50

Burned rock midden and lithic scatter near the Devil's Sinkhole. The midden is about six meters in diameter and is undisturbed except for a small portion of one edge that has been cut by a road.

Location: 35 meters northwest of the Devil's Sinkhole.

Materials collected: No collection.

41 Ed 51

A burned rock midden about 30 x 5 meters in size and having a depth of about 1 meter at its thickest. Lithic debris were very sparse. Considerable damage has been done to the site by a road cut.

Location: 350 meters west of the Devil's Sinkhole and in the road.

Materials collected: No collection.

41 Ed 52

A burned rock midden about 25 meters in diameter surrounded by an extensive scatter of lithic debris. The site appears undisturbed. Depth of the deposit is estimated at 1.5 meters.

Location: 0.15 miles west down ranch road from the Devil's Sinkhole and about 75 meters north of the road.

Material Collected: No collection.

41 Ed 53

A complex of 12 and perhaps more burned rock middens located on the plateau's edge. The area encompassed is in the shape of a triangle roughly 150 meters on a side. An extensive lithic scatter covered the entire area. Except for the construction of a road and windmill, the site is undisturbed.

Location: About one mile southeast of the Devil's Sinkhole on a dirt road leading toward the Hackberry Creek. A windmill marks the northern extension of the site and the road cuts the eastern edge.

Materials collected: 2 *Darl,* 1 *Ensor,* 1 *Bulverde,* 1 *Pandale,* 1 *Nolan,* 3 *Castroville,* 2 *Langry,* 1 *Pedernales,* 1 *Kinney*-like, 7 untyped point fragments, 19 biface fragments, 1 pierce worked quartz.

41 Ed 54

A flake scatter that evidently indicates a quarry site on a ridge top. The flint is brownish in color and coarse grained. Fragments of bifaces were noted but not collected.

Location: On ridge top about 0.6 miles southeast of 41 Ed 53.

Materials collected: No collection.

41 Ed 55

Three closely associated burned rock middens on an upland ridge. A lithic debris scatter encompasses all the middens. Area is 100 x 20 meters.

Location: Ridge running southeast from the Devil's Sinkhole.

Materials collected: No collection.

41 Ed 58

A slight scatter of lithic debris and perhaps a small quarry site located on the slope of a minor drainage of Hackberry Creek. No burned rock observed and depth is minimal. Area of the site is probably no more than 40 x 15 meters.

Location: At the head of a minor drainage of Hackberry Creek approximately 0.5 miles southeast of the Devil's Sinkhole.

41 Ed 59

Small scatter of burned rock and lithic debris in a flat area near the bottom of a minor tributary of Hackberry Creek. No depth to the deposit, size is about 30 meters in diameter.

Location: Slightly downslope from 41 Ed 58.

Materials collected: No collection.

41 Ed 60

Small burned rock midden located at the confluence of a tributary with Hackberry Creek. Area is 25 square meters and depth 75 cm. The adjacent area is surrounded with unworked flint raw material.

Location: Approximately 10 meters downstream from 41 Ed 59.

Materials collected: No collection.

41 Ed 61

A burned rock midden about 3.5 meters long and 2 meters wide on the edge of a tributary of Hackberry Creek. Very little lithic debris were noted.

Location: North side of tributary containing 41 Ed 59 and about 50 meters upstream from the Whitworth property line.

Materials collected: No collection.

41 Ed 62

A small burned rock midden about 5 meters in diameter on a terrace at the juncture of two minor drainages of Hackberry Creek. One edge is eroding into the streambed. A scatter of lithic debris surrounds the midden.

Location: Opposite the tributary from 41 Ed 61 and slightly downstream.

Materials collected: No collection.

41 Ed 63

A small burned rock midden disturbed by tree growth in a tributary of Hackberry Creek. Area is 200 square meters and depth about 85 cm.

Location: On the west side of the channel, 280 meters downstream from 41 Ed 62.

Materials collected: No collection.

41 Ed 64

A small, shallow burned rock midden located at the juncture of two minor drainages of Hackberry Creek. Area of the midden is 7 x 2 meters and it is surrounded by a lithic scatter.

Location: About 2.5 miles downstream of 41 Ed 62 and opposite site 41 Ed 63.

Materials collected: No collection.

41 Ed 65

A small burned rock midden and associated scatter of lithic debris and burned rock on the west side of a small hill. A bluff edge is about 35 meters from the site. Area is unknown.

Location: Southwest of the crest of hill 2314 on the quadrangle map.

Materials collected: No collection.

41 Ed 66

Three burned rock middens located just below the highest point of a hilltop. A scatter of lithic debris and burned rock encompasses all three middens. Total area is 50 x 70 meters and each midden is about 60 cm thick.

Location: Hill 2314.

Materials collected: No collection.

41 Ed 67

A large burned rock midden on a ridge. Area is about 20 x 15 meters and depth about 75 cm. Midden has been disturbed by tree growth.

Location: Ridge running south of 41 Ed 53.

Materials collected: No collection.

41 Ed 68

A small burned rock midden with lithic debris and burned rock scattered around it. Area of the site is about 75 x 40 meters. It is situated on a terrace of Hackberry Creek at the juncture of it and a tributary. A corral is located on part of the site.

Location: On south side of Hackberry Creek where a dirt road running west from Ranch Road 335 crosses the creek bed.

Materials collected: No collection.

41 Ed 69

A scatter of lithic and debris and burned rock on a terrace of Hackberry Creek. Due to undergrowth area of the site could not be estimated. More than likely it does have some depth to the deposit.

Location: Opposite the tributary from 41 Ed 68.

Materials collected: No collection.

41 Ed 70

A six meter in diameter burned rock midden located on a slope above a tributary of Hackberry Creek. It is divided by a fence line that places half of the site on the Gilmore Ranch and half on the highway right-of-way. Except for the fence the site is not disturbed.

Location: On west side of Ranch Road 335 roughly 0.5 miles from the Gilmore Ranch entrance.

Materials collected: 1 *Frio*, 1 ovate biface.

41 Ed 71

Two burned rock middens side by side on the edge of a small bluff. Each midden is undisturbed and about 9 meters in diameter. The middens actually seem to spill off the bluff to the flat below. Interestingly, only the lower flat seemed to be occupied, the upper being devoid of lithic debris.

Location: On the north side of the road leading from the Devil's Sinkhole to the Whitworth Ranch house.

Materials collected: 2 *Montell*, 2 *Pedernales*, 2 biface fragments, 1 stemmed biface fragment, 1 piece red ochre.

41 Ed 72

A burned rock midden roughly 6.5 meters long and 3.5 meters wide on the edge of a small bluff and spilling over it. Lithic debris were scarce. Site has been cut in two by a road.

Location: In the road from the Devil's Sinkhole to the Whitworth Ranch house.

Material Collected: No collection.

41 Ed 73

A large area of burned rock, probably disturbed, that does not show the mounding characteristic of middens. Artifacts are few.

Location: On a low terrace of a tributary to Hackberry Creek; directly opposite the corral complex at the Whitworth Ranch headquarters and a small, slow spring in the vertically cut bank.

Materials collected: None.

41 Ed 74

A moderate sized, well-mounded midden of burned rock and humic soil. Nearly circular, it is approximately .7 meters high and covers 400 m^2 of area. There has been some disturbance by the numerous sheep which pasture in the area.

Location: Approximately 75 meters north-northeast of 41 Ed 52.

Materials collected: Base of a probable *Marshall* projectile point.

41 Ed 75

A burned rock midden some 10 meters in diameter with a surrounding lithic debris scatter. A small rock fence was built across the site but has fallen, leaving only a line. Otherwise the site is undisturbed.

Location: West of the dirt road leading to the Whitworth ranch house and near the Whitworth property line.

Materials collected: 1 *Frio*, 1 untyped point fragment.

41 Ed 76

A burned rock midden about 25 x 13 meters in size near the plateau edge. Very little lithic debris observed.

Location: About 100 meters southwest of site 41 Ed 74.

Materials collected: 1 *Frio*.

41 Ed 77

Apparently a quarry, this site contains a great deal of naturally fractured flint with some man made debris. Site is on the crest of a hill and no burned rock was observed.

Location: 1.4 airline miles southwest of the Gilmore ranch house.

Materials collected: No collection.

41 Ed 78

A small midden and scatter of lithic debris on a terrace of Hackberry Creek where a tributary enters. Area is about 50 x 30 meters.

Location: On the south bank of Hackberry Creek, 2.2 airline miles due south of the Devil's Sinkhole.

Materials collected: 1 *Castroville*, 3 biface fragments.

41 Ed 79

Burned rock midden on the south side of Hackberry Creek. Area of the site is 250 square meters and depth approximately 35 cm. Lithic debris were relatively scarce.

Location: On the west side of a small north flowing tributary to Hackberry Creek, and on the south side of Hackberry itself.

Materials collected: No collection.

41 Ed 80

Two burned rock middens on a high flat above Hackberry Creek and near its juncture with a tributary. Each midden is about 7 meters in diameter and disturbed by clearing. Lithics are scattered around the middens but rarely on them.

Location: On a dirt road leading from the flat to site 41 Ed 79, a historic ranch house.

Materials collected: No collection.

41 Ed 81

Burned rock midden about 20 meters in diameter and 1 meter thick on the high flat area above Hackberry Creek and situated near a tributary of the creek. Site has been disturbed a little by clearing.

Location: Down dirt road from site 41 Ed 80.

Materials collected: 1 *Bulverde*, 3 biface fragments.

41 Ed 82

A small scatter of burned rock and lithic debris on a ridge top near Hackberry Creek. In a flat area near the ridge is a flint exposure that appears to have been utilized.

Location: Just off road from Kalentine Hole to gas well 1952.

Materials collected: No collection.

41 Ed 83

A large midden of burned rock and ash standing nearly a meter high. The area is used today as a salt station for cattle and the site is badly disturbed. Artifacts are moderately abundant.

Location: On a low terrace on the east side of Hackberry Creek opposite Kalentine Hole, and north of a small east flowing tributary.

Materials collected: *Montell* projectile point, 1 untyped point fragment.

