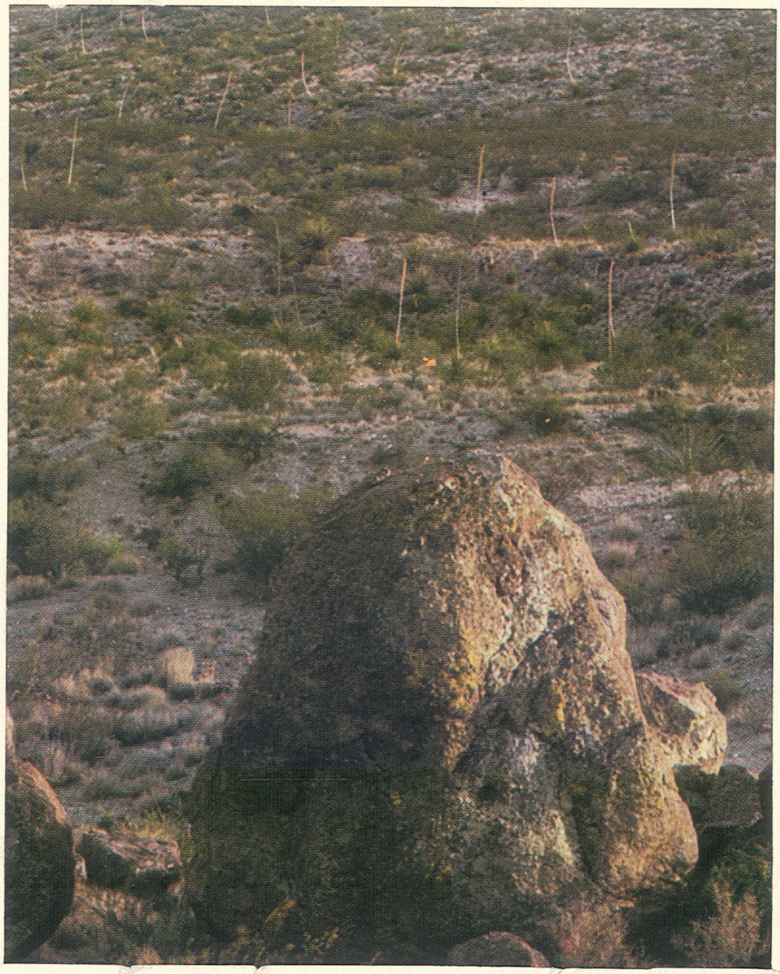
THE SOLITARIO

A NATURAL AREA SURVEY
NO. 9



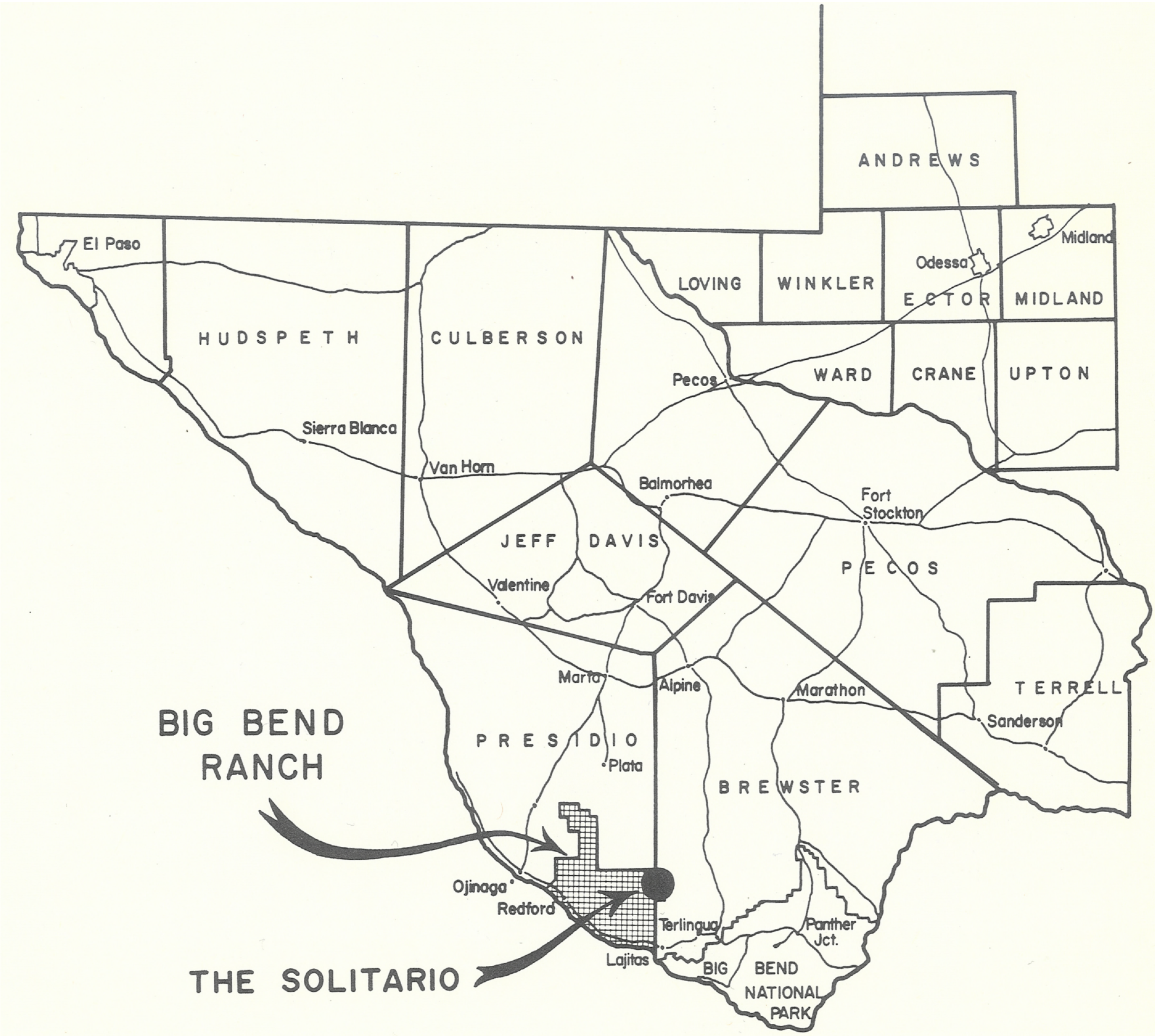
Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976

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 Solitario area survey. Transparencies of his photos of this and other survey areas have been filed with the Natural Areas Survey project, Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin. Mr. Bradshaw is one of the finest nature photographers of the Southwest. His work on these natural areas is sure to increase public awareness of the need to save and protect.

THE SOLITARIO

A NATURAL AREA SURVEY
NO. 9

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976



ANDREWS
El Paso
Midland
Odessa
LOVING
WINKLER
ECTOR
MIDLAND
HUDSPETH
CULBERSON
Pecos
WARD
CRANE
UPTON
Sierra Blanca
Van Horn
Balmorhea
Fort Stockton
JEFF DAVIS
Valentine
Fort Davis
PECOS
Marfa
Alpine
Marathon
TERRELL
Sanderson
BIG BEND RANCH
PRESIDIO
Plata
BREWSTER
Ojinaga
Redford
Terlingua
Panther Jct.
Lajitas
BIG BEND NATIONAL PARK
THE SOLITARIO

THE UNIVERSITY OF TEXAS AT AUSTIN
LYNDON B. JOHNSON SCHOOL OF PUBLIC AFFAIRS
AUSTIN, TEXAS 78712

Texas Parks and Wildlife Commission
Pearce Johnson, Chairman
4200 Smith School Road
Austin, Texas 78744

Dear Mr. Chairman:

The Lyndon B. Johnson School of Public Affairs of The University of Texas at Austin respectfully submits herewith its report, The Solitario: A Natural Area Survey, pursuant to the joint request of the Texas Historical Commission, the General Land Office, and the Texas Parks and Wildlife Department, and in fulfillment of Inter-agency Contract (74-75) 1168.

The Solitario, like each of the other areas undertaken at your request, was scientifically and historically surveyed, mapped, and photographed, which involved the recruitment and direction of a field team of geologists, archeologists, botanists, zoologists, paleoentomologists, ornithologists, cartographers, photographers, landmen, and historians.

Texas is a diverse and beautiful land with a rich heritage and abundant natural and scientific wonders that should be preserved for the wise use and enjoyment of ourselves and of generations 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
Director
Natural Areas Survey

FOREWORD

The Natural Areas Survey project of the Lyndon B. Johnson School of Public Affairs at The University of Texas at Austin presents this study of The Solitario, a unique Texas natural feature. This report is respectfully submitted to the Governor, the Texas Legislature, and the Texas Parks and Wildlife Commission in order that they be more fully informed about the resources of the state.

All studies in this series were prepared by multidisciplinary teams representing the natural and social sciences. Each study presents a comprehensive survey of the plants, animals, and geology of the area, as well as a review of its importance to man, both ancient and modern. The sites were chosen to fall within the definition of natural areas used in the Texas Outdoor Recreation Plan (Texas Parks and Wildlife Department 1975), "natural areas are areas or sites, which, because of their scenic beauty, rarity, recreation value, uniqueness, ecological importance, or cultural value should be protected for posterity."

There are perhaps a few hundred natural areas remaining in Texas, ranging from sections of mountainous land to half-acre sloughs. They can be found among our mountains, plains, shores, and woodlands. Together they could form a network of wildlife sanctuaries and study areas. It is our hope that citizens and state officials will commit themselves to the cause that these areas be preserved as remnants of the natural world and as sanctuaries for the rare and fragile living things which are succumbing to man's increase on this globe. If these areas are overtaken by development, these studies will provide a bare record of the beauty and scientific wonder which was lost.

With the release of this and the companion reports of this year, the list of project areas now stands at thirteen. Other reports in the series are:

Capote Falls
Matagorda Island
Mount Livermore and Sawtooth Mountain
(and supplement)
Victorio Canyon
Blue Elbow Swamp
Devils River
Canadian Breaks
Devil's Sinkhole Area—
Headwaters of the Nueces River
Fresno Canyon
Bofecillos Mountains
Colorado Canyon
Falcon Dam-Thorn Woodland

ACKNOWLEDGEMENTS

Material for this and the four other reports in this series was assembled and edited by Don Kennard. Editorial contributions to the final manuscripts were made by Griffin Smith, Jr., Senior Editor of *Texas Monthly* magazine, Truett Latimer, Executive Director, Texas Historical Commission, Dr. Marshall Johnston, Professor of Botany, The University of Texas at Austin, Curtis Tunnell, State Archeologist, and Edgar B. Kincaid, Jr.

Color frontispiece was by Reagan Bradshaw. Erlene and Linda Hill were responsible for typography and prepared the layout with the help of B. J. Hill. We are indebted to Dr. Keith Arnold, Dr. Stephen Spurr and Ross Shipman of the Division of Natural Resources and Environment, to the Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, and to Ronnie Fiesler, Barbara Walker, and John McCully of our staff for their assistance in handling the multitude of details and arrangements necessary to produce these reports.

We are especially indebted to Exxon Co. USA whose interest, encouragement, and generous grant of funds made possible the publication of these reports and significantly enhanced the field research effort of this and other projects undertaken by the Survey.

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

Robert O. Anderson, Robert B. Anderson, Joe Mims, and Ralph Hager of the Diamond A Cattle Company and the Big Bend Ranch

Bob Armstrong, Commissioner of the General Land Office

Jack Burns, Alpine, Texas

Ned Fritz and the Texas Natural Area Survey

Clayton Garrison, Paul Schlimper, Mark Gosdin and numerous employees of the Texas Parks and Wildlife Department

Texas Historical Commission and its staff

Chairman Pearce Johnson and the members of the Texas Parks and Wildlife Commission

Raul and Enrique Madrid of Redford, Texas

Dr. Hugh Meredith, President, and Dr. Mike Powell, Sul Ross State University

Pioneer Nuclear, of Amarillo, Texas

Red Oliver, Steve Kennedy and Mike McKann, General Land Office

George Pool, U.S. Public Health Service, El Paso, Texas

Linda Roark, Terlingua, Texas

Anders Saustrup and the staff of the University of Texas Rare Plant Study Center

CONTRIBUTORS

BARBARA J. BASKIN – B.A. Anthropology, The University of Texas at Austin. Former Survey Archeologist with the General Land Office and Texas Archeological Survey, and the Texas Historical Commission. Author of archeological section of the Colorado Canyon and Bofecillos Mountains reports.

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.

MARY BUTTERWICK – B.A., M.A. Botany, The University of Texas at Austin. Botanical Team Leader, director of the botanical fieldwork, and principal author of the botany sections of all reports.

DWIGHT E. DEAL – B.S. Rennselaer Polytechnic Institute; M.S. 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, 1972-1973; Director, National Speleological Society; Geologist and Director, Chihuahuan Desert Research Institute, Alpine, Texas. Coordinator of the Scientific Team and author of geological section of each report.

CHRISTOPHER J. DURDEN – B.Sc., McGill University; M.S., Ph.D. Geology and Biology, Yale University. Curator of Geology and Entomology at the Texas Memorial Museum, The University of Texas at Austin. Author of butterflies section in Solitario, Fresno Creek, and Bofecillos Mountains reports.

C. WAYNE HANSELKA – A.A. Victoria College; N.S., M.S., Ph.D. Range Management, Texas A&M University. Fields: Wildlife Management and Range Management. Former Associate Professor of Range Animal Science, Department of Range Animal Science, Sul Ross State University; Area Range Specialist, Texas A&M University Research and Extension Center, Corpus Christi, Texas. Author of Range Management section in Solitario and Fresno Canyon reports.