41 Ed 84

A moderate (400 m^2), .4 meter high, burned rock midden with little visible cultural material.

Location: 30 m up the small tributary from 41 Ed 83 and on the same side.

Materials collected: None

41 Ed 85

A small rockshelter about 4 meters long, 1 meter deep and 1 meter high, deposit is about 1 meter thick and composed of burned rock and soil. A small talus of burned rock is in front of the shelter.

Location: Opposite streambed from 41 Ed 84.

Materials collected: No collection.

41 Ed 86

Individual fire hearth eroding from a dark humic soil nearly 2 meters deep. Most hearths are 20 to 40 cm below the surface, but one was observed at an 80 cm level. The surface itself was heavily vegetated, obscuring any artifactual material which may have been present.

Location: On the high, triangular piece of land between Hackberry Creek and the Nueces River at their confluence.

Material collected: No collection.

41 Ed 87

A small midden approximately .6 meters deep and 400 square meters in area. The surrounding area is littered with the fractured flint of an outcrop. Worked stone is fairly abundant, but whole tools are scarce.

Location: On the flat top of a low ridge 300 meters east of Hackberry Creek and 40 meters south of a deep, dry tributary streambed.

Materials collected: No collection.

41 Ed 88

An old farmstead; the fireplace chimney, and foundations of an old house are intact, and to their south is a well preserved stone-and-wood storage crib. Stonework is composed of locally occurring natural materials.

Location: On the east side of Hackberry Creek and the north side of Thurman Hollow where the two meet.

Materials collected: No collection.

41 Ed 89

A surface scatter of lithic debris on a headwater ridge of a tributary of Hackberry Creek. Area of the site is 150 square meters.

Location: Tributary of Hackberry Creek south of

Gilmore ranch house.
Materials collected: No collection.

41 Ed 90
Burned rock eroding from the side of the second terrace above Hackberry Creek. Area was impossible to estimate due to vegetation. A depth of at least 35 cm was observed in a road cut.
Location: 0.5 miles upstream of the Hackberry Creek and Nueces River confluence.
Materials collected: No collection.

41 Ed 91
A large burned rock midden about 40 meters long and 25 meters wide. Site is situated on a terrace above a small drainage containing a spring.
Location: Opposite drainage from the Whitworth ranch corrals.
Materials collected: No collection.

41 Ed 92
A small, low midden of approximately 110 m^2 area, composed of burned rock and dark, humic soil. The deposit mound about a .3 m above the natural ground surface. Very little lithic debris was observed.
Location: On a triangular piece of terrace between joining members of a south flowing tributary to Hackberry Creek approximately 1 km above their meeting.
Materials collected: No collection.

41 Ed 93
A small, scattered burned-rock midden with little lithic debris. The site appears to be basically surficial.
Location: On a wedge of flat land between two joining tributaries in the valley of a south flowing tributary to Hackberry Creek, almost a mile above its juncture with Hackberry Creek.
Materials collected: No collection.

41 Ed 94
A scatter of lithic debris on a terrace of a tributary of Hackberry Creek. Area is estimated at 400 square meters. Materials limited to surface only.
Location: Tributary of Hackberry Creek south of Gilmore ranch house.
Materials collected: No collection.

41 Ed 95
A small, low burned rock midden without much accompanying artifactual material.
Location: Atop the headwater highland of a small tributary west of Hackberry Creek.
Materials collected: None

41 Ed 96
A small, low burned rock midden; little other cultural material associated.
Location: 75 meters south of 41 Ed 95.
Materials collected: No collection.

41 Re 12
A small terrace of Hackberry Creek with burned rock eroding out of the edges and present on the surface. Lithic debris were present. Area of the site is about 10 x 40 meters. Slightly disturbed by road cut in one section.
Location: Southeast corner of the Frost Ranch road and Ranch Road 335 intersection.
Materials collected: No collection.

41 Re 13
Scattered burned rock and fire hearths appearing in a road cut terrace on Hackberry Creek. Maximum depth is about 50 cm but area could not be estimated.
Location: On county road immediately after crossing Hackberry Creek.
Materials collected: No collection.

41 Re 18
A burned rock midden of about 5 meters in diameter on a terrace of Hackberry Creek. Lithic debris were noted on and around the midden.
Location: Just south of the county road immediately beyond 41 Re 13.

41 Re 19
A burned rock midden once about 8 x 6 meters in surface area but reduced to a smaller size by a road cut. Depth was estimated at 70 cm. The site appears to be very disturbed.
Location: On county road beyond Hackberry Creek, the road cuts the north side of the midden.
Materials collected: No collection.

41 Re 20
The bare remnant of a burned rock midden that has been destroyed by a caliche pit. The surviving portion is about 6 x 1 meters and achieves a thickness of 40 cm.
Location: South of the county road in an old caliche pit in the road cut.
Materials collected: No collection.

41 Re 21
A large flat terrace of Hackberry Creek with burned rock and what is possibly a buried midden visible on the surface. Surface area is about 100 x 75 meters, depth could not be estimated.

Location: Terrace is cut by county road immediately beyond 41 Re 20.
Materials collected: No collection.

41 Re 22
Burned rock scattered over a terrace of Hackberry Creek and exposed in a road cut to a depth of 45 cm. The site is about 40 meters long while width could not be estimated. Site has been disturbed by road cut and erosion.
Location: At second crossing of Hackberry Creek by country road. A red bump gate is located on the terrace.
Materials collected: No collection.

41 Re 23
Two burned rock middens separated by a road on a terrace of Hackberry Creek. The terrace has been plowed, disturbing the middens which are about 14 meters in diameter. Total site area is estimated at 75 x 45 meters.
Location: County road at Hackberry Creek crossing.
Materials collected: 1 *Frio.*

41 Re 24
A slight scatter of burned rock and lithic debris on the first terrace above Little Blue Hole. Area of the site is about 40 x 20 meters and is probably of little depth.
Location: Immediately southwest of Little Blue Hole.
Materials collected: No collection.

41 Re 25
A large burned rock midden once about 45 x 35 meters in surface area at the meeting of Hackberry and Little Blue Hole Creeks. Lithics were abundant and depth was estimated at 1.5 meters. Site is almost wholly destroyed by road building.
Location: At the intersection of the Eagle Ranch road and Garner Ranch road.
Materials collected: Several unidentifiable bone fragments.

41 Re 26
Two burned rock middens about 20 meters long and 6 meters wide located above the Blue Hole. One midden edge is eroding into the creek, the other into the road cut. Underlying these middens and separated by a layer of soil 40 cm in thickness seems to be a separate cultural level indicated by lithic debris eroding out. The one diagnostic artifact found seemed to be associated with the middens.
Location: Above the Blue Hole and next to the road cut.
Materials collected: 1 *Bulverde.*

41 Re 27
Either one large burned rock midden that has been split by a stream or two middens located on either bank of the stream and eroding into it. Each is over a meter thick and about 5 meters wide. Little lithic debris.
Location: At the intersection of a side channel with Joy Hollow.
Material collected: No collection.

41 Re 28
A 5 meters in diameter burned rock midden on a terrace of East Rose Draw. A dirt road cuts the lithic scatter associated with the midden in two.
Location: South side of East Rose Draw on the Eagle Ranch.
Materials collected: No collection.

41 Re 29
Two burned rock middens within 25 yards of each other on a terrace of the Nueces River. One is fairly well destroyed by road construction, the other intact. Area estimated at 35 x 35 meters.
Location: Eagle Ranch road at the Nueces River.
Materials collected: No collection.

41 Re 30
A complex of three burned rock middens on a terrace of the Nueces River. The largest is about 30 x 37 meters in size, the two others about 15 meters in diameter. Underlying the middens in the terrace soil is a layer of scattered burned rock and individual fire hearths that can be seen eroding out of the bank. Much of the complex has been disturbed by construction but a large portion, more than half, is still intact.
Location: On Eagle Ranch road, below the road is a dam across the Nueces River.
Materials collected: 1 *Clifton.*

41 Re 31
Two burned rock middens on a terrace of the Nueces River, each about 15 meters in diameter. One has been damaged by a driveway, the other is intact.
Location: Directly in front of the Damon Stott home.
Material Collected: No collection.

41 Re 32
A scatter of lithic debris and burned rock on a terrace of the Nueces River. Area is about 30 x 75 meters and has little depth. Site has probably been extensively surface collected.

Location: Between the Eagle Ranch building complex and the skeet range.
Materials collected: No collection.

41 Re 33
A heavily disturbed burned rock midden on a terrace of the Nueces River. Depth appears to be about 1 meter, area 30 x 60 meters. Part of the site lies under the Eagle Ranch road.
Location: Between the Nueces River and the Eagle Ranch rifle range.
Materials collected: No collection.

41 Re 34
Two burned rock middens located on the edge of a side drainage of the Nueces River. Both have been all but totally destroyed for road fill. Total area is 75 x 75 meters and a depth of over 1 meter.
Location: Just south of the intersection of the Red Arrow Cave road and the Eagle Ranch road.
Materials collected: No collection.

41 RE 35
Two burned rock middens located on a flat terrace above a tributary drainage of the Nueces River. Both have been superficially disturbed by burning. Each midden is about 15 meters in diameter with the associated flake scatter covering an area of 60 meters in diameter.
Location: Next to the first hunting blind on the road to Red Arrow Cave.
Materials collected: No collection.

41 Re 36
Two burned rock middens that have mostly eroded into a tributary of the Nueces River. In the tributary below is a spring. Area is about 45 x 20 meters and depth probably does not exceed 40 cm.
Location: On the road to Red Arrow Cave just east of a red bump gate.
Materials collected: No collection.

41 Re 37
Two burned rock middens of small size on a high flat hilltop above the Nueces drainage. Construction of a windmill and tank has disturbed the deposits. Size could not be estimated but is confined to the hilltop.
Location: At windmill on Red Arrow Cave road.
Materials collected: No collection.

41 Re 38
A lithic debris scatter on a hilltop above the Neuces River drainage. Area is about 45 meters in diameter and consists of surface scatter only.
Location: Hilltop directly above Red Arrow Cave.
Materials collected: No collection.

41 Re 39
A sparce scatter of lithic debris on a hilltop south of Red Arrow Cave. A windmill and tank have disturbed the deposits.
Location: Hilltop south of Red Arrow Cave with a windmill and tank on it.
Materials collected: No collection.

41 Re 40
Identical in description of 41 Re 39 except located on the hilltop directly south of that site.
Materials collected: No collection.

41 Re 41
A probable quarry site about 75 meters in diameter located on a hilltop. The flint material is in large cobble form and is of a brownish color. Only a slight amount of worked material was observed.
Materials collected: No collection.

41 Re 42
A burned rock midden on a terrace of the Nueces River. Area is 11 meters in diameter, depth estimated at 60 cm. Lithic debris were abundant. Site is undisturbed.
Location: Across a side drainage from the Stott Ranch house.
Materials collected: No collection.

41 Re 44
A burned rock midden on a terrace of the West Rose Draw. Site is 27 meters in diameter and about 80 cm thick. A small amount of lithics was observed on the midden itself.
Location: A terrace of West Rose Draw.
Materials collected: No collection.

41 Re 45
A burned rock midden on a terrace of West Rose Draw. The midden is 12 meters in diameter but almost wholly destroyed by bulldozing.
Location: On the westernmost part of the same terrace 41 Re 44 is located on.
Materials collected: No collection.

41 Re 46
A possible burned rock midden that appears to have been almost completely buried. A compact cluster of burned rock and a slight lithic scatter is all that is visible.
Location: A terrace of West Rose Draw.
Materials collected: No collection.

41 Re 47

Description substantially the same as that for 41 Re 46 except no cultural material other than burned rock was observed.

Materials collected: No collection.

SUMMARY AND CONCLUSIONS

A total of 102 sites were visited and recorded in the course of this reconnaissance. In temporal measure, they ranged from early Archaic to historic times; nothing attributable to a Late Pleistocene occupation was found, although several high terrace remnants clinging to the walls of the Hackberry Creek valley were examined for possible Pleistocene remains. The cultural affinities of the material both observed and collected from prehistoric sites seem to fall within the established sequences and designs characterizing broadly the Edwards Plateau and Central Texas Aspects. Additionally, the morphology and locations of sites conform to patterns considered typical in the Central Texas archaeological province.

Only three artifacts, all projectile points, from two sites could indicate influence from an outside region, in this case the southeastern Trans-Pecos. Two of these are *Langtry* points, a type best known from the Amistad Reservoir excavations but also found through much of Central Texas and in sections of Oklahoma. Curiously, the *Langtry* projectile points from Oklahoma and Amistad are quite similar in design, although not in size, while those reported in Central Texas (Johnston, Suhm, and Tunnell, 1962) appear to be commensurate in size with the Amistad recoveries but are much cruder in execution. Attempting to divine the meaning of this broad distribution and perplexing regional variation would be a protean exercise. For our purposes it is sufficient to say that the *Langtry* design appears to be part of an early contracting stem tradition in both southwest Texas and Oklahoma. At Amistad Reservoir the contracting stem design gave way in the Middle Archaic to designs with complexly constructed stems, while the Oklahoma sequence shows an easy graduation into the *Gary* paradigm which broadly characterized the later Archaic of the southwest Eastern Woodlands. The Central Texas Early Archaic does not seem to have experienced such an early pronounced period of contracting stem popularity, and sandwiched as it is between Trans-Pecos and Oklahoma this situation is problematic. The *Langtry* projectile points recovered in the Hackberry Creek vicinity tend toward the size and quality of the Trans-Pecos varieties rather than the Central Texas examples, and for this reason it is felt they represent cultural interaction on an undefined level with the Trans-Pecos Archaic people.

A more unusual occurrence is that of a *Pandale* point, a design that seems to be fairly restricted to the Trans-Pecos region. From the investigations at Amistad Reservoir this point is known to be an Early Archaic form often found in conjunction with *Nolan* points. Due to its more restricted distribution, this point also would seem to indicate some relationship with the southeastern Trans-Pecos. Since this is only a single indicator, however, this statement can only be considered conjecture and is in need of excavation to provide verification.

Presented below is a chart of the projectile point paradigms found during this reconnaissance arranged in temporal and regional sequence. There are dangers in using only surface collections to discuss temporal situations, since the bulk of earlier occupations may be buried beneath those of later peoples. Still, a tentative appraisal of the temporal aspect of the archaeological resources in the area can be made if it is recognized that drastic revisions are likely to occur should many of the sites be excavated.

TEMPORAL INDICATORS AND SITES

Time	Point Type	No. of Sites	No. of Specimens
Toyah	Perdiz	1	4
	Clifton	1	1
Austin	Scallorn	2	2
Transitional Archaic	Darl	2	3
Late Archaic	Ensor	3	3
	Montell	4	5
	Frio	4	4
	Castroville	2	2
	Marshall	2	2
Middle Archaic	Pedernales	5	6
Early Archaic	Bulverde	3	3
	Nolan	1	1
Trans-Pecos Forms	Langtry	1	2
	Pandale	1	1

The chart shows only sporadic occurrences of Early Archaic forms except for the *Bulverde* style which is thought to be transitional between the Early and Middle Archaic periods. Occupation seems to increase toward the end of the Early Archaic and continues on strongly throughout the Archaic and Neo-American periods. Missing from this sequence are historic aboriginal sites, which are comparatively rare and often difficult to separate from European occupations on the basis of surface collections and Paleo-Indian sites.

Site distribution and the problems presented by it comprise one of the more interesting facets of this reconnaissance. By far the most common type of site is the burned rock midden, most often located along either the Hackberry Creek or Nueces River drainages. When found away from these systems, they are often near upland springs or in minor drainages that may have been flowing at some point in prehistory. This pattern is a common one elsewhere in Central Texas (Suhm, 1958).

An excellent example of the influence of aquatic resources can be found in the Hackberry Creek drainage where Ranch Road 335 crosses the streambed. Immediately downstream from the road are several large springs that supply all of the perennial water in this sector of the drainage. Upstream from the road there are only a few small springs creating occasional pools of water and lacking the discharge necessary to keep the creek itself flowing. Below the road virtually every high terrace on flat area near the creek bed is occupied, while upstream sites were found to be few and small. Downstream from the springs area, however, the density of sites is also small, but for a different reason. The valley is broad yet entrenched in the limestone bedrock, and the frequent flash flooding which occurs in the area created complex and confusing sedimentological units, with heavily eroded areas neighboring thickly alluviated ridges and mounds. The one site located in the valley floor beyond the vicinity of the springs appears to be a burned midden with the top barely exposed.

In contrast to this pattern of dependency upon water and its attendant plant and animal life are a series of sites located along the edge of the plateau and a ridge extending into the Hackberry Creek drainage. One of these sites, 41 Ed 53, was the largest found during this reconnaissance, consisting of twelve, possibly more, burned rock middens of varying sizes in a small area. Most of the middens were located on the edge of the plateau, while the most distant was roughly 150 meters from the edge. While no other sites were found on the plateau surfaces that could rival this one for size, midden groups were not unusual, occasionally occurring in clusters of twos or threes. Midden groups did not occur as a rule, in the drainage valleys. Projectile points collected from these multistructured sites usually indicated Middle or Late Archaic occupations, although site 41 Ed 53 produced material from the Early through Transitional Archaic periods.

Apart from its size, 41 Ed 53 is unusual in that it and the other plateau sites are located more than one kilometer from the nearest source of water known to the authors. Included in this distance is an elevation difference of 300 feet, and although this is not extreme, it can be quite demanding physically on a daily basis.

Why, then, were these and other large sites located well away from water when the pattern in other areas seems very closely related to the water supply? The most probable answer is that resources not found in the drainages existed on the plateau that were considered essential to the Archaic economy; the need for water itself in these sites may have been satisfied with less daily strain than would be involved in climbing out of the stream valley every day to exploit the resources of the plateau surface.

Defining these resources is difficult. Aside from faunal remains, little is known about the wild foods exploited by prehistoric man in Central Texas. Some broad suggestions can be made, however.

The flat plateau surface today is an open savannah with significant growths of Oak near its erosional edges. The abundant fall mast produced by the Oak stands and the expanses of grass would have been attractive to Deer, Bison, and perhaps Antelope. Acorns and grass seeds would have been profitable also as a food source for man. An additional upland resource may have been the scattered stands of Mexican Pinyon Pine (*Pinus cembroides*) which produce edible nuts, although smaller in size and quantity than those of its southwestern cousin (*Pinus edulis*).

There was undoubtedly some seasonality involved in the dicotomy of plateau and drainage sites, just as there is likely some overlap of function in the minor drainage sites which combine some of the vegetal resource characteristics of each area. What the patterns may have been, however, cannot be seen from surface data alone, and deductive models based on biotic distributions in the area cannot be constructed from the statically oriented floral and faunal studies now extant. In our opinion, this question of economy is the more important goal of excavation in Central Texas at this time. Chronology, which is so imperfectly preserved in burned rock middens, is not likely to gain much sophistication from the Hackberry Creek sites; most often, temporality is extended from sequences obtained in caves and stratified terraces (none of which are prominent site types in the area) rather than developed out of middens. Similarly, studies focusing on cultural patterns have not synthesized adequately all of the data available to them into an acceptable problem formulation that would justify excavations to that end. Thus we must recommend strongly that further archaeological work be oriented toward obtaining data useful to a reconstruction of the ecosystems which have operated in the past. The resources of the Hackberry Creek drainage, which appear to be disrupted little by amateur archaeologists or agricultural activities would be, in our opinion, an excellent place to start.