WILLIAM R. HUDSON, JR. – B.A. Anthropology, Wake Forest University; Candidate for M.A. Anthropology, The University of Texas at Austin. Former Survey Archeologist with the General Land Office, Texas Archeological Survey, and Texas Historical Commission. Author of archeological section of the Solitario and Fresno Canyon reports.

ANTHONY JOERN – B.S. Zoology, University of Wisconsin; Ph.D. Ecology, The University of Texas at Austin. Studied grasshoppers in the Sonoran Desert during summers of 1972 and 1973 in connection with a National Science Foundation Grant to Dr. Daniel Otte; dissertation research on arid grasslands in the Chihuahuan Desert; now a research fellow at the University of Nebraska School of Life Sciences. Author of section on grasshoppers in the Solitario report.

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

JIM LAMB – B.A. Biology, The University of Texas at Austin. Botanical Assistant in fieldwork, in preparation of collections, and in writing the botany section of the Bofecillos Mountains report, and the botany appendums for Solitario, Fresno Canyon, and Colorado Canyon reports.

RICK L. LoBELLO – B.A., William Jewel College, M.S. Biology, Sul Ross State University. Former Assistant Instructor of Zoology at Sul Ross State University and former Zoological Curator at the Kansas City Museum of History and Science; Ranger Naturalist at the Big Bend National Park and Yellowstone National Park. Author of avifauna section of the Solitario report and vertebrate fauna section of Bofecillos Mountains report.

BRUCE SAUNDERS – B.A. Government, Denison University; M.A. History, Southwest Texas State University; Ph.D. History, The University of Texas at Austin. Former history instructor at Austin Community College, Southwest Texas State University, and The University of Texas at Austin. Author of history sections of all reports.

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 Solitario, Fresno Fanyon, Colorado Canyon, and Rio Grande-Falcon Thorn Woodland reports.

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. Former Committee Counsel to the Texas Senate Interim Drug Committee; Senior Editor, *Texas Monthly* magazine; Texas Institute of Letters Stanley Walker award winner. Project Editor and author of the "Impressions" section of each report.

STUART STRONG – B.A. Political Science, University of Alabama; M.A. Botany, The University of Texas at Austin. Former co-director of the Rare Plant Study Center, The University of Texas at Austin. Botanical Assistant in fieldwork, in preparation of collections, and in writing the botany section of the Solitario, Fresno Canyon, Colorado Canyon, and Rio Grande-Falcon Thorn Woodland reports.

TABLE OF CONTENTS

IMPRESSIONS OF THE SOLITARIO

Griffin Smith, jr.

Austere, aloof, the vast circular geologic uplift called the Solitario lies in splendid isolation 12 miles due north of Lajitas. From the air a casual observer might mistake it for the crater of a meteorite or the collapsed cone of an ancient volcano, so startling is its symmetry. From the ground its jagged limestone rim roils up like a wave of stony whitecaps above the turbulent surface of the Big Bend country.

There is—has always been, since the days of the Spaniards and before—a sense of separateness about the Solitario. One ascends to the brink of this elevated, sloping bowl, eight miles across and sealed inside almost impenetrable walls, expecting that some kind of paradise must surely lie within: if not a lost kingdom, then at least some well-watered, fertile respite from the surrounding countryside. But the allure of Xanadu is an illusion. Unlike the Big Bend's other hidden place, the green and hospitable Chisos Basin, the interior of the Solitario is arid and forbidding. It is a respite from nothing; instead, it distills into itself all the harsh wild beauty of the uncompromising Chihuahuan Desert.

This portion of Robert Anderson's 320,000-acre Big Bend Ranch is above all else a remarkable geologic library. Few places in Texas exhibit such a complex terrestrial history, and still fewer yield up their secrets so readily. To the practiced eye the story is plain: the torturously folded ancient Paleozoic rocks lying exposed in the Solitario's center; the limestone sifted down by Cretaceous seas and then thrust into a great protective escarpment by the still-unknown forces that uplifted the Solitario dome some 50 million years ago; the lava flows and ash falls of Tertiary time; and the effects of erosion that began, millennia past, when the ancestral Rio Grande began to carve a steady downward course, draining runoff out of the Solitario through four narrow and ever-deepening canyons.

These canyons, locally known as Shutups, provide the only natural passages into the Solitario. (In the north, a primitive road now vaults the rim.) The way is difficult: gradients sometimes reach 400 feet per mile, and the canyon floors are hemmed by walls of limestone and red conglomerate towering as much as 750 feet. In the Lower (or southern) Shutup—the largest, most isolated, and most breathtakingly beautiful of the four-smooth-sided *tinajas* cup deep pools of jade-green water, obstructions or diversions depending upon one's mood. Except in the driest seasons, a shallow flowing stream two or three feet wide meanders over gravel bars between these pools, disappearing and re-emerging as if by whim. But the calm, steep-shadowed serenity of the Shutups is deceiving: floods accompanying late summer thunderstorms transform them into places of mortal peril, roaring gorges where giant boulders are tumbled about by the current's overwhelming force.

So rugged is the interior of the Solitario that a good day's expedition seldom covers more than 15 miles, and then only with the aid of a sturdy four-wheel-drive vehicle. To the north, shale lowlands and low sandstone ridges predominate; to the south, volcanic tuff. Characteristic desert grasses, much thinned by grazing, survive in scattered clumps. The black and green chert of the Maravillas Formation and the distinctive white rocks of the Caballos Novaculite cap the high ridges rising from the basin floor, contrasting sharply with dark igneous mountains like Needle Peak. Man-made landmarks are few: some scattered tanks, the pumphouse at Tres Papalotes, and the remote, forgotten Burnt Camp. Permanent surface water is altogether lacking. This is the rawest country known to Texas; to enter the Solitario is to take leave of everything but elemental nature.

Its plant life is, with a few notable exceptions, typical of the Big Bend. Geologic diversity, however, allows species that ordinarily grow in widely separated sites to flourish in close proximity to one another. The rim hosts ocotillo, agave, sotol, and desert shrubs like silver-leaf; the interior basin, creosote, mesquite, catclaw acacia; while in the relatively more hospitable Shutups, ash, soapberry, walnut, and buckeye struggle for water in the dry months and cling for life against the periodic torrents. These canyon plants and others like the Havard plum are relics of an earlier age when the climate of the Solitario was cooler and wetter than it is today; they endure in their isolated canyons only because the high cliffs provide shade and shield them from the Solitario's brutal evaporation rate (at 90 inches a year, the highest in the state).

The pre-eminent botanical treasure of the Solitario is the colony of some 45 Hinckley oaks clustered together on a low limestone ridge. Except for another small colony near the abandoned mining town of Shafter, these tiny, two-foot-high shrubs are the only known examples of their kind. Because no seedlings have been found and because their sparse acorns are regularly attacked by predators, botanists speculate that the Solitario Hinckleys may be the last remnants of a Pleistocene population that has survived, against all odds, by reproductive cloning.

Three other plants, rare to Texas, exist in the Solitario. The Fendler lipfern has been found in a shady side canyon near the Lefthand Shutup. Along the rim, both the night-blooming cereus and the milkwort *Polygala minutifolia* display their distinctive, though quite different, white flowers. *Echinocereus stramineus,* the strawberry pitaya cactus, is by no means either rare or endangered; but its presence in dense profusion along the Solitario's interior slopes is a reassuring sight to epicurean admirers of this, the desert's most delicious edible.

The Solitario's zoology, like its botany, is noteworthy less for any inherent uniqueness than for the way it brings together within a single small area a great variety of normally scattered life forms. Lying near the center of the Chihuahuan Biotic Province, it harbors a vertebrate fauna that is a virtual microcosm of the huge Chihuahuan Desert. One finds familiar vertebrates like Kangaroo rat, Checkered Whiptail lizards, jackrabbits, cottontails, and mockingbirds. More than 100 species of birds have been identified within the Solitario, among them two rare Elf Owls seen nesting near Tres Papalotes. The Big Bend Gecko, a rare lizard, has been found near the Lefthand Shutup, and Leaf-Chinned bats are known. Myriad species of grasshoppers abound, as they do throughout the Big Bend.

The effects of the Solitario's isolation can be seen directly on its botany and its zoology. There is a marked scarcity of foreign plant forms, contrasting sharply to neighboring Fresno and Colorado Canyons. And the predators of this 40,000-acre basin are distinctly different from those that prowl the adjacent countryside. In most of West Texas, man's gradual extermination of large carnivores has left the field to smaller animals like raccoons, skunks, and foxes. In the Solitario the situation is reversed. Cougars and coyotes rule, the rest are scarce or absent. Attracted by the seclusion of this strange wild place, the cougar has kept its rank in the natural order of things—for how much longer, no one can say.

Waking to a coyote's cry under a canopy of stars, one realizes how far from humankind the Solitario is. From all evidence it has always been so. Nineteen archaeological sites have been identified within its boundaries, some dating back perhaps 12,000 years; but their contents—scattered lithic tools, fire-cracked rocks, manos, metates, and soot-blackened shelter ceilings—suggest that prehistoric man paid only brief visits in search of food and weapons before returning to the more congenial regions of Fresno and the Bofecillos: a temporary sojourner, nothing more. Its Spanish history is nonexistent. Even the American ranchers, who did not arrive in numbers until the twentieth century, set up their own residences far away. The occasional overnight campsite of the cowhand is man's only recurring modern presence. So far as we know, in twelve thousand years not one permanent human habitation has ever been constructed in the Solitario.

No lost kingdoms here, nothing of the kind was ever seen in this negative oasis. But those who know it best insist it is enchanted, will tell you of strange things that happen on moonless nights, will tell you of the three men who sat in the half-light of a campfire at Tres Papalotes when a fourth came up and stood by them, all silent, before fading into the shadows. In the Solitario, they will tell you, you always know who else is there; and there were just three men there that night, not four. Who then was the fourth?

Such stories are, one understands, a commonplace of cowboy folklore: the silent stranger who emerges from the dark to share the fire and melts away unseen, an apparition. But somehow they seem more believable out here, in this prickly, hollowed-out cup of earth, inside these fierce excluding walls, where one small campfire crackles vainly against the universal dark. Ghosts, if they be, would surely come.

A BRIEF HISTORICAL SURVEY OF THE BIG BEND AREA

Bruce D. Saunders

Almost hidden in a remote corner of West Texas is a vast area of land that modern civilization has left virtually untouched for decades. The whole region of the Big Bend—bounded on the west and south by the Rio Grande, the Pecos River on the east, and the state of New Mexico on the north—has been a very difficult area to settle. Summer temperatures that can occasionally soar to 55° centigrade (130°F) during the day and then drop rapidly at night, a limited amount of annual rainfall, a scarcity of springs and waterholes, the presence of spectacular but treacherous mountain ranges, all have contributed to the region's lack of early settlers. It is a forbidding area that has attracted only the strongest and most determined individuals who must constantly battle the natural elements found there. Yet there is a beauty and grandeur to the open spaces of this region that the majestic mountain ranges and deep valleys accentuate. Man has been forced to wrestle the land away from the cactus, ocotillo, mountain lions, rattlesnakes, and scorpions that have successfully inhabited the land for centuries. Visitors find the area exhilarating and challenging and often succumb to what columnist and historian Frank Tolbert calls "Big Bend Fever." Walter P. Webb, the noted historian, agreed with Tolbert but pointed out that the malady had an insidious nature because people were often "homesick for a place that could never be their home."[1]

It has always been difficult to exist in this arid land. The early Indian villages were all situated along the banks of the Rio Grande or smaller tributaries to make use of the water and the fertility of the alluvial plains that appeared after the high waters carried soil

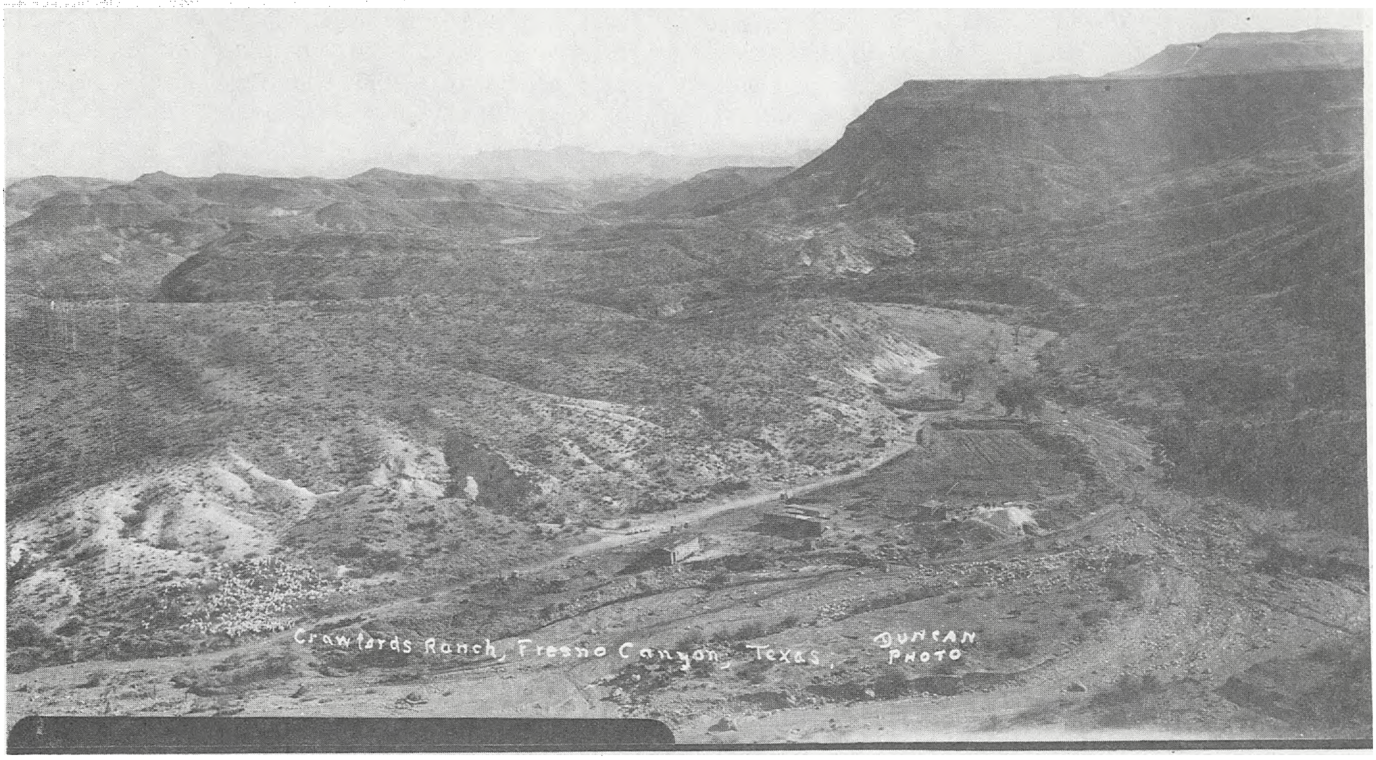
Aerial view of Canyon Colorado, better known as the River Road over the Big Hill. This view is to the west, looking up the Rio Grande that can be seen for miles to the left of the also winding road. Until that masterpiece of road construction was completed a couple of years ago, this part of the Big Bend was impassable. Today it is the route of the Camino del Rio. Picture made September 22, 1965.

and deposited it as the floods receded. Life was so precarious that a drought, a crop failure, or another type of natural disaster often destroyed entire villages or forced them to relocate in other areas. Even an environmental shift could upset the delicate balance that allowed the Indians to cling to a subsistence form of agriculture in the river valleys.[2] Archeologists have located early villages along the Rio Conchos, near its confluence with the Rio Grande, and on the right bank of the Rio Grande.[3] The settlement called Tapalolmes, located near the present site of Redford, Texas, was well established in 1747 when Rabago y Teran observed it during his travels. The natives later crossed the river and built a settlement on the left or west bank.[4] Other villages had been observed and described over a hundred years earlier. The intrepid Spanish explorer Cabeza de Vaca crossed the Rio Grande in 1535, but the exact location of his route has been a subject for lively debate among historians, geographers, and geologists. There is little doubt that he visited the La Junta de los Rios (the confluence of the Rio Conchos and the Rio Grande) area, named the local Indians "the people of the cows," erected a cross, and designated the area "La Junta Pueblo de las Cruces."[5] Robert T. Hill, the famous American geologist of the Trans-Pecos region, maintained that de Vaca wandered from a location near the present site of Ft. Davis on a southwestern course that carried him down Terlingua Creek to Lajitas and then across the Rio Grande at or near the famous San Carlos ford. He then continued on a southwestern heading but reversed his course and took a northern route to La Junta.[6] Hill based his findings on de Vaca's accurate descriptions of the geographic and geologic features he passed in west Texas. Hill was unable to understand why a large number of historians had been unable to correctly plot de Vaca's route.[7]

Many of the early settlers of the Big Bend area and the people that lived along both sides of the Rio Grande who were present when de Vaca came through west Texas were cave dwellers. They spent part of their time in dry caves above the river and the rest of it along the rivers and arroyos planting and harvesting crops.[8] A larger and more organized tribe, the Jumanos, were active in the La Junta area from 1650 until the 1770s. They were first critically observed when the Antonio de Espejo expedition passed through the La Junta area in 1582-1583. They were good farmers but never practiced irrigation, a fact that brought starvation as a constant visitor to the tribe. The Jumanos possibly were related to the pueblo-building tribes who spread southward along the Rio Grande. They allied themselves with the Apaches, their former enemies, during the 1693-1715 period, yet there was still a gradual reduction in the size of their tribe during the 18th century.[9] There is very little accurate information available on this tribe, and, as Newcomb states, "of all the Texas Indians, the Jumanos are the least known, and the few facts about their culture we do possess seem to raise more questions than they answer."[10] He concludes that they were "an important outpost of civilization, a pioneer people who had been temporarily successful in establishing settlements on the fringe of Puebloland."[11]

The Jumanos and the other tribes of the southwest were often viewed as subjects for conversion to Catholicism. A number of *entradas* and *visitas* crossed into the Trans-Pecos area, commencing in 1581 when the Fray Augustin Rodriquez expedition reached La Junta on July 6.[12] Composed of three priests, a sergeant, 19 Indian scouts, and 600 head of cattle, sheep, goats, and hogs, its major purpose was to explore the territory and christianize the natives.[13] The Espejo *entrada* left San Bartolome in early November, 1582, with a complement of 15 soldiers, some servants, a priest, and over 100 horses and mules, to rescue the members of the Rodriquez expedition. Espejo, a wealthy Mexican citizen who was attempting to atone for a crime he had committed, financed and led the expedition as it marched up the Conchos River to the Rio Grande. On December 9, 1582, it arrived at La Junta, where the horses were rested for eight days before it headed northward to El Paso del Norte.[14] Espejo eventually led his men farther north to Santa Fe, then east to the Pecos River, down it to the Sheffield Crossing, west to Kokernut Springs (Alpine), and then down Alamito Creek to the Rio Grande, just south of Presidio, Texas.[15] The Dominquez de Mendoza expedition explored the area north and east of La Junta and travelled up Alamito Creek to Alpine.[16] Both the Espejo and Mendoza expeditions opened a new trade route from Mexico to the United States that remained virtually unused for a century and a half.

An American expatriate was the first man to realize the value of the route that the early explorers had found. Dr. Henry Connelly was a Kentucky physician who moved to Chihuahua, Mexico in 1828. He worked as a clerk in a retail store for a Mr. Powell, saved his money, and later bought the business from Powell. Dr. Connelly left Mexico in April, 1839 via the Rio Conchos to La Junta, crossed the Rio Grande, and headed up Alamito Creek. Eventually he reached his destination, Independence, Missouri. There he loaded either pack mules or a wagon train with goods to sell in Mexico. His first round trip lasted 16 months and was very successful. With Edward J. Glasgow, another American expatriate in Chihuahua, he formed a partnership that continued in



The Crawford Ranch and small farm in Fresno Canyon, lower part of Brewster County, about 1918. It was in an isolated location, but several Army mule pack trains passed by every week, going to and from Lajitas when a cavalry troop was on the Rio Grande. Through the Fresno Canyon was the main route between Lajitas, Terlingua and Marfa then, but not after 1920. Mr. Crawford had the largest goat herd in this part of the Big Bend, and he also grew the first citrus fruit in this part of Texas (oranges and lemons).

a profitable manner until the end of the Mexican War in 1848. Connelly married a Mexican woman and fathered three sons before he moved to the United States States just after the Treaty of Guadalupe-Hidalgo was signed. In 1849 he settled in the New Mexico Territory where he purchased the largest mercantile store in the region. In 1861 and again in 1864, President Abraham Lincoln appointed him territorial Governor, a post he held until the time of his death in 1866.[17]

Connelly's Trail, better known as the Chihuahua Trail, opened a prosperous era for the Missouri merchants and for the Rio Grande Valley area near La Junta and Presidio. After the Rio Grande was finally and firmly established by the Treaty of Guadalupe-Hidalgo as the boundary between the United States and Mexico, new residents began slowly to settle along the river in order to profit from the growing commerce between the United States and Mexico. One of the earliest settlers was Ben Leaton who relocated near the San Jose Mission in 1848 on some land that his wife, the former Doña Pedraza, had purchased in 1833. Leaton, who was born in Kentucky and later lived in Chihuahua, opened a very lucrative trading post, El Fortin. Later called Fort Leaton, it attracted business from the Indians, American travellers and merchants, and Mexicans who crossed the river to trade. Leaton, a mysterious man, disappeared in the early 1850s, setting off a long and complicated series of court battles over his land.[18] Fort Leaton is in the process of being reconstructed on its original location several miles south of Presidio near the mouth of Alamito Creek.[19]

Fort Leaton, the outpost of civilization in the Big Bend region, was a favorite stopping point for Americans who crossed the Chihuahua Trail or who were exploring the area. One of the first groups of visitors included Colonel Jack Hays. He had been commissioned, along with Samuel Highsmith, to find a new trade route between San Antonio and El Paso del Norte. Businessmen in San Antonio had raised over $800 to finance the expedition of 35 Texas Rangers and Indian guides. They left the Alamo City in August of 1848, undoubtedly never believing that they would almost starve to death before reaching the security of Fort Leaton in late October.[20] Samuel Maverick, a veteran of the Mier Expedition and the

Mexican War, kept a detailed diary that indicates the problems they encountered. It took a month to reach the Devil's River. After crossing it, they entered the Big Bend region and became lost. Maverick's diary illustrates their suffering. September 29: men were "crawling like flies on side of mountain." October 2: "To banks of the Rio Grande, where we killed and ate a panther." October 4: "Mustang meat in request." October 7: "No food. Here we begin to eat bear grass." October 10: "Killed a mule. Meat poor and tough." On October 19, the weary band reached the small Mexican town of San Carlos, mainly through some directions a group of Indians had given them, and obtained bread and milk to restore themselves.[21] They travelled north from San Carlos, crossed the Rio Grande, and spent 16 days at Fort Leaton recovering from their ordeal and resupplying for their return trip to San Antonio. Hays ruled out any thought of a continuation of the trip to either El Paso de Norte or Chihuahua City.[22] Although the Hays-Highsmith group was the first expedition to reach Fort Leaton from San Antonio, the results of the trip were not impressive or satisfactory. One member of the party, Dr. Wahm, went insane and deserted as the expedition wandered aimlessly in the Big Bend region. The Indians found and cared for him and later permitted him to return to San Antonio a year and a half after he first left with Hays and Highsmith.[23]

The year after the Hays trip, the United States Army, eager to find a shorter route to the west, dispatched Lieutenant W. H. C. Whiting of the Corps of Engineers to seek a safe route from San Antonio to El Paso del Norte. He had difficulty traversing the Trans-Pecos area but reached Fort Leaton in six weeks. He resupplied there and enjoyed the type of hospitality that made Ben Leaton famous throughout the west. Whiting recorded in his diary that he dined on stewed chicken with chili, tortillas, roast turkey, frijoles, coffee, and whiskey, with Leaton's famous peach brandy as an after-dinner drink.[24] Whiting and his assistant, Lieutenant W. F. Smith, continued up the Rio Grande to El Paso del Norte and returned to San Antonio via a new route that ran southwest between the Pecos and San Pedro Rivers to Las Moras Creek and then into San Antonio. It was an improved route that covered an estimated 645 miles.[25]

Following Whiting's successful mission, the Army attempted to find a shorter and safer route to El Paso del Norte via the Rio Grande. Captain John Love proceeded from Ringgold Barracks, near Rio Grande City in the lower valley, up the river to a spot he estimated as 1,014 miles from his starting point. He led a company of a dozen men, using a flat-bottomed boat that measured 50 by 16 feet and drew only 18 inches of water. They used this boat for what he estimated to be the first 967 miles, but at Brooks Falls they changed to a smaller boat that took them to an impassable point they believed was 25 miles south of Presidio. While they failed to navigate all the way to El Paso del Norte, they considered they had proved that over a thousand miles of the Rio Grande was navigable, even if only in small boats.[26] Love's report was quickly contradicted in another Army document that stated that the Rio Grande was only ten inches deep above Eagle Pass and thus impassable much of the year. The second report, the work of a small party of Army men under the command of Lieutenant Martin Luther Smith, was based on a trip via flat boats to a point eight miles above the confluence of the Rio Grande and the Pecos Rivers.[27] Despite Capt. Love's optimistic report, the Rio Grande was not the best route from San Antonio to the Big Bend Region, El Paso del Norte, or Chihuahua City.