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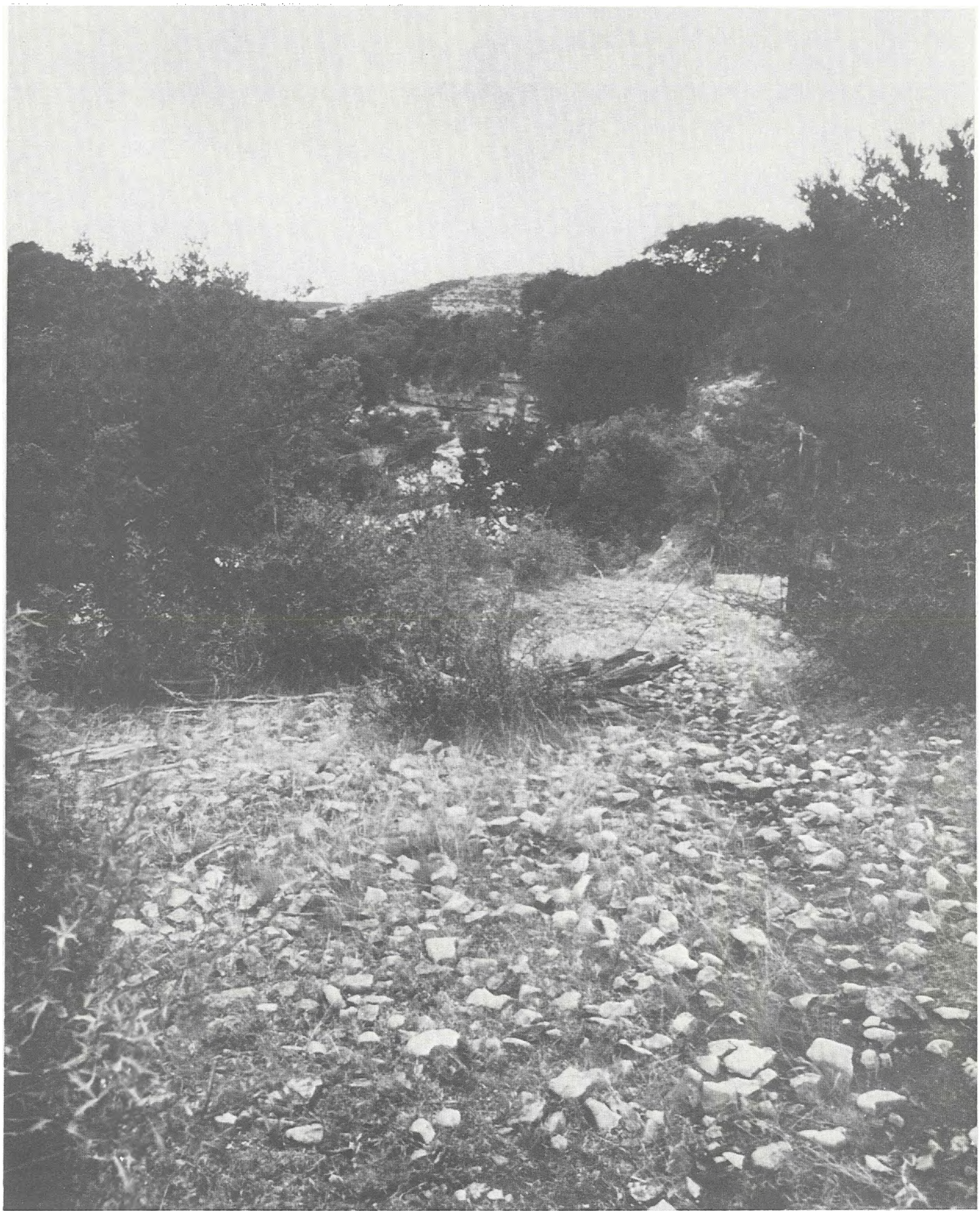


FIGURE 1
41 RE 26: The top of the two middens overlooking the blue hole spring.

FIGURE 2

41 ED 83: Central area in the foreground has been disturbed and compacted by cattle crowding to the salt blocks visible in the center right foreground and center left background.

FIGURE 3
41 ED 70: Burned rock midden portion of site is at the right; cultural material extended away from the site to the vicinity of the photographer. Hackberry Creek bottoms are in the background.

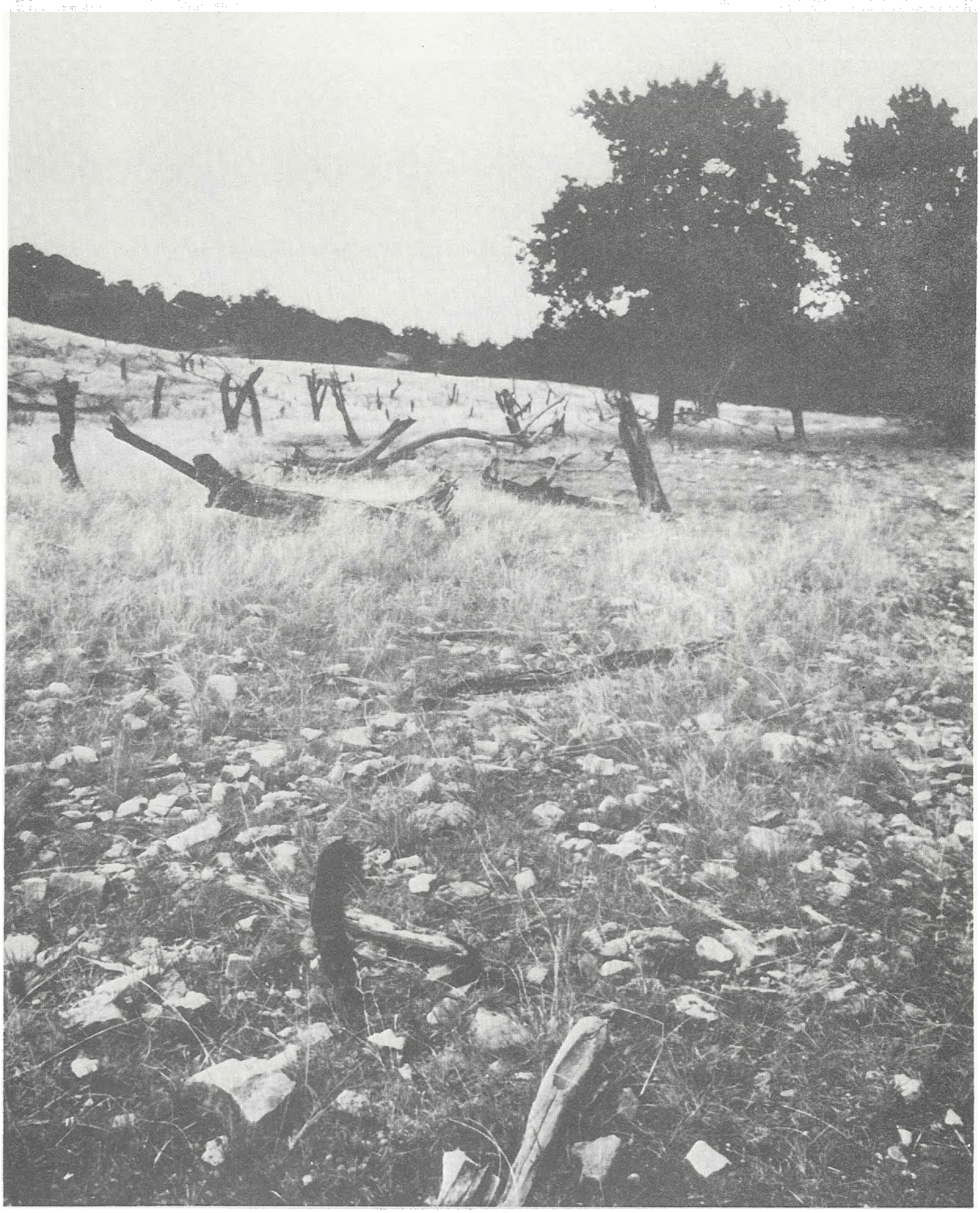


FIGURE 4
41 RE 28: Grass covered midden is in immediate foreground.

FIGURE 5
41 ED 28: View east along the terrace top towards ranch road 335.

FIGURE 6
41 ED 36: View west towards side canyon headwaters highlands; figure is standing on 41 ED 36. Over the rim of the highlands are 41 ED 95 and 96.

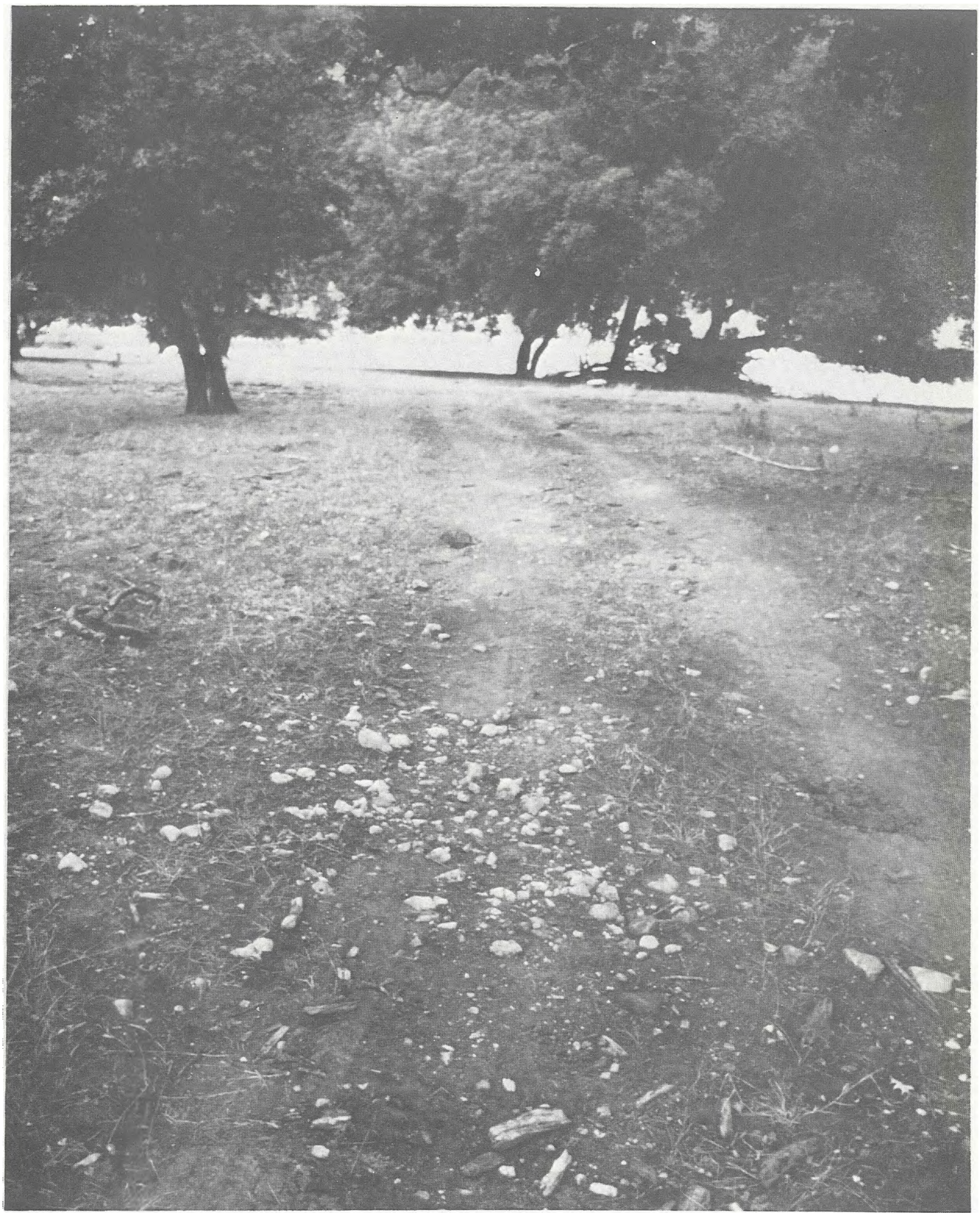


FIGURE 7
41 RE 22: A small hearth is eroding in the roadbed in the foreground; Nueces River channel in the background.

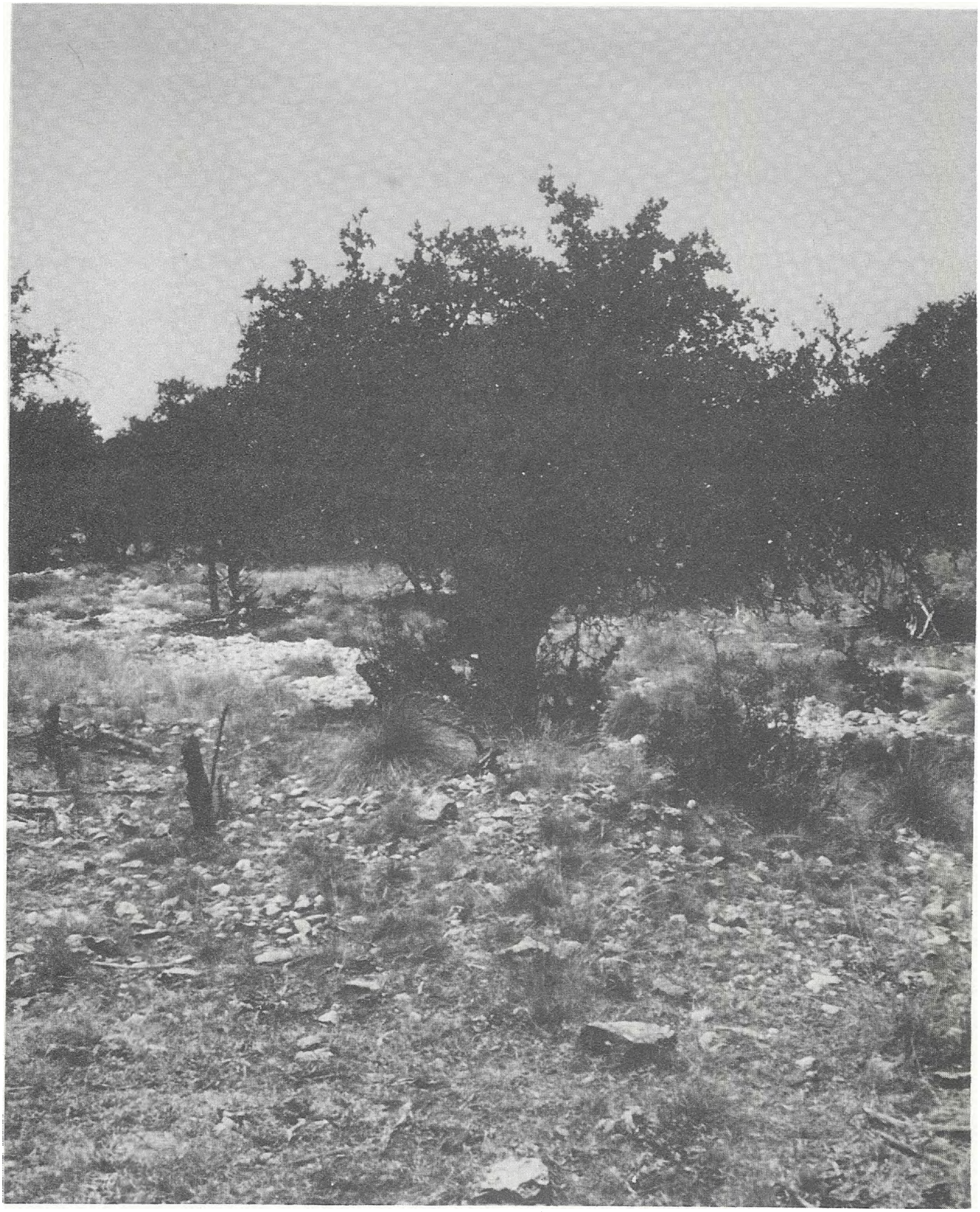


FIGURE 8

41 ED 60: Rocky hillock directly in front of the tree is a very small burned rock midden sitting on a flint outcrop.

FIGURE 9

41 ED 88: House foundations and chimney, "crib" behind.

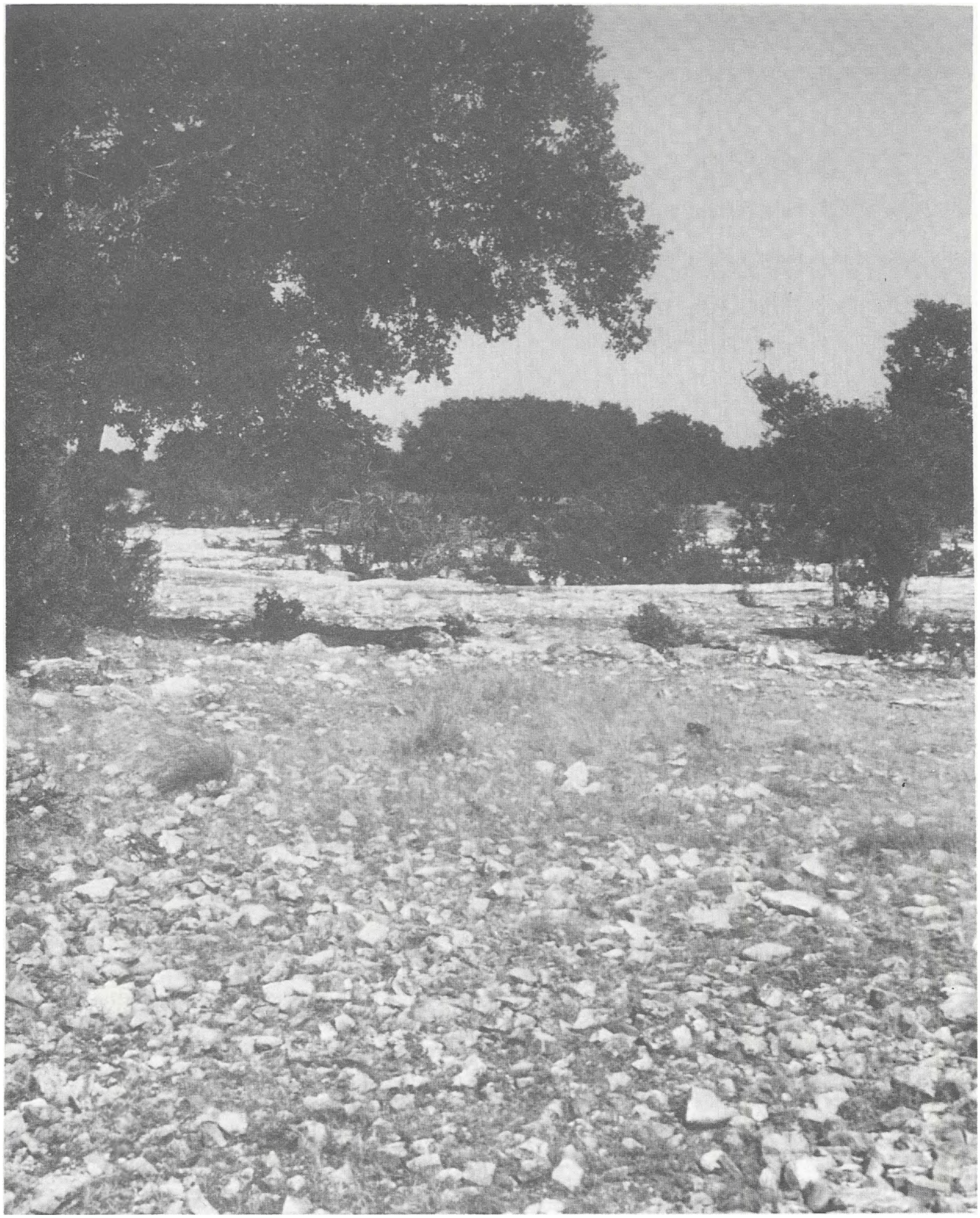


FIGURE 10
41 ED 50: In the foreground is a small burned rock midden; Devil's Sinkhole is behind.