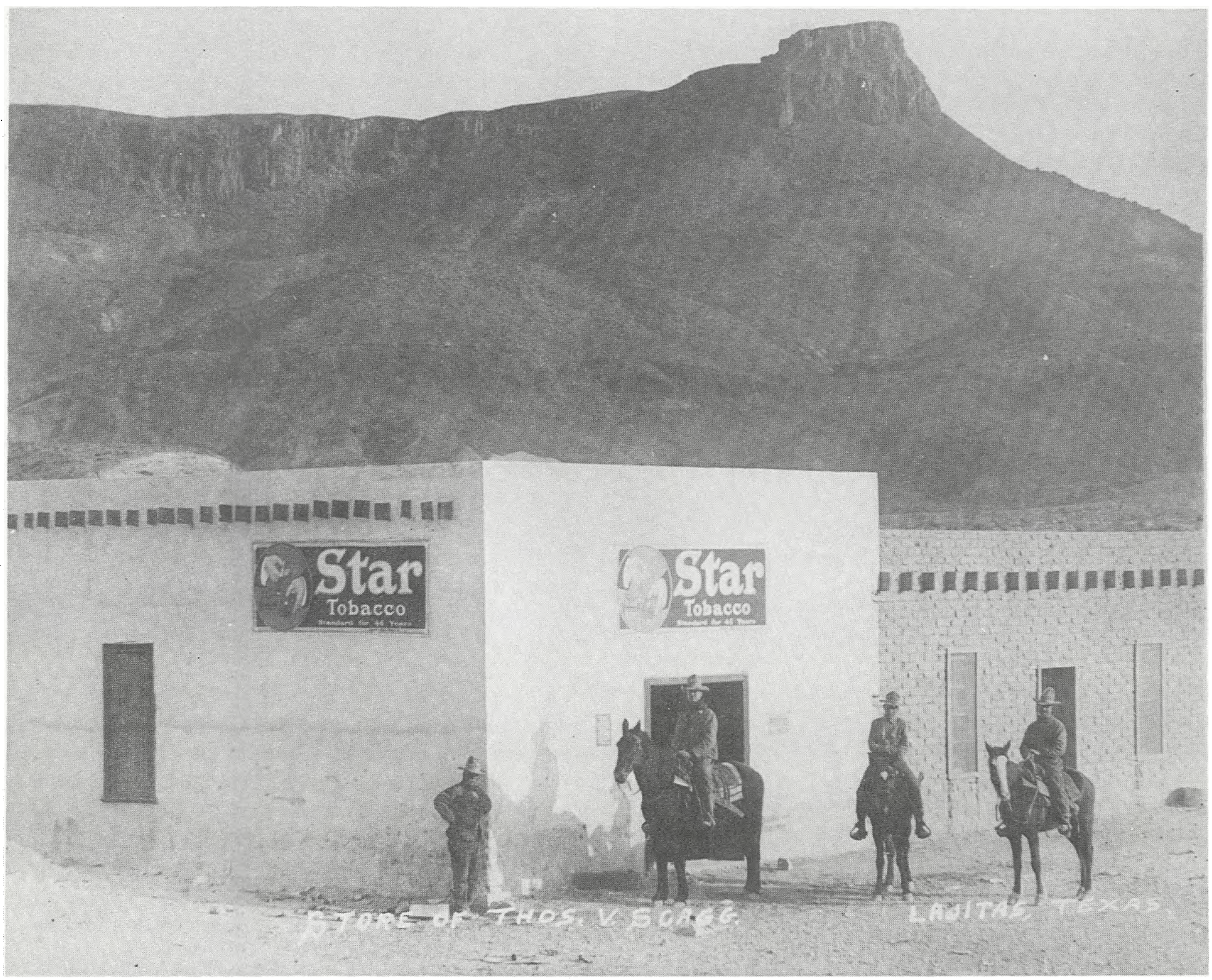
American interest in the exploration of the southwest continued for other reasons. Pursuant to the terms of the Treaty of Guadalupe-Hidalgo, the United States Army organized a number of reconnaissance missions that were ordered to survey carefully the border region along the Rio Grande. John Russell Bartlett was the first Boundary Commissioner, but his poor knowledge of the west, problems with the Indians, disagreements with Mexico, and a shortage of funds sharply curtailed his effectiveness.[28] Major William H. Emory, an astronomer attached to the Topographical Corps of the United States Army, assumed command of the surveying party as it started to work its way south along the Rio Grande to its mouth. Emory faced numerous problems that included the severity of the climate, lack of funds to pay his men or purchase supplies, and the rugged nature of the terrain he had to map. Emory and his skilled assistants carefully classified and catalogued the flora and fauna they found along the length of their route. They were most impressed when they travelled from Fort Leaton south toward the canyons of the Rio Grande. Emory remarked that it was "a section of country which for ruggedness and wilderness of scenery is perhaps unparalleled."[29] They observed that a one-to-three-mile-wide valley extended from Fort Leaton south to the Bofecillos Mountains where it narrowed to form a canyon. Farther to the south, near the present Lajitas Trading Post, Emory reported that the Comanche Pass ford was the "most celebrated and frequently used crossing place of the Indians."[30] He happened to meet Chief Mano of the Apache Tribe who was leading a band of men through the ford to Durango, Mexico.[31] Emory's work in the Big Bend region was the first detailed scientific exploration completed in the Big Bend region, but other men who followed added more information to his collection of samples and observations.

All of these explorations of the area and the continued expansion of American interests convinced several Americans living in Mexico that the border region along the Rio Grande near Presidio and immediately to the south held the promise of commercial success. Milton Faver, like Ben Leaton, came to Presidio after living in Mexico and marrying a Mexican woman. He ran a freight line between Ojinaga (near La Junta) and Meoque and later operated a general store in Ojinaga, but he finally moved to the west bank of the Rio Grande and eventually owned four large ranches to the north and east of Presidio. He was one of the most successful ranchers in the region and amassed a herd of over 20,000 longhorns before his death in 1889.[32] John W. Davis settled near Alamito Creek where he raised horses and cattle in the 1850s. He employed between 15 and 20 Mexican families to operate his ranch. He decided to leave the southwest in 1892 to return to his native North Carolina after the death of his Mexican wife.[33] John W. Spencer, one of Leaton's original business partners, moved with his Mexican wife and large family to the American side of the river in the 1850s to enter the horse-raising business near Fort Davis. The Indians stole most of his stock, so he moved back near the Rio Grande for security reasons, settling north of Presidio and entering the cattle business.[34] John D. Burgess, another early businessman in the Presidio area, followed the same general pattern as Leaton and Spencer. He entered the freighting business in 1851 and then bought some land on the American side of the river and went into competition with Leaton. He took over Leaton's Trading Post and continued to work in the freighting business for the next 20 years. He became entangled in a bitter feud with several of Leaton's heirs, including the new husband of Leaton's widow.[35]

Both Burgess and Leaton recognized the need for adequate transportation in the Big Bend area. The freighting business was a lucrative occupation for many individuals who ran lines both in Mexico and the United States and profited from the growing trade between the two nations. Connelly's Chihuahua Trail was the first successful route connecting northern Mexico with the American midwest, but other routes were needed. In 1869 August Santleben inaugurated a stagecoach route between San Antonio and Chihuahua City via Fort Stockton and Presidio. He made a number of round trips in the 1870s, carrying goods of all types, especially silver from the Mexican mines. In 1876 he attempted to organize a large-scale freighting business in Chihuahua City, but the completion of the El Paso del Norte-Chihuahua City railroad forced him to abandon his plans.[36] Henry Skillman's San Antonio-El Paso mail route, established in 1850, was extended to Presidio on the Rio Grande on a weekly basis in 1870 and brought the area into closer contact with the rest of Texas and the United States.[37] Drivers on the Chihuahua Trail used the prairie schooner as their principal vehicle. It had a bed 24 feet long but was only 4½ feet wide with wooden sides that extended to a height of 5½ feet. The rear wheels were almost six feet high, while the front wheels were a foot shorter. A team of 16 mules pulled an average load of 14,000 pounds. Drivers had to have the skills of a mechanic, a veterinarian, a gunfighter, an overland navigator, a cook, and a businessman to survive on the trail.[38] The advance of the railroad hastened the end of mule-drawn freight wagons and the lines that served many remote areas in the southwest. The Rio Grande area was bypassed in 1883 when the Southern Pacific Railroad crossed the Trans-Pecos region to the northwest of the river, helping to found and promote the towns of Sanderson, Marathon, Marfa, and Valentine along its route. A line did not reach to the Rio Grande until 1930 when the Atchinson, Topeka and Santa Fe linked Alpine and Presidio and provided a connection, via the Mexican National Railroad, to the west coast of Mexico.[39]

Adequate transportation and the location of United States Army posts in the southwest were closely connected to the success of the cattle business in the Big Bend area. Railroads were used to bring in many of the initial herds and to transport the steers to the markets in the midwest. The location of a major Army garrison at Fort Davis in 1854 had an important impact on the establishment of the cattle business in the Big Bend since the demand that Fort Davis generated for fresh beef helped to accelerate the growth of many ranches.[40] Frequent Indian raids, a hot and arid climate, and the long distances to markets continued to frustrate many ranchers. The rich grasses of the region, especially the numerous varieties of grama grasses, that existed in "the most profuse abundance over the entire surface of these table lands, is nutritious during the whole year, and the plains between the Rio Grande and the Pecos seem intended by nature for the maintenance of countless herds of cattle."[41] The early cattle were Mexican and Spanish breeds, but these were gradually replaced as the Texas longhorns were brought into the area. The longhorns, which were seen in many colors, interbred with the native stock to produce a large wild animal that could survive on the native grasses without requiring large amounts of water.[42] Early cattle drives were organized in the 1860s, headed not toward the markets in the midwest but along the Chihuahua Trail into Mexico. These drives, which reached their peak in 1868-1869, were safe from Indian attacks but often fell prey to the raids of the Mexican rustlers that attacked along the route.[43] The most prosperous period for the cattle industry in the Big Bend region came in the 1880s. A land rush during the first part of the decade resulted in the formation of many large ranches. J. T. Gano founded the Estado Land and Cattle Company in 1885 on 55,000 acres with 6,000 head of cattle he brought in from Dallas and Uvalde.[44] Meyer Halff started his ranch with 50,000 acres and added more later while Milton Faver in the 1880s controlled four large ranches with between 10,000 and 20,000 head of cattle.[45] The severe winter of 1885-1886 helped to push over 60,000 head of cattle into the Big Bend, but it proved disastrous as they quickly overgrazed much of the open range. The first large-scale cattle roundup was held the following summer, August, 1888, to sort out the strays and to help preserve the rapidly diminishing grasslands.[46] The introduction of barbed wire in 1888 and the appearance of the Hereford about the same time ended the first significant era in the cattle business.[47]

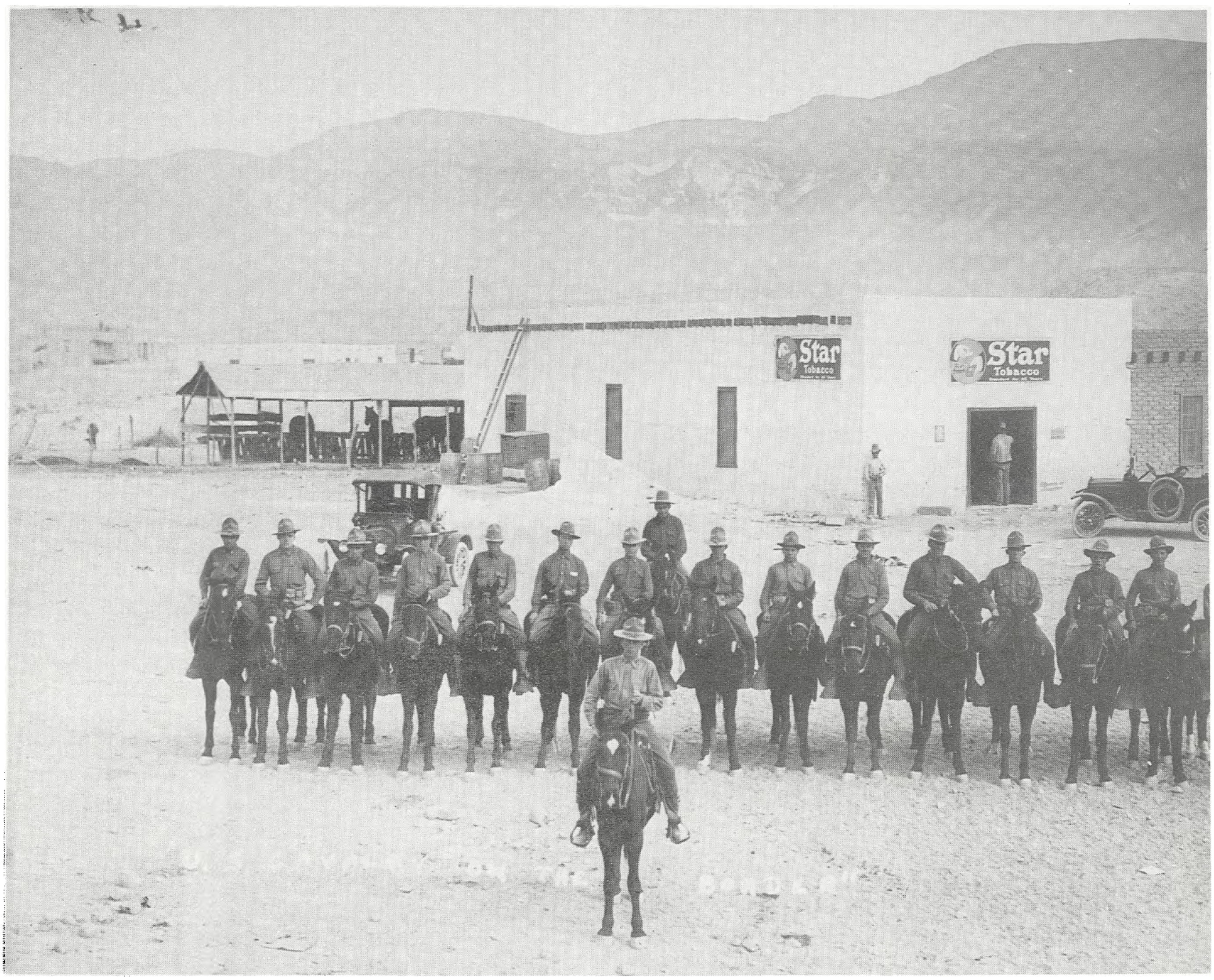
Less romantic, but still economically significant to



The trading post farthest from a railroad on the Mexican border was at Lajitas, Texas. It was 108 miles from Alpine or Marfa, Texas. From 1911 through 1920, it probably was also the busiest for in that period its regular large Mexican border trade area on both sides of the Rio Grande was made larger by the numerous quicksilver mines nearby. The largest mine at Terlinqua had its own store but the small mines did not. This picture of Thomas V. Scaggs' Trading Post at Lajitas, Texas, was made in 1916. It shows Scaggs at the corner of his store building talking to Texas Ranger Jeff Vaughn, Cavalry Officer Lt. Stilmax, and Texas Ranger Bill Palmer. A troop of the 6th Cavalry and these two Texas Rangers were stationed at Lajitas.

the area, was the sheep industry that Milton Faver founded. He was the first important sheepman to battle the cattlemen for a place on the open range for his flocks in the 1880s.[48] Although the first sheep were introduced in the La Junta region in the 1560s, they did not play a major role in the economy until three centuries later when their total economic value exceeded the value of all the cattle in Texas.[49] Ranchers like Faver fought for the sheepmen, introduced improved breeds, and persuaded others like George Crosson to enter the business. Crosson bought 1,800 ewes from Faver's large flock in the 1880s and was able to enlarge his own holdings to over 20,000 head by 1889.[50] The 1892-1893 drought crippled the sheep business in the Big Bend, and the Cleveland administration's interference with the Wilson-Gorman Tariff of 1894 caused a large reduction of the duty on raw wool that dealt another serious blow to the sheep raisers of the United States, especially in Texas. The sheepmen of the Big Bend did not recover from these disasters until the 1930s.[51]

Although the region along the Rio Grande was somewhat better suited for livestock, a number of successful farms were started in the 1870s. Using water from the river to supplement the limited rainfall on the rich alluvial soils, farmers were able to "raise any crop that grows in Texas," according to an early report from a civil engineer. "Its (the area between Presidio and Redford) yield is enormous, as much as 80 bushels of corn and 50 bushels of wheat being grown to the acre."[52] Irrigation of these fertile lands began in the 1870s just south of Presidio and



This picture was made in 1916 at Lajitas Texas, of Thomas Scaggs Trading Post and part of a troop of the 6th Cavalry. It is not known which troop these troopers belonged to as the troops were rotated. The officer was Lt. Stilmax. The cavalry had its stables at the rear of the trading post when this picture was made but later moved them beyond the second large white building.