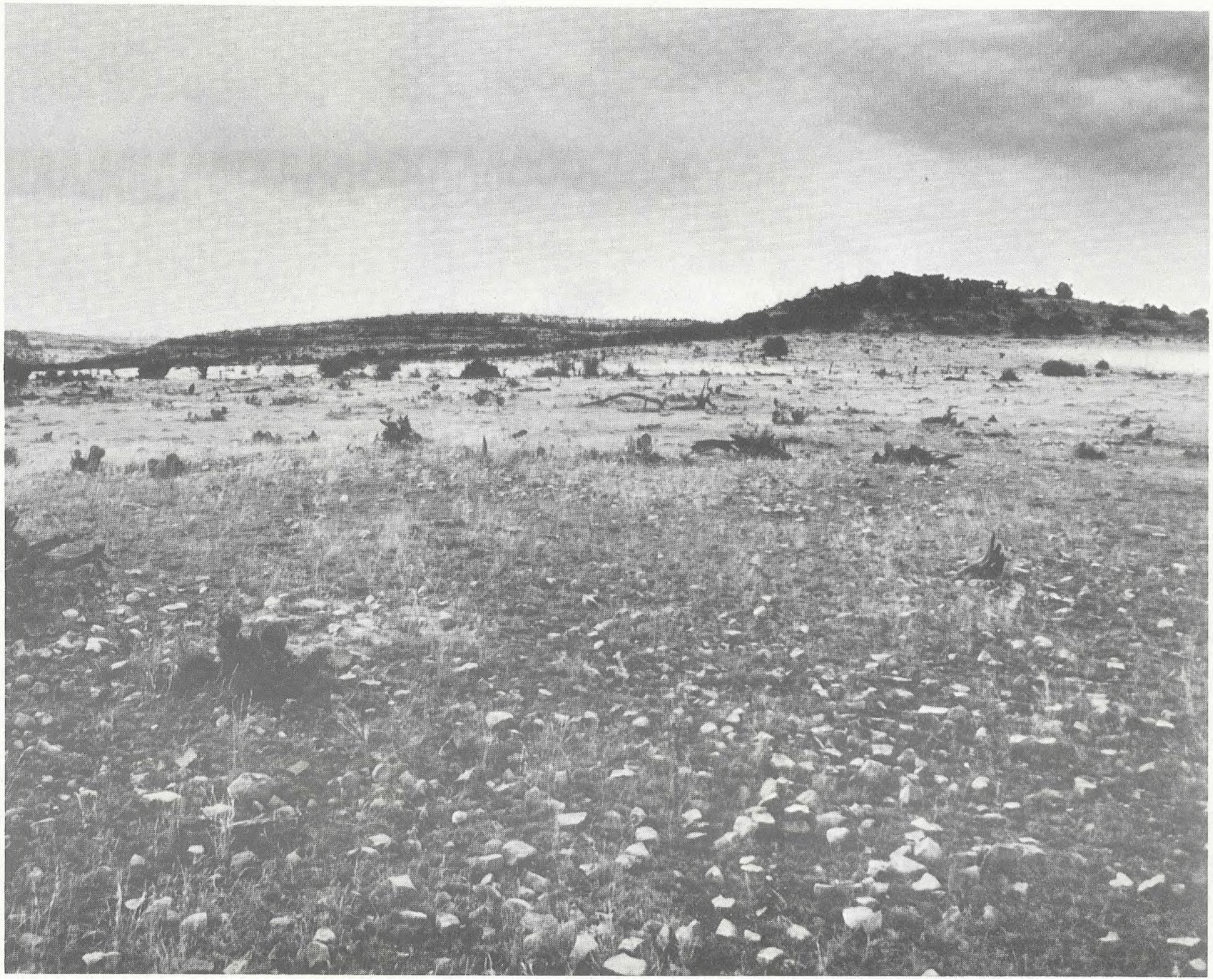


FIGURE 11
41 ED 80: Burned rock concentrations are in the foreground; this area had been cleared of brush recently.

FIGURE 12
Projectile Points: Top row–Langtry; middle–Nolan left, untyped right; bottom row–Bulverde.

FIGURE 13
Projectile Points: Top row, L to R–Ensor (3), Pandale, untyped; second row, L to R–Castroville (2), Marshall (2); third row–Frio; bottom row L to R–Pedernales (3), Montell.

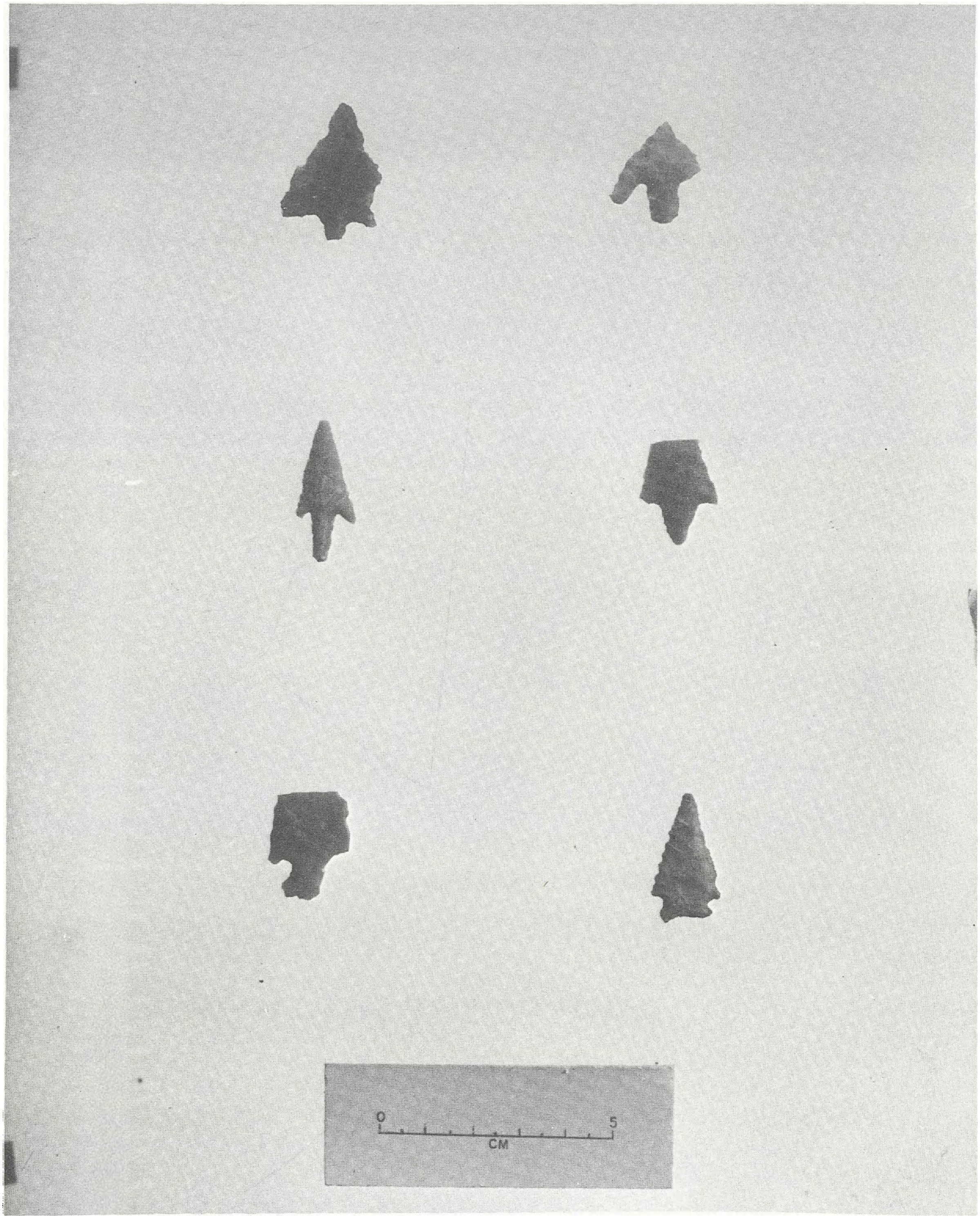


FIGURE 14
Projectile Points: Top–Cliffton left, Perdiz right; middle–Perdiz; bottom–Scallorn.