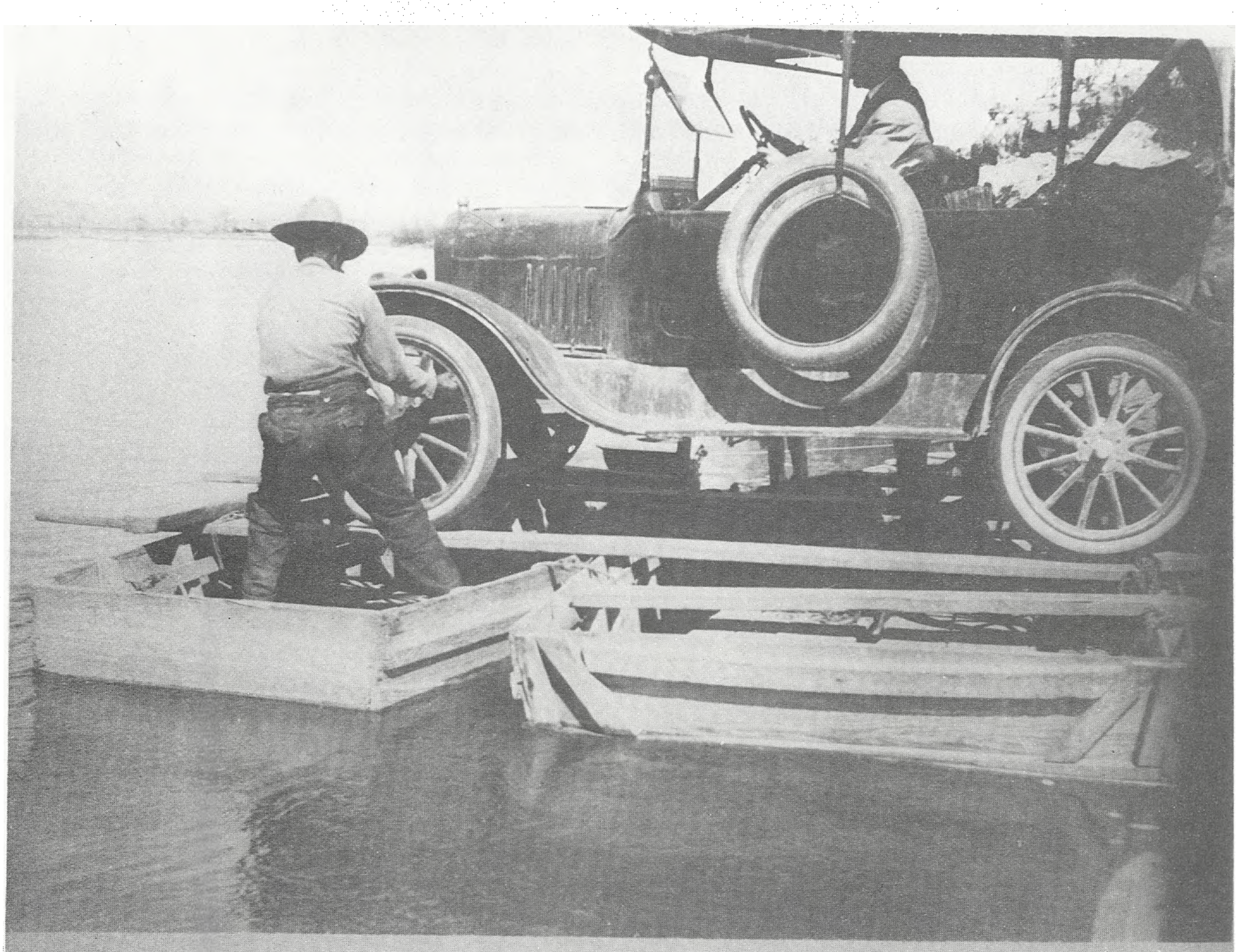
Two wagons pulled by burros and loaded with handmade ropes were being hauled from Lajitas 108 miles to Alpine, Texas, in 1921. They were made by Mexicans in Mexico, sold to Scaggs' Trading Post in Lajitas, Texas, as there was no market for them in this part of Mexico, where everybody made their own ropes.

extended to Redford. One of the earliest farmers in the area was Secundio Lujan who obtained a quarter section of land (160 acres) from the state of Texas in 1875. To obtain water from the river to irrigate his land along its course, he formed the Polvo Irrigation Company. It constructed a 550-foot dam of loose rock, from two to four feet high, that channeled water into an irrigation canal five miles long, six feet deep, and six feet wide at the top. To blast through the hard, igneous rock that he found along the route of the canal, Lujan had to travel over 200 miles to Chihuahua City to purchase gunpowder. He was a very successful farmer, growing beans, onions, corn, and wheat, and later concentrating on cotton.[53] Cotton production totalled 97 bales in 1921 but increased dramatically to 4,789 bales in 1930.[54] Recently farmers have concentrated on onions and the famous Presidio cantaloupes.[55] Other crops just north of the Polvo/Redford area included beans raised after crops of oats, barley, and wheat had been harvested. A few crops, such as corn and beans, were occasionally grown without the benefit of irrigation, usually just north of Presidio where the water level of the Rio Grande was unpredictable and often too low to permit construction of irrigation projects.[56]

As the twentieth century neared, the arid region along the Rio Grande was relatively prosperous but still thinly settled. Presidio County had only 580 residents in 1860 and 40 years later could boast of an increase to 4,125, a substantial gain but very few residents considering the size of the county.[57] Transportation was still slow and difficult, but improving. Ranching and farming occupied most residents. Silver mining developed into a major industry at Shafter, about 30 miles from the river, where the metal was first discovered in 1882 and mined continuously for 40 years. An estimated two million tons of ore produced about $20 million in silver during the operating days of the mines.[58] Farther south, cinnebar, the ore for mercury (commonly called quicksilver) was mined from 1892 until 1971.[59] About one-fourth of all the mercury produced in the United States came from these mines.

One other important natural resource of the area is the native candelilla wax plant (*Euphorbia antisyphilitica*). It grows in abundance on the colluvial limestone slopes and gravel terraces on both sides of the Rio Grande. The plant is harvested and boiled in an acid bath to produce a high-quality wax which is used in chewing gums, floor and auto polishes, crayons, cosmetics, lubricants and a variety of other products. Wax produced in Mexico is supposed to be marketed through the Bank of Mexico, although much of it finds its way across the border and is marketed with the relatively small quantity of wax produced in Texas.[60]

The growing prosperity of the area along the Rio Grande was threatened in the first two decades of the twentieth century when the political and social unrest that spread across Mexico spilled into the United States. In the early part of the century, the Big Bend area had been relatively peaceful since the last raids of the Indians had been effectively ended in the 1880s when a large force of American soldiers had been stationed in a series of forts along and near the border. Francisco (Pancho) Villa, the Mexican bandit and outlaw, often crossed the border into Texas when the Mexican authorities were chasing him. He occasionally hid with his men in the Alamito Creek area, safe from capture but a threat to the stability and peaceful nature of the area.[61] The United States Army was ordered into the area in 1916. A small detachment of cavalry was stationed at the Lajitas Trading Post, and others were garrisoned at Marfa. Aircraft permitted the early pilots of the U.S. Army Signal Corps to patrol the river and locate potential problems before they grew too large to handle.[62] Border raids were common throughout this period.



In 1921 when this picture was made, and earlier, the Rio Grande always had more water than it has today. Then there were not as many large irrigated farms along it. At Lajitas, where this picture was made, occasionally an auto had to cross the Rio Grande, as this Model T Ford of a Texas mining man who had been to San Carlos or some other mining town in the state of Chihuahua. There was a Mexican at Lajitas who had a couple of wooden flat bottom boats that could be converted into ferry boats big enough to cross an auto, as this picture shows.

An estimated 80 Mexican bandits crossed the border during the night of May 5, 1916, to raid both Glenn Springs and Boquillas, Texas. A number of residents were killed, including several American soldiers. President Wilson retaliated by sending a large force to patrol the border region. Another serious raid occurred more than a year later at the Brite Ranch, located near Valentine.[63]

While ranching and farming continued and the border bandits crossed the river to rustle cattle and rob storekeepers, another new industry for the Trans-Pecos area was being established. Robert T. Hill, a geologist, was perhaps the first person who recognized the natural beauty of the Trans-Pecos region, especially the area along the Rio Grande. He planned and led the first successful expedition that explored the Rio Grande from Presidio to Langtry.[64] He ordered the lumber for his three boats shipped from San Antonio to Del Rio where he assembled them and then forwarded them to Marfa via the railroad. Hay wagons carried the thirty-by-three-foot boats the last 75 miles to Presidio. Warnings of impassable boulders in the river, of an outbreak of small pox in Presidio del Norte, and of Mexican bandits who roamed the area frightened off two members of the eight-man expedition before it even got to the river.[65] Although the International Boundary Commission said the river was impassable, Hill set out with five men on October 5, 1899. On the second day of the trip they reached Polvo (in Spanish "dust"), "an appropriately named village" of a half-dozen adobe houses and a store.[66] Stopping to investigate, Hill met the storekeeper, Samuel J. Hensley, who pointed out spots of dried blood on the floor and walls that had resulted when a Mexican bandit had murdered his predecessor several months earlier.[67] Hill and his companions had been warned about a notorious bandit named Alvarado, or "Old White Lip" because half of his moustache was black and the other half white.[68] Although the party did not see "Old White Lip," he was in the vicinity, and several months after Hill had completed his trip, Hensley wrote that Alvarado had robbed a man of $1,200 and assaulted his wife near the area where Hill and his men had camped. Shortly afterwards, the Mexican police shot and killed Alvarado and one of his lieutenants.[69] To prevent any attacks, Hill ordered one man to stand guard over the members of the expedition while they were portaging their boats or when they were sleeping. The 600-foot walls of Colorado Canyon, the geological formations, the wind-eroded rocks, and the size of Santa Elena Canyon all impressed Hill.[70] His descriptive coverage of the river trip that appeared in *Century Magazine*, along with his other field work in the Trans-Pecos area, helped to stimulate interest in the region along the Rio Grande.

Although tourism was increasing and the scientific community had begun to take an active interest in the natural features of the area, ranching continued as the most important economic activity. Older ranches, like the C. H. Madrid spread founded in the 1870s, survived the severe drought of 1892-1893 and were prospering in the 1920s. The Madrids built a water system from a spring to the ranch house and maintained a small orchard of peach, orange, and fig trees, using the irrigation system they had constructed.[71] The D. H. S. Smith ranch, a short distance north of the Madrid Ranch and in Fresno Canyon, grew out of a land grant to the Dallas and Wichita Railroad in 1881. J. L. Crawford later assumed control over it, but sold it to Harry Smith in the 1930s. Smith grazed from 3,000 to 4,000 Angora goats on the ranch, despite the attacks of coyotes, panthers, bobcats, and wolves.[72] Joe Brady bought the large ranch in 1941, installed more water lines, and raised cattle. He used wetback labor that came to him for jobs from across the Rio Grande. The "river telegraph" and possibly "avisadores" kept the work force advised of the location of the Border Patrol and the wages and working conditions on the various ranches on the Texas side of the river.[73] Brady sold the acreage to an Ohio man named Mooney just after World War II. He later sold part of the land to the Fowlkes brothers, owners of the neighboring ranch. Mooney left Texas, although he still owned a part of the land, including the ranch house and the surrounding orchard, both of which have suffered in recent years from a lack of maintenance.[74]

The Fowlkes brothers, Edwin and Manny, came to the Big Bend area shortly before World War II from Jeff Davis County to the north and gradually put together a large (almost 200,000-acre) ranch north of Redford. The severe seven-year drought of the 1950s, among other factors, resulted in the Fowlkes brothers' sale of the ranch to the Big Bend Ranch Corporation, which in the 1960s sold to Robert Anderson's Diamond A Cattle Company. Anderson continues to operate the large ranch, which, by lease or purchase now contains about 320,000 acres, straddling two counties, Presidio to the west and Brewster to the east. He grazes cattle in the Fall and Spring and opens it to hunters during the deer season. An ardent conservationist and naturalist, Anderson has permitted many scientific groups to visit and explore the Solitario, a large partially eroded laccolith that stands virtually undisturbed on the eastern edge of his ranch property. Its outstanding geological formations, archeological sites, flora, and fauna form a large open research site for many scientists.

Life along the river continues at the same leisurely pace that de Vaca must have observed over 400 years ago. But new interest in the scientific treasures of the area, in the beauty of the mountains and the arroyos, and in the desire to enjoy the vast openness of an undisturbed region has brought more people than ever to this remote sector of Texas. Following the modern highway south from Presidio, a visitor can see the green farmland on the alluvial plains of the Rio Grande, pass through the small town of Redford, and approach the first of the numerous breathtaking canyons of the Rio Grande. Driving along the river in air conditioned comfort, it is hard to imagine that de Vaca walked through this area, or that Echols drove camels on this route from Presidio in 1860, or that Colonel Jack C. Hays and his men wandered for 12 days without food just to the south of this spot. Just below Black Rock Canyon, the small village of Lajitas, population nine, slumbers in the warm sun. Again, it is hard to picture elements of the United States Cavalry garrisoned at the Trading Post or the international transactions for cattle being conducted on a sandbar in the middle of the river. It is even more difficult to visualize the Comanche bands as they once swooped down their trail to cross the San Carlos Ford to invade Mexico to loot and kidnap the natives. The full September moon was known as the "Mexican Moon" in Comanche camps as it signaled the time for another raid, but in northern Mexico the same moon was called the "Comanche Moon," and people fled to the mountains to protect themselves and their property.

Farther to the south of Lajitas lies the awesome Santa Elena Canyon that lured Robert T. Hill in 1899 and today attracts thousands of outdoorsmen and adventurers who paddle their canoes and rubber rafts down the river between the canyon's steep walls. It is now part of a 700,000-acre national park that was formed after the land was given to the National Parks Service. Big Bend National Park protects the natural beauty of the area and guards the flora and fauna of this unusual region from destruction. The area just above the park, rich in natural beauty and with a wealth of scientific treasures, would be enhanced by the same type of protection to preserve its rich historical background.

Pictures and captions of photographs in this section are from The Smithers Collection, Photography Collection, Humanities Research Center, The University of Texas at Austin.

NOTES

1. William O. Douglas, *Farewell to Texas: A Vanishing Wilderness* (New York, 1967), 48. This current brief survey was written without the benefit of Ronnie C. Tyler's *The Big Bend: A History of the Last Texas Frontier* (Washington, 1975), a very thoughtful and detailed treatment of the area, which appeared in print after the survey had been completed.

2. J. Charles Kelly, "Factors Involved in the Abandonment of Certain Peripheral Southwestern Settlements," *American Anthropologist*, 54 (July-September, 1952), 382-385.

3. See J. Charles Kelly, "The Historical Indian Pueblos of La Junta de los Rios," *New Mexico Historical Review*, 24 (October, 1952), 251-295 and 28 (January, 1953), 21-51 and also Howard G. Applegate and C. Wayne Hanselka, *La Junta de los Rios Del Norte y Conchos* (El Paso, 1974) 2-23.

4. Kelly, "Historical Indian Pueblos," 28 (January, 1953), 40-41.

5. Cabeza de Vaca, "The Narrative of Cabeza de Vaca," trans. by Frederick W. Hodge, in Hodge, ed., *Spanish Explorers of the Southern United States*, 1528-1543 (New York, 1907), 99-105.

6. Robert T. Hill, "Cabeza de Vaca Crosses the Rio Grande at Last," *Dallas Morning News*, March 11, 1934, 8.

7. *Ibid.*

8. Victor J. Smith, "Survey of Indian Life in Texas," West Texas Historical and Scientific Society *Circular*, No. 5 (1941), 8-10.

9. W. Newcomb, *The Indians of Texas: From Prehistoric to Modern Times* (Austin, 1961), 228-234 and Herbert H. Bolton, "The Jumano Indians in Texas, 1650-1771," *Southwestern Historical Quarterly*, 15 (July, 1911), 66-84.

10. Newcomb, *The Indians of Texas*, 224.

11. *Ibid.*

12. Applegate and Hanselka, *La Junta de los Rios*, 13-14 and Victor J. Smith, "Early Spanish Explorations in the Big Bend of Texas," West Texas Historical and Scientific Society *Publication*, No. 2 (1920), 56.

13. Herbert E. Bolton, ed., *Spanish Exploration in the Southwest, 1542-1706*, (New York, 1908), 138-139.

14. Bolton, ed., *Spanish Exploration in the Southwest*, 161-164 and Smith "Early Spanish Explorations in the Big Bend," 57-58.

15. Applegate and Hanselka, *La Junta de los Rios,* 14.

16. J. Charles Kelly, "The Route of Antonio de Espejo Down the Pecos River and Across the Texas Trans-Pecos Region in 1583; Its relation to Texas Archeology," West Texas Historical and Scientific Society *Publication,* No. 7 (1939), 7 and Smith, "Early Spanish Exploration in the Big Bend," 59-68.

17. William E. Connally, ed., *Doniphan's Expedition and the Conquest of New Mexico and California* (Topeka, 1907), fn. 65, 276-282.

18. J. J. Bowden, *Spanish and Mexican Land Grants in the Chihuahuan Acquisition* (El Paso, 1971), 194-208.

19. For a general review of Leaton, see Levitt Corning, *Baronial Forts of the Big Bend: Ben Leaton, Milton Faver and the Private Forts in Presidio County* (San Antonio, 1967), 19-41 and Elton Miles, "Old Fort Leaton: A Saga of the Big Bend," in Wilson Hudson, ed., *Hunters and Healers: Folklore Types and Topics* (Austin, 1971), 83-102.

20. James K. Greer, *Colonel Jack Hays* (rev. ed., Waco, 1974), 217-225; Averam C. Bender, "Opening Routes Across Texas," *Southwestern Historical Quarterly,* 37 (October, 1933), 118-119; Ralph P. Bieber, ed., *Exploring Southwestern Trails, 1846-1854* (Glendale, 1938), 31-38; William A. Goetzmann, *Army Exploration in the American West, 1803-1863* (New Haven, 1959), 227-228, and John S. Ford, "Jack Hays in Texas," typescript, John Salmon Ford MMS, Box 2Q512, University of Texas Archives, 173-174.

21. Samuel Maverick, "Chihuahuan Expedition," typescript, Samuel Maverick MMS, Box 2R210, University of Texas Archives.

22. J. D. Affleck, "History of Jack C. Hays," typescript, J. D. Affleck MMS, Box 2Q402, University of Texas Archives, 748.

23. Greer, *Colonel Jack Hays,* 222.

24. William H. C. Whiting, "Whiting's Diary," *Publication of the Southern History Association,* 10 (1906), 83-85.

25. Goetzmann, *Army Exploration in the American West,* 228-230.

26. M. L. Crimmins, "Two Thousand Miles by Boat in the Rio Grande in 1850; with a Biographical Sketch of the Army Actions of Captain John Love," West Texas Historical and Scientific Society *Publication,* No. 5 (1933), 44-52.

27. Goetzmann, *Army Exploration in the American West,* 227.

28. John R. Bartlett, *Personal Narrative of Exploration and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua Connected with the United States and Mexican Boundary Commission during the Years 1850, 1851, 1852, and 1853* (New York, 1854) and Goetzmann, *Army Exploration of the American West,* Chapter 5, "The Boundary Survey," 153-208.

29. William H. Emory, *Report on the United States and Mexican Boundary Survey Made Under the Direction of the Secretary of the Interior,* 2 vols. in 3, U.S., House of Representatives, 34th Congress, 1st. Session (Washington, 1857), I, 80.

30. *Ibid.,* 81.

31. *Ibid.*

32. John E. Gregg, "The History of Presidio County," (unpublished MA Thesis, University of Texas, 1933), 283-286; Mrs. O. L. Shipman, *Taming the Big Bend: A History of the Extreme Western Portion of Texas from Fort Clark to El Paso* (Marfa, 1926), 26-27; Corning, *Baronial Forts of the Big Bend,* Chapter 3, "Don Milton, Lord of Three Manors," 43-64; Barry Scobee, "Don Milton Faver: Founder of a Kingdom," West Texas Historical and Scientific Society *Publication,* No. 19 (1963), 41-45 and Virginia Madison, *The Big Bend Country of Texas,* rev. ed. (New York, 1968), Chapter 7, "Longhorns to Herefords," 102-125 and Ch. 8 "Cattle are Kings," 126-134.

33. Robert M. Utley, "Longhorns of the Big Bend: A Special Report on the Early Cattle Industry of the Big Bend Country of Texas," typescript, U.S. Department of the Interior, National Parks Service, Region 3 (Santa Fe, 1962), 24-25.

34. Gregg, "The History of Presidio County," 281-282 and Utley, "Longhorns of the Big Bend," 16.

35. Miles, "Old Fort Leaton," 93-94; Carlysle G. Raht, *The Romance of Davis Mountains and Big Bend Country: A History,* edition Texanna (Odessa, 1963), Chapter 7, "1847–," 84-92; and Utley, "Longhorns of the Big Bend," 12-13.

36. August Santleben, *A Texas Pioneer: Early Staging and Overland Freighting Days on the Frontiers of Texas and Mexico,* ed. by J. D. Affleck (New York, 1910), 101-102; Raht, *The Romance of Davis Mountains,* 245-246.

37. Raht, *The Romance of Davis Mountains,* 127-131; 189.

38. *Ibid.,* 231-246. See Odie B. Fault, *The U.S. Camel Corps: An Army Experiment* (New York, 1976) for a concise and well documented study of Secretary of War Jefferson Davis' attempt to introduce African Camels in the Trans-Pecos region.

39. Barry W. Hutcheson, *The Trans-Pecos: A Historical Survey and Guide to Historic Sites,* (Lubbock, 1970), 113-114 and Clifford Casey, "The Trans-Pecos in Texas

History," West Texas Historical and Scientific Society *Publication,* No. 5 (1933), 15.

40. Utley, "Longhorns of Big Bend," 13.

41. U.S., Congress, Senate, *Reports of Exploration and Survey to Ascertain the Most Practical and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean,* Senate Executive Document 78, 33rd Congress, 2nd Session (Washington, 1856), Capt. John Pope, "Report of Exploration of a Route from the Red River to the Rio Grande," 8.

42. Utley, "Longhorns of the Big Bend," 20; 30-31.

43. *Ibid.,* 23.

44. James B. Gillett, "The Old G4 Ranch," *Voice of the Mexican Border,* October, 1933, 82-83.

45. R. D. Holt, "Pioneer Cattlemen of Brewster County and the Big Bend Area," *The Cattleman* 24 (June, 1942), 21-22, Gregg, "The History of Presidio County," 72 and Utley, "Longhorns of the Big Bend," 25-26.

46. Barry Scobee, "The First General Cattle Round-up of the Davis Mountains-Big Bend District," West Texas Historical and Scientific Society *Publication,* No. 3 (1930), 45-47.

47. Henry T. Fletcher, "From Longhorns to Herefords: A History of Cattle Raising in Trans-Pecos Texas," *Voice of the Mexican Border,* October, 1933, 64-66.

48. Madison, *The Big Bend Country of Texas,* Chapter 10, "Sheep in the Big Bend," 147-154.

49. Winifred Kupper, *The Golden Hoof: The Story of Sheep in the Southwest* (New York, 1945), 40; 61.

50. T. C. Davis, "The +IN Ranch; History and Development of a Pioneer Ranch," *Voice of the Mexican Border,* October, 1933, 77.

51. Hutcheson, *The Trans-Pecos,* 124-125.

52. Thomas U. Taylor, *Irrigation Systems of Texas,* Department of the Interior, United States Geological Survey (Washington, 1902), 19.

53. Interview with Mrs. Lucia R. Madrid, June 23, 1975 and Taylor *Irrigation Systems of Texas,* 20.

54. Gregg, "The History of Presidio County," 139.

55. Interview with Mrs. Lucia R. Madrid, June 23, 1975.

56. Samuel B. Buckley, "Trans-Pecos Texas," *Geological and Agricultural Survey of Texas* (Houston, 1876), 56.

57. U.S., Bureau of the Census, *Ninth Annual Census of the United States: The Statistics of the Population of the United States* (Washington, 1863), 64 and U.S., Bureau of the Census, *Eleventh Census of the United States: The Statistics of the Population of the United States* (Washington, 1894), 41.

58. Hutcheson, *The Trans-Pecos,* 126-128.

59. C. A. Hawley, "Life Along the Border," West Texas Historical and Scientific Society *Publication,* No. 44 (1964), 7-88; James M. Day, "The Chisos Quicksilver Bonanza in Big Bend of Texas," *Southwestern Historical Quarterly,* 64 (April, 1961), 427-450; Madison, *The Big Bend Country of Texas,* Chapter 13, "The Cinema of Cinnabar," 177-194 and see also, Kenneth B. Ragsdale, "History of the Chisos Mining Company: A Social and Economic Study of the Terlingua Quicksilver District," unpublished PhD Dissertation, University of Texas, 1974.