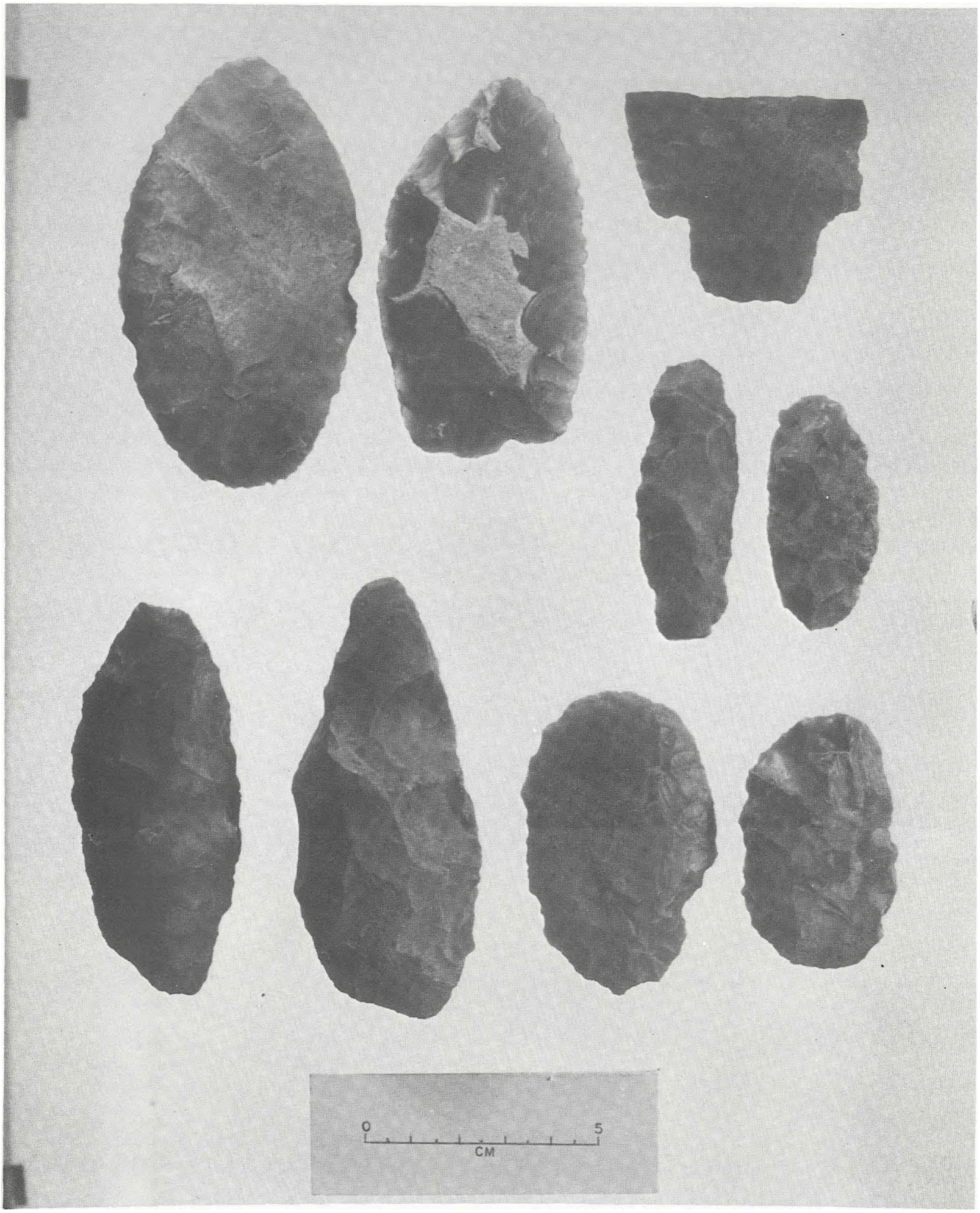


FIGURE 15
Thin Bifaces

NOV

MAPS TO ACCOMPANY

DEVIL'S SINKHOLE AREA–HEADWATERS OF THE NUECES RIVER

A Natural Area Survey

Part VIII of VIII

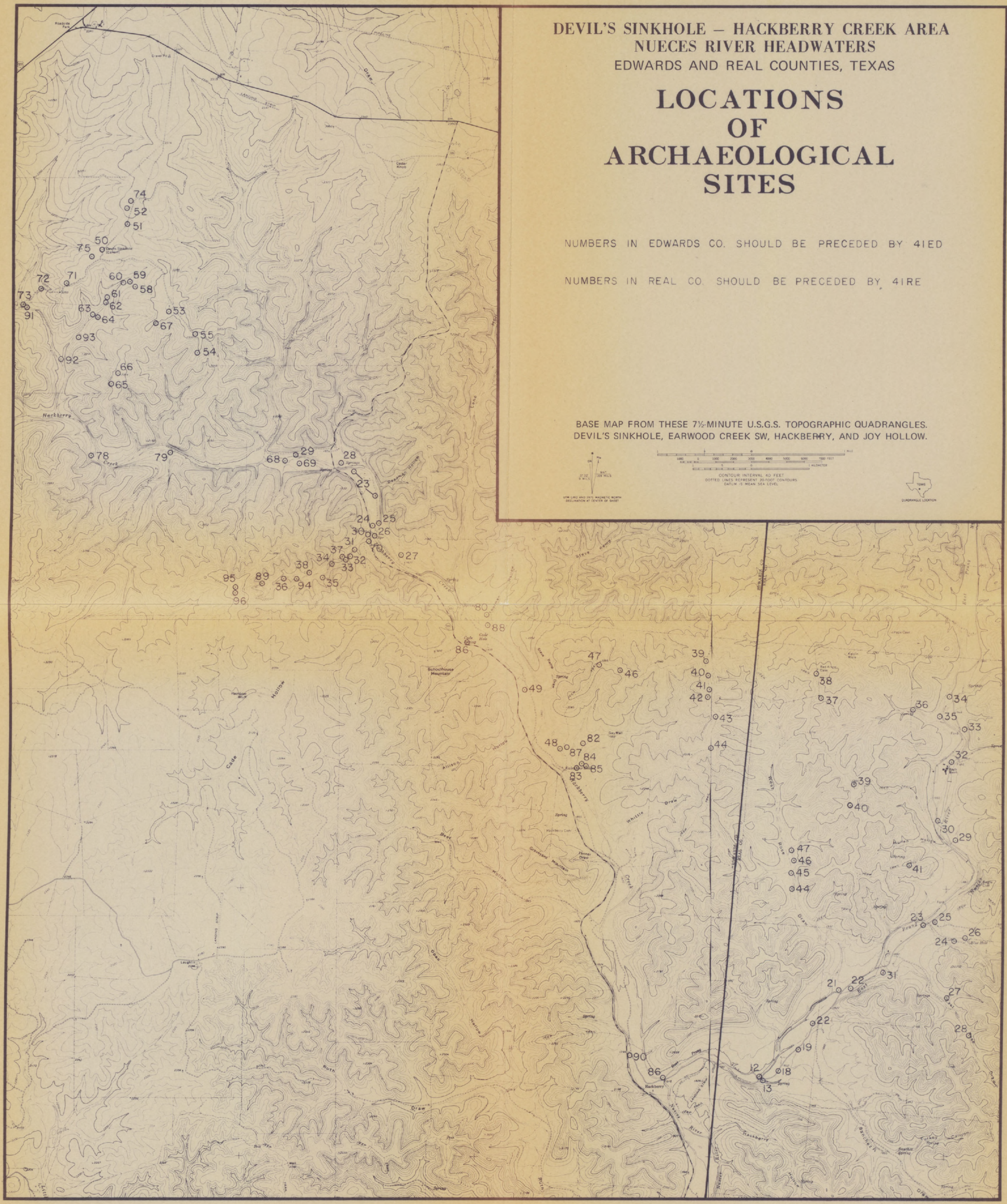
1. Locations of Archaeological Sites
2. Major Plant Associations (3 sheets)

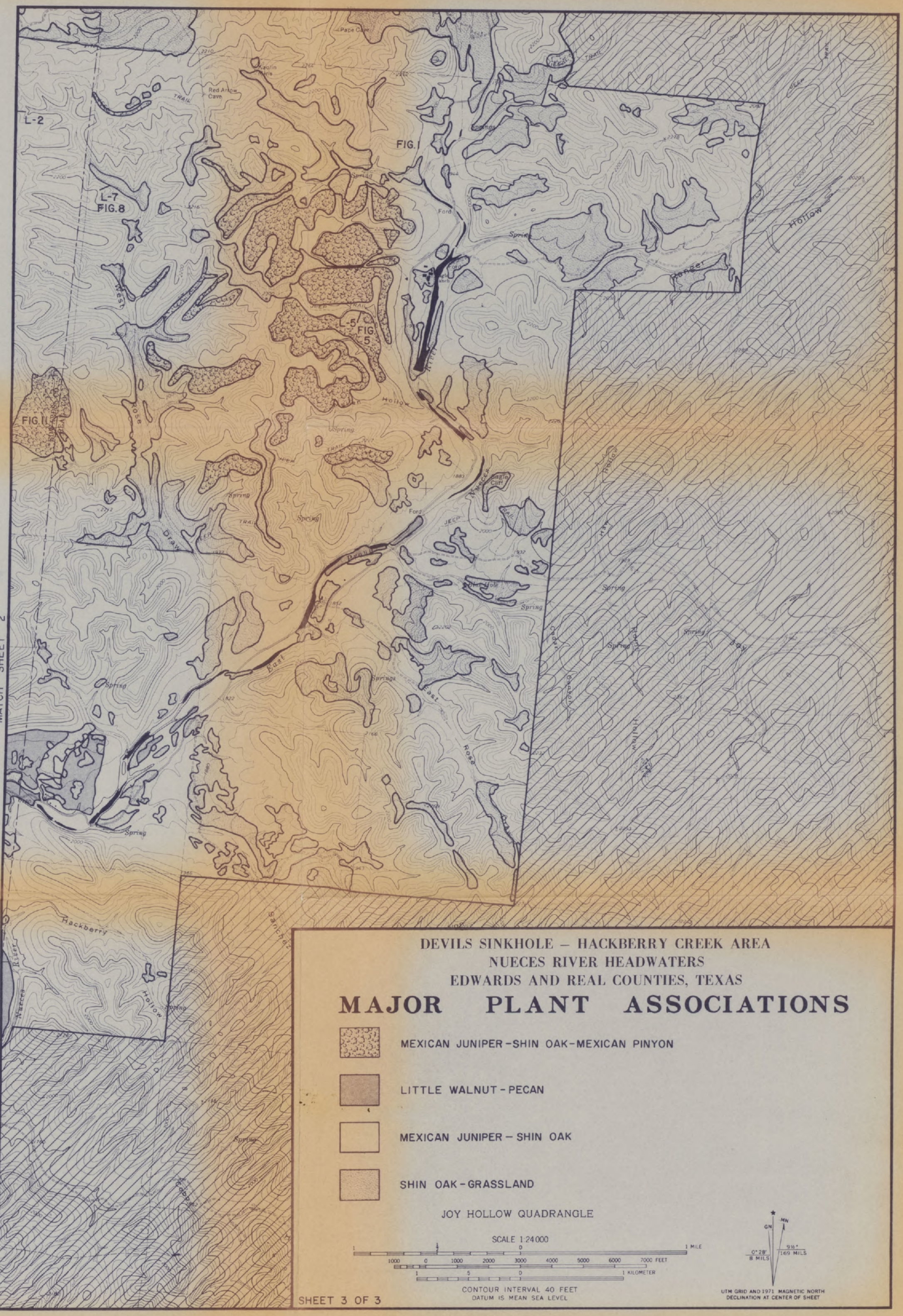
[redacted]