60. Ross A. Maxwell, *The Big Bend of the Rio Grande: A Guide to the Rocks, Geologic History, and Settlers of the Area of Big Bend National Park* (Austin, 1969), 95-99 and Douglas, *Farewell to Texas,* 80-82.

61. Interview with Ralph Hager, Foreman of the Big Bend Ranch, June, 1975.

62. Stacy C. Hinckle, *Wings and Saddles: The Air and Cavalry Punitive Expedition of 1919* (El Paso, 1967) and William D. Smithers, "Bandit Raids in the Big Bend Country," West Texas Historical and Scientific Society *Publication,* No. 19 (1963), 75-105.

63. Ronnie C. Tyler, "The Little Punitive Expedition in the Big Bend," *Southwestern Historical Quarterly,* 78 (January, 1975), 277-282. See also, Jodie P. Harris, "Protecting the Big Bend—A Guardsman's View," *Southwestern Historical Quarterly,* 78 (January, 1975), 292-302 for a contempary cartonnist's view of the duty in the Big Bend. For the raid on the Brite Ranch, see Noel L. Keith, *The Brites of Capote* (Fort Worth, 1950), Ch. 5, "Fury on Horseback," 107-127.

64. See Nancy Alexander, *Father of Texas Geology: Robert T. Hill* (Dallas, 1976) for a good biography of Hill. See especially Chapter 11, "Running the Canyons of the Rio Grande," 120-134 for a short summary of Hill's 1899 trip down the river. Another briefer summary of Hill and his work is in Ella F. Parker, "Robert Thomas Hill, Dean of Texas Geology" (unpublished MA Thesis, University of Texas, 1960).

65. Robert T. Hill, "Running the Cañons of the Rio Grande: A Chapter of Recent Exploration," *The Century Magazine,* 61 (January, 1901), 372-373.

66. *Ibid.,* 376.

67. *Ibid.*

68. *Ibid.*, 375.

69. Samuel J. Hensley to Robert T. Hill, February 24, 1901, Robert T. Hill MSS, Box 2N185, University of Texas Archives.

70. Hill, "Running the Cañons," 377-379.

71. Interview conducted by Mike McKann with Enrique Madrid, May 22, 1973, and used in his master's thesis, *The Recreational Potential of Chorro Canyon, Presidio County, Texas* (unpublished MA thesis, Texas Tech University, 1975.

72. Interview conducted by Mike McKann with Mrs. Hallie Stillwell, January 8, 1974, and used in his master's thesis, *The Recreational Potential of Chorro Canyon, Presidio County, Texas* (unpublished MA thesis, Texas Tech University, 1975).

73. For the only information available on the "avisador," see the William D. Smithers Photographic Collection of over 12,000 photos and descriptions in the Photographic Collection of the University of Texas, Austin, Harry Ransom Center, 6th floor.

74. Interview conducted by Mike McKann with Joe Brady, March 26, 1973, and used in his master's thesis, *The Recreational Potential of Chorro Canyon, Presidio County, Texas* (unpublished MA thesis, Texas Tech University, 1975).

75. *Ibid.*

THE GEOLOGIC ENVIRONMENT OF THE SOLITARIO, BREWSTER AND PRESIDIO COUNTIES, TEXAS

Dwight Deal

INTRODUCTION

The Solitario is one of the most unique and fascinating geologic areas of western North America and is an impressive place to visit. The rocks exposed in the center are so strikingly dissimilar from the surrounding country that even a visitor untrained in geology is impressed with the uniqueness of the area. The surrounding rim of limestone ridges visually isolates the Solitario; this, plus the difficulty of access, resulted in the early Spanish settlers referring to this place as "El Solitario."

This report is prepared for the Natural Areas Survey, Center for Natural Resources and Environment, The University of Texas at Austin. The basic resource documents describing the geology of the Solitario are a Ph.D. dissertation (Herrin 1958) and a Master's thesis (Corry 1972). The appendices to this report are taken essentially in total from Corry's thesis and are used with his permission. I have visited the area on numerous occasions since 1967 and spent 10 days there in June of 1975 with the Natural Areas Survey field party.

This report is designed to provide a comprehensive overview of the geology of the Solitario to be used by both geologists and interested laymen. Although I have attempted to reduce geological jargon to a minimum in this report, some users may find it helpful to refer to the *Glossary of Geology* (Gary and others 1972). The area is geologically extremely complex and those desiring a more detailed description of the geology are referred to the works by Herrin and Corry.

The Solitario is a remarkably circular, domed uplift approximately 13 km (eight miles) in diameter on the Presidio-Brewster County line in the Big Bend area of Texas. The outer rim of the Solitario is formed by a circular band of limestone mountains of Cretaceous age, everywhere dipping steeply outward away from the center of the uplift. The center of the dome has been eroded, exposing complexly folded and faulted older rocks of Paleozoic age. The center of the Solitario is generally topographically lower than the surrounding limestone hills, although occasional resistant ridges rise to comparable elevations. Most of the drainage from the interior of the Solitario passes through four steep and narrow canyons, locally called "shutups," through the limestone mountains. Fresno Creek flows southward past the western edge of the Solitario, separating the largely sedimentary terrain of the Solitario from the Bofecillos volcanic field to the west.

Because the geologic history of the Solitario is so complex, it is helpful to think in terms of the following sequence of geologic events:

1) The deposition and subsequent intense folding and faulting of the old sedimentary rocks of Paleozoic age which are now exposed in the eroded interior of the Solitario.

2) The later deposition of the limestones and associated sedimentary rocks of Cretaceous age.

3) The intrusion of magma and associated igneous activity that accompanied the domal uplift of the Solitario itself.

4) The later volcanic activity, including lava flows and volcanic ash falls, associated with the initial erosion of the Solitario and the contemporaneous growth of the Bofecillos Volcano to the west of the Solitario.

5) The exhumation of the center of the Solitario by tributaries of Terlingua and Fresno Creeks, the creation of the landscape as we see it today, and the deposition of young stream and slope deposits.

PREVIOUS WORK

Geologists have long been fascinated with the complex of rocks exposed in the Solitario. Investigations of the Terlingua-Solitario region of the Big Bend country began soon after the Apache and Comanche Indians were driven out of the area by the westward expansion of the Anglo settlement following the Civil War. Most of Trans-Pecos Texas was covered by Von Streeruwitz in 1890, but he apparently did not visit the Solitario. Near the turn of the century, G. K. Gilbert, J. A. Udden, and R. T. Hill visited the area but nothing on the Solitario was published by Gilbert or R. T. Hill. Udden and B. F. Hill (1904) did include the Solitario in their "Geologic Map of a Part of West Texas." Then, in 1907, Udden described the general

The Solitario Uplift.
Oblique aerial photograph looking north-northwest, taken on September 19, 1972.
Copyright 1974 by Pioneer Nuclear, Inc.

structural and stratigraphic relations between the Solitario and the surrounding country.

Powers in 1921 first described the Solitario in detail. He noted the wide range of rock units present and observed that any explanation of the origin of the dome must account for both the intrusive and extrusive igneous activity found within the central basin. He also compared the origin of the Solitario with the origin of the Wells Creek Basin in Tennessee, which has since been shown to be an impact structure. That comparison provided the stimulus for Corry's (1972) Master's thesis.

Sellards (1932, 1933) and Sellards and others (1933) described overthrusting in the Solitario and pointed out the similarity in structure and stratigraphy of the Solitario, the Marathon Uplift, and the Ouachita Mountains of Arkansas and Oklahoma. Sellards and others (1931) also published a geologic map of the Solitario based on the Terlingua 1:125,000 topographic quadrangle.

J. T. Lonsdale in 1940 made a comprehensive investigation of the igneous rocks in the Terlingua-Solitario region. He concluded that the Solitario dome most likely originated as a result of the intrusion of an underlying laccolith.

Herrin (1958) completed a detailed study of the stratigraphy of the Solitario for a Ph.D. dissertation at Harvard University.

J. L. Wilson (1954) described the general features of the stratigraphy of the Ordovician rocks in the southern Marathon region and the Solitario. King's (1937) classic paper on the Marathon region still serves as a standard for the understanding of the Paleozoic stratigraphy within the Solitario dome. A number of quadrangles around the Solitario dome have been mapped. The Agua Fria Quadrangle to the northeast was mapped by Moon (1953), and Erickson (1953) mapped the Tascotal Mesa Quadrangle to the north. McKnight (1970) mapped the Bofecillos volcanic field to the west of the Solitario, a map which included the western and southwestern portions of The Solitario Quadrangle.

Flawn and others (1961) have presented an overview of the Ouachita System including the Paleozoic history of the Solitario. Maxwell and others (1967) mapped the geology of Big Bend National Park southeast of the Solitario dome.

The most comprehensive work within the Solitario was that of Herrin (1958), who mapped and measured the stratigraphy of the area in great detail at the expense of several years labor. Corry's (1972) primary interest was in the origin of the Solitario dome, and although he spent six weeks in the field within the Solitario in the fall of 1971, he relied heavily upon Herrin's earlier studies. Corry did make some modifications to Herrin's stratigraphic section, primarily in revising the nomenclature to correlate Herrin's work with the later works of Maxwell and others (1967), McKnight (1970), and C. I. Smith (1970). These later workers added considerably to our knowledge of the Cretaceous and volcanic sequences. Corry's principal object was to supplement Herrin's (1958) work on the structure of the Solitario dome and to determine the origin of it. He redrew Herrin's geologic map on the new topographic quadrangle, The Solitario, published at the scale of 1:24,000 with a contour interval of 40 ft. by the U.S. Geological Survey in 1971. Corry also included part of McKnight's (1970) mapping in his geologic map of the Solitario (Corry 1972: Fig. 1). A copy of that map, recently revised by Corry, is reproduced as the geologic map of the Solitario which accompanies this report.

More recently, additional geologic investigations have been undertaken by Pioneer Nuclear in its mineral exploration program within the Solitario. Its drilling information should provide valuable insights into the origin of the Solitario, but at this time the results of that program are not public information. The General Land Office, primarily concerned with state land within the Solitario and Fresno Canyon area, compiled a file report on the area which summarized, in a general way, the geology and natural history of the area (McKann and others 1973).

Charles Groat (oral communication August 1975) indicated that Corry, Herrin, and McDowell are preparing a revised geologic map of the Solitario Quadrangle for publication by the Texas Bureau of Economic Geology. Fred McDowell and his coworkers at The University of Texas at Austin are in the process of determining the radioactive isotope ages of the volcanic rocks in the Bofecillos Mountains and surrounding areas, including the rim sill in the Solitario. Their age determinations are not yet available.

I have visited the area repeatedly since 1967 with student groups, other geologists (including a weekend with Corry), and The University of Texas Natural Areas Survey field team. Although the detailed mapping indicated some minor errors in Corry's map (1972: Fig. 1), it is substantially correct and is more than adequately accurate for the purposes of this report.

PHYSIOGRAPHY AND ACCESS

The rim of limestone hills (Fig. 1), marking the outer edge of the Solitario, has summit elevations that range between about 1300 and 1550 m (approximately 4500 and 5000 ft) in elevation. The floor of

FIGURE 1

The Solitario Rim. View is southward from the summit of Fresno Peak. Mountains in the distance are south of the Rio Grande and in Mexico. Photo by Dwight Deal

FIGURE 2

Interior of the Solitario. Rim escarpment in background. Photo by Dwight Deal the interior of the Solitario (Fig. 2) ranges in elevation from 1250 to 1350 m (approximately 4100 to 4400 ft) above sea level. The occasional hills of resistant chert or igneous material rise to elevations between 1400 and 1550 m (approximately 4600 and 5000 ft). From the top of most of the higher hills in the central basin, vistas of the higher mountains in the distance, outside of the Solitario, can be seen through gaps in the limestone rim.

The Central Basin

Vehicular access to the central basin of the Solitario is usually from the north. One extremely rough four-wheel-drive road enters from the southeast but is rarely used. Ranch roads make two circular loops in the central basin, the "inner loop" and the "outer loop." This terminology has been used informally by geologists visiting the area and is slightly misleading. The northern and eastern portions of both loops are the same, extending from a road junction approximately 1.4 km (0.9 mile) southwest of McGuirks Tanks northeasterly to the junction with the northern access road, easterly across the Brewster-Presidio County line to the tank known as Rodriguez (or East) Tank to a point providing easy access to the Lefthand Shutup, where the road turns south to Tres Papalotes. This portion of the ranch road network within the Solitario is normally traversable by a pickup truck and on two occasions, once in the fall of 1965 and once again in the fall of 1972, the West Texas Geological Society successfully visited Tres Papalotes in several large Greyhound buses (Fig. 3). From Tres Papalotes the road continues southwestward crossing the Presidio-Brewster County line in an arroyo bottom to a road junction north of a point about halfway between Needle Peak (Black Needle Peak) and Eagle Mountain. Travel on the rest of the road network within the Solitario commonly requires a four-wheel-drive vehicle.

At the road junction northwest of Eagle Mountain, the inner loop turns northwestward, circling northward along the western edge of the limestone hills (the central graben) in the very center of the Solitario, past a large earthen tank, to the road junction 1.4 km from McGuirks Tanks. The road to the west is the outer loop and leads to the Righthand Shutup.

The lefthand road at the junction northwest of Eagle Mountain continues southward to a point approximately 500 m east of the summit of Needle Peak where there is another road junction in an arroyo bottom. The outer loop turns right, passing south of Needle Peak, turning northwestward along the eastern base of the southwestward-dipping limestone sequence which forms Fresno Peak, through the headwaters of the drainage passing through Los Portales Shutup to Burnt Camp, and then through the headwaters of the drainage to the Righthand Shutup, turning eastward south of Solitario Peak and joining the inner loop at the road junction southwest of McGuirks Tanks.

From the road junction in the arroyo bottom just east of Needle Peak, the lefthand fork follows down the drainages to the Lower Shutup and then turns eastward, steeply ascending the limestones of the rim escarpment. This road is usually in very bad condition but eventually does lead southeasterly across the rim escarpment and joins a network of jeep trails that lead into Saltgrass Draw to the east and Contrabando Creek to the south.

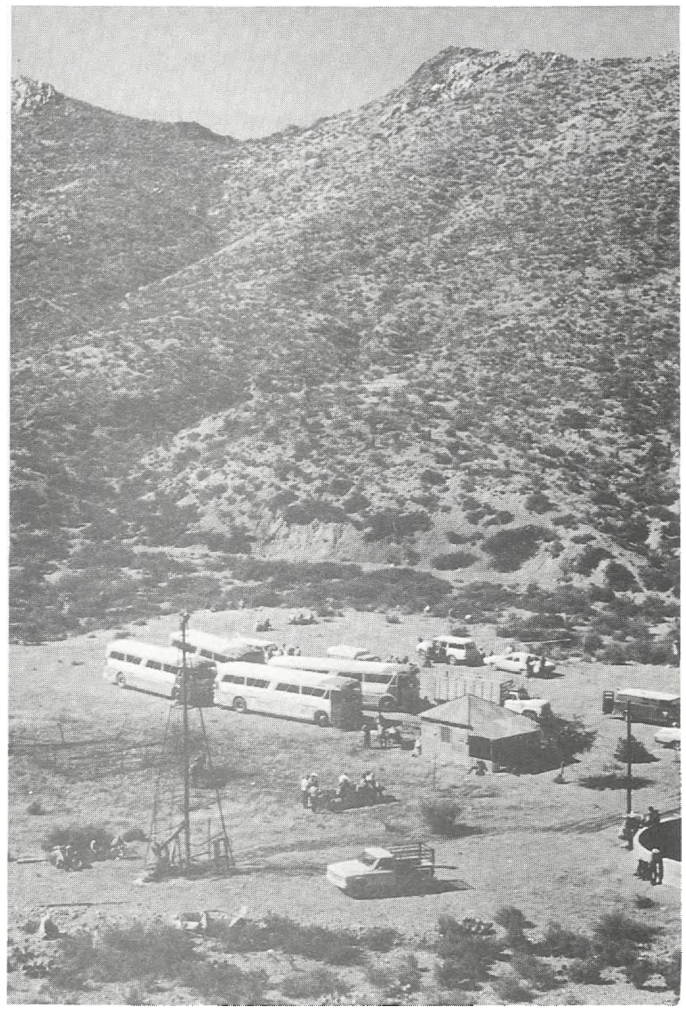


FIGURE 3

The West Texas Geological Society at Tres Papalotes in 1972. The trip to view the geological wonderland in the center of the Solitario attracted professional geologists from across the nation and was the second time the Society brought large Greyhound buses into the area. Big Bend Ranch expended considerable effort to prepare the road, which stayed in good condition only until the next rain. Photo by Dwight Deal

There is a new road network on the north side of the central hills, south of Rodriguez Tank and west of Tres Papalotes, constructed by Pioneer Nuclear to reach drill sites for their mineral exploration program in the Solitario.

Following the lead of Herrin (1958) and Corry (1972), I find it convenient to divide the physiography of the central basin into several units, each reflecting a characteristic geology and topography:

1) Shale lowlands. These are the lowlands eroded from the soft shales of the Tesnus Formation of Mississippian-Pennsylvanian age. Typical examples of this type of physiography are the narrow valley at Tres Papalotes and the lowlands northwest of Needle Peak.

2) Lowlands with low ridges about 10 m high. These areas are characteristically underlain by sandstones and silty limestones of the Cambrian Dagger Flat Sandstone and the lower Ordovician Marathon Formation. This type of physiography characterizes much of the northern part of the central basin, north of the central limestone hills and south of McGuirks and Rodriguez Tanks.

3) Ridges with intermediate heights of about 30 m. These are usually held up by well-cemented sandstones of Ordovician age and occur at scattered locations throughout the basin.

4) High ridges standing up to 150 m above the basin floor. These are formed by the black, white, and green chert of the Maravillas Formation and the Caballos Novaculite of Devonian, Mississippian, and Ordovician ages. These hard and resistant rocks form most of the high ridges within the basin (such as those in the vicinity of Tres Papalotes, north of Rodriguez Tanks, and east of Burnt Camp).

5) The limestone hills of the central block. A large down-dropped block of Cretaceous limestone occurs inside the inner loop, in the center of the Solitario basin. This block forms the "crestal graben" and is extensively intruded and overlain by igneous rocks. Most of the block dips gently to the south, but the northern edge is sharply upturned with vertical and near-vertical beds.

6) The volcanic lowlands. A fairly large area of lowlands eroded from soft, light-colored volcanic tuff and agglomerate (volcanic ash and associated stream and mud-flow sediments) occurs in the southeastern portion of the central basin. This is the area erroneously referred to by Lonsdale (1940) and shown on the geologic maps accompanying the two West Texas Geological Society guidebooks to the area (1965, 1972) as the "volcanic vent area."

7) Resistant volcanic peaks. Several igneous intrusions are more resistant than the surrounding sedimentary and volcanic rocks and form dark, resistant peaks. Examples include Solitario Peak (Fig. 4) in the northwestern portion of the Solitario, Needle Peak in the south, and a low resistant ridge with prominent horizontal columnar jointing in the northern part of the central basin just west of Rodriguez Tank (called the "Woodpile" by Corry).

The Rim Escarpment and the Shutups

The rim escarpment, a rugged outcropping of steeply dipping limestones of Cretaceous age, surrounds the central basin. It averages about 1.4 km (4700 ft) above sea level and 100 m (300 ft) above the interior basin. The average width of the rim escarpment is about 3 km (less than two miles), and its outside dimension is approximately 13 km (about eight miles) in diameter.

The interior basin of the Solitario is drained by four major streams, which cut narrow canyons (shutups) through the limestone rim. The shutups have received their names by directional reference from the commonly used access road from the north. The main stream network in the northern part of the interior of the Solitario, draining the area around McGuirks Tanks and Tres Papalotes, passes through the Lefthand Shutup (which cuts the northeasterly rim of the Solitario) and flows into Terlingua Creek to the east. The stream course through the Lefthand Shutup is about four and three-fourths kilometers (approximately three miles) long, decreasing from approximately 1250 to 1150 m (approximately 4100 to 3800 ft) in elevation, having an approximate grade of 20 m per kilometer (about 100 ft per mile). At one point the walls rise about 180 m (approximately 600 ft) above the canyon floor.

The southern part of the interior of the Solitario drains the area of volcanic tuff lowlands (erroneously referred to in some reports as the "vent" area) in the vicinity of Needle Peak and Eagle Mountain. This drainage cuts through the southerly rim of the Solitario in one of the most impressive limestone canyons in west Texas, the Lower Shutup. The canyon floor is approximately four and one-half km (approximately two and three-fourths miles) in length, slightly shorter than that of the Lefthand Shutup. The gradient of the Lower Shutup is steeper, dropping approximately 45 m per kilometer (about 250 ft per mile) from approximately 1250 to 1050 m (approximately 4100 to 3400 ft) above sea level, and the canyon walls are higher, ranging up to 230 m (about 750 ft) above the floor of the shutup. The Lower Shutup drains southward into Fresno Creek, joining it just north of the Wax Factory Laccolith.

Two shorter tributaries of Fresno Creek drain the western portion of the interior of the Solitario, cutting the Righthand Shutup, just south of Solitario

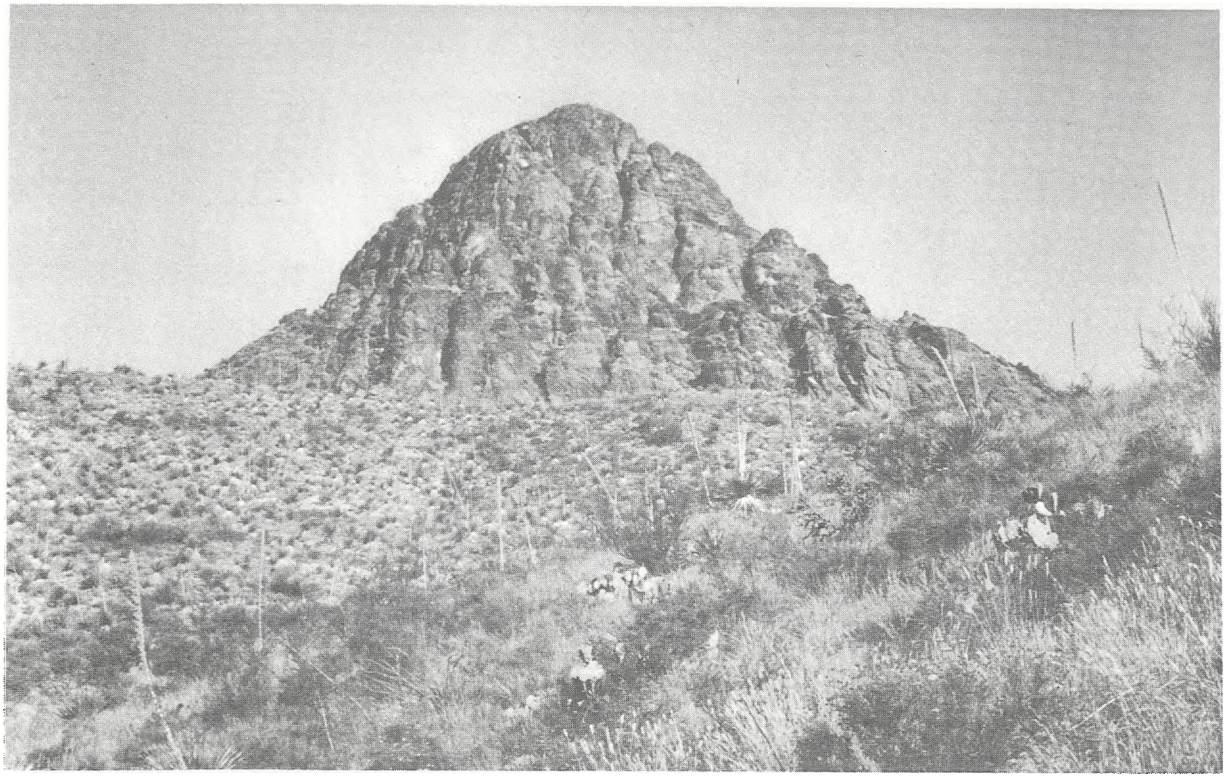


FIGURE 4

Solitario Peak. This volcanic neck intrudes the northwest rim of the Solitario.
Photo by Dwight Deal

Peak and the Los Portales Shutup, just north of Fresno Peak. Both of these shutups are shorter, approximately two and one-half km (about one and one-half miles) in length, have steeper gradients (approximately 80 m per km or 400 ft per mile), and have canyon walls that range up to 180 m (600 ft) in height.

The walls of the shutups are particularly spectacular because the outward dip of the limestones of the rim escarpment often reaches 50°. Flowing water is rare in the shutups, except after torrential rains. During the flash floods, very large rocks are moved through them. Corry (1972:97) noted a block of limestone approximately six m by six m by six m (nearly 20 ft on a side) in Los Portales Shutup, overlying a 55-gallon drum in the arroyo bottom. Standing water in isolated bedrock pools, "tinajas," are usually found in the shutups, even in the drier seasons.

Fresno Canyon

Outside the Solitario and west of the rim escarpment, Fresno Creek drains southward and has excavated a major canyon. Fresno Creek and its tributaries have eroded the western edge of the steeply dipping limestones, forming prominent flatirons in the area of Los Portales. The western edge of Fresno Canyon is formed by volcanic rocks of the Bofecillos volcanic field. Southwest of the Solitario rim and east of Fresno Creek are exposed a sequence of volcanic tuffs on top of Cretaceous clays and flaggy limestones. The geology of the Fresno Canyon area and of the Cretaceous rocks above the massive limestones of the rim escarpment is described in a companion volume (Deal 1976a).

CLIMATE

No climatic records have been kept in the Solitario itself. A U.S. Weather Bureau Station was in operation in Presidio from 1957 to 1969. Dietrich (1965:14-23) presented a fairly elaborate discussion of both regional and local climate of the Presidio and Bofecillos Mountain area just to the west of the Solitario. He went into a rather detailed discussion of the Koppen classification of climate, analyzed the climatological data from 27 meteorological stations in Trans-Pecos Texas (Fig. 5). The data from the eight U.S. Weather Bureau stations is shown in Table 1, arranged in order of decreasing station elevation to

Table 1 — Climatological data, eight U.S. Weather Bureau stations in Trans-Pecos Texas.
(from Dietrich 1965: Table 2)

STATION		TEMPERATURE								PRECIPITATION		KOPPEN CLASSIFICATION	
		Extremes				Means							
		High		Low									
Name	Elevation (ft. above MSL)	°F	Year	°F	Year	Jan. (°F)	July (°F)	Annual (°F)	Record period *	Mean annual (inches)	Record period *	r = o.44t - 3	Climate symbol
Mt. Locke	6790	98	1962	−10	1962	41.7	70.0	57.2	†1945-63	18.72	1945-63	25.17	*BSk*
Chisos Basin	5300	102	1958	− 3	1949	48.9	74.8	63.2	†1948-63	15.19	1949-63	27.80	*BSk*
Alpine	4433	106	1932 1936	− 2	1933	46.7	77.4	63.2	WBN	15.42	WBN