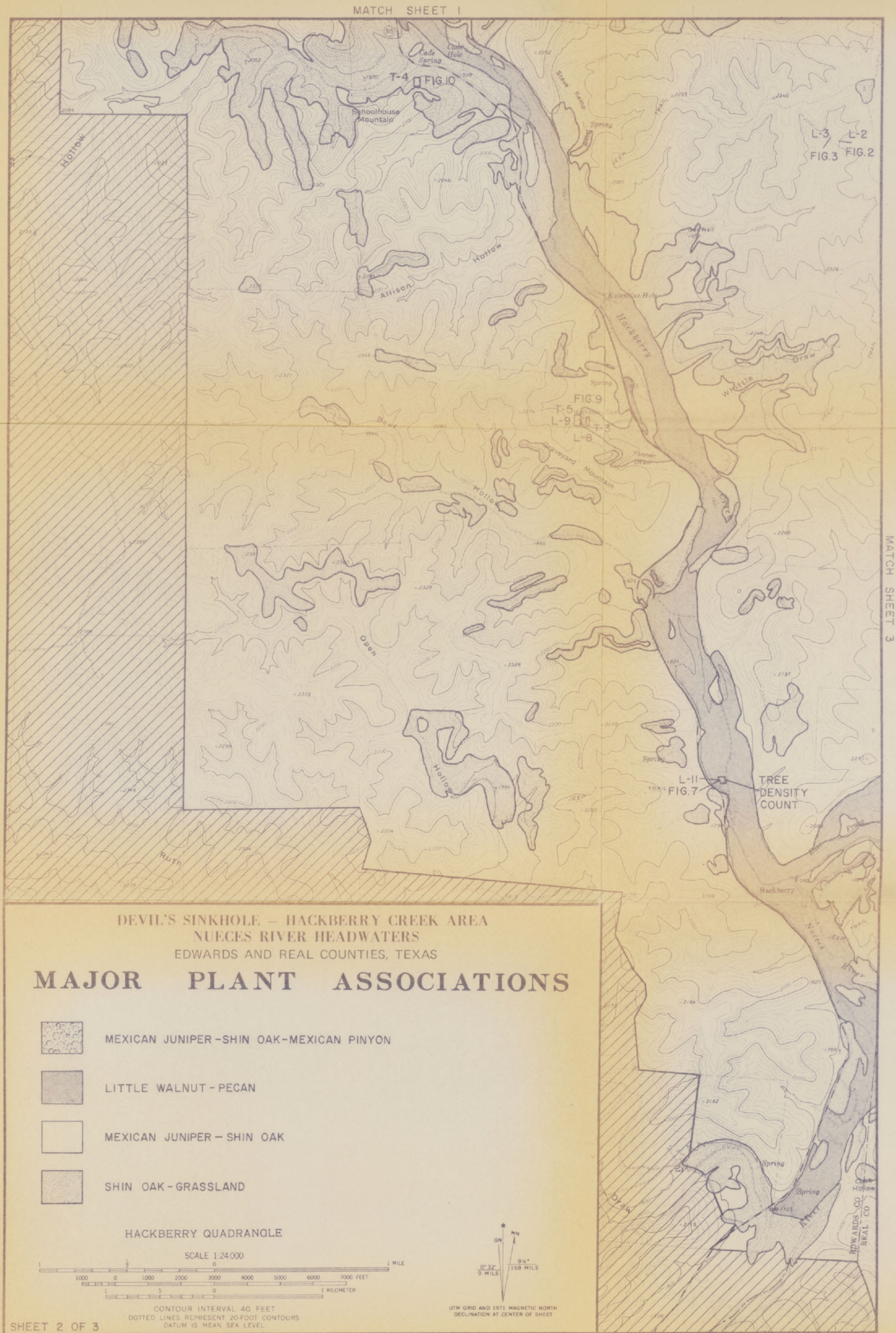
DIVISION OF NATURAL RESOURCES AND ENVIRONMENT

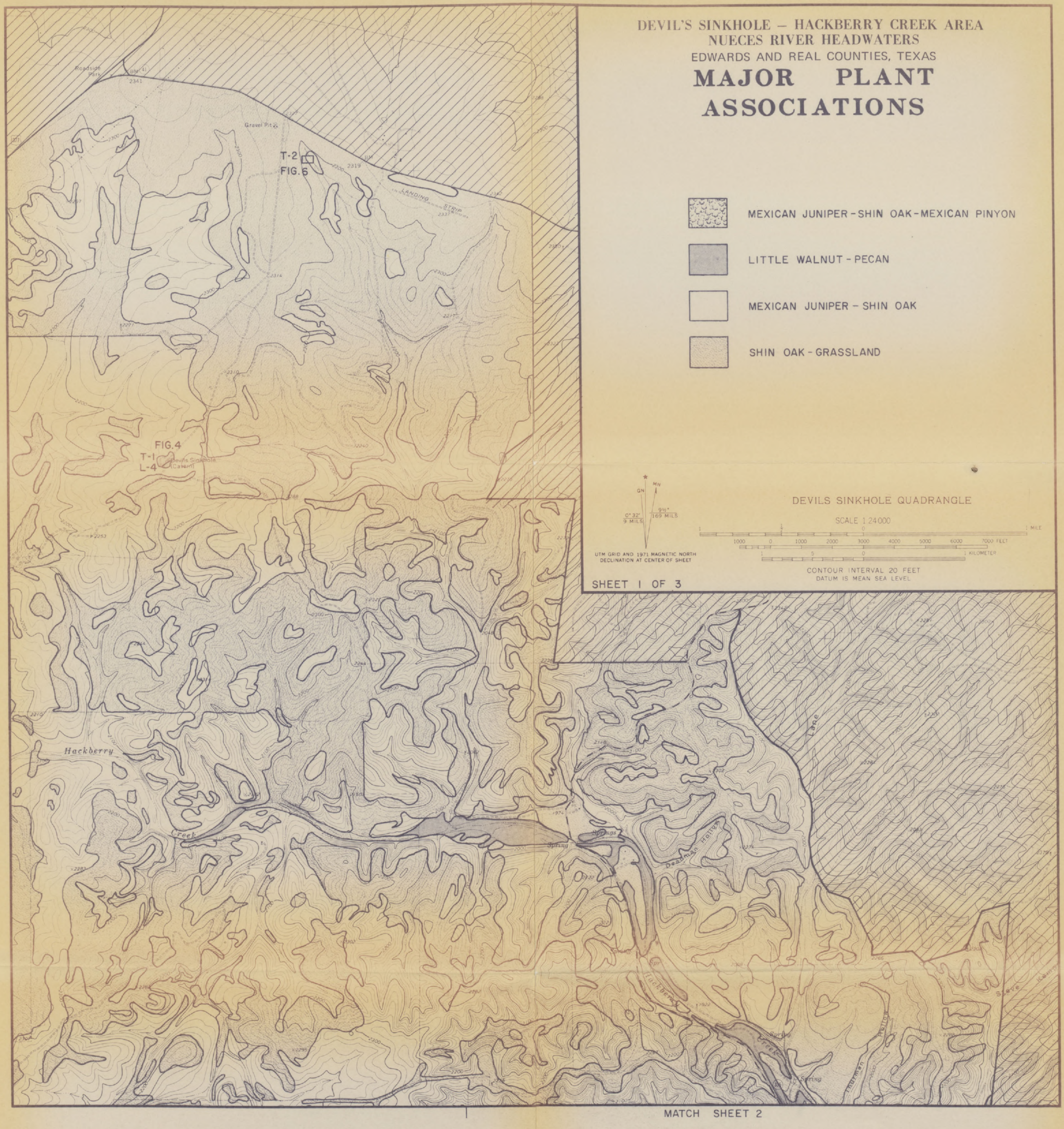
The University of Texas at Austin

1975


DEVIL'S SINKHOLE – HACKBERRY CREEK AREA
NUECES RIVER HEADWATERS
EDWARDS AND REAL COUNTIES, TEXAS
LOCATIONS OF ARCHAEOLOGICAL SITES
NUMBERS IN EDWARDS CO. SHOULD BE PRECEDED BY 41ED
NUMBERS IN REAL CO. SHOULD BE PRECEDED BY 41RE
BASE MAP FROM THESE 7½-MINUTE U.S.G.S. TOPOGRAPHIC QUADRANGLES.
DEVIL'S SINKHOLE, EARWOOD CREEK SW, HACKBERRY, AND JOY HOLLOW.
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL


DEVILS SINKHOLE – HACKBERRY CREEK AREA
NUECES RIVER HEADWATERS
EDWARDS AND REAL COUNTIES, TEXAS
MAJOR PLANT ASSOCIATIONS
MEXICAN JUNIPER-SHIN OAK-MEXICAN PINYON
LITTLE WALNUT-PECAN
MEXICAN JUNIPER – SHIN OAK
SHIN OAK-GRASSLAND
JOY HOLLOW QUADRANGLE
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SHEET 3 OF 3
MATCH SHEET 2
FIG. I
FIG. II
L-2
L-7
FIG. 8
L-5
FIG 5
Hackberry
Hollow
Spring
TRAIL
East
Rose
Ford
Red Arrow Cave
Nueces
River


MATCH SHEET 1
MATCH SHEET 3
DEVIL'S SINKHOLE – HACKBERRY CREEK AREA
NUECES RIVER HEADWATERS
EDWARDS AND REAL COUNTIES, TEXAS
MAJOR PLANT ASSOCIATIONS
MEXICAN JUNIPER-SHIN OAK-MEXICAN PINYON
LITTLE WALNUT-PECAN
MEXICAN JUNIPER – SHIN OAK
SHIN OAK-GRASSLAND
HACKBERRY QUADRANGLE
SCALE 1:24 000
1 MILE
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET
SHEET 2 OF 3
T-4
FIG.10
Schoolhouse Mountain
Cade Spring
Cade Hole
Steve Kemp
Spring
L-3
L-2
FIG.3
FIG.2
Hollow
Allison
Kalentine Hole
Hackberry
Whittle
Draw
FIG.9
T-5
L-9
T-3
L-8
Bear
Well
Graveyard
Mountain
Tanner
Draw
Hollow
Open
Hollow
Spring
L-11
FIG.7
TREE
DENSITY
COUNT
Ruth
Hackberry
Nueces
River
Spring
Spring
Draw
EDWARDS CO
REAL CO
TRAIL
JEEP



MATCH SHEET 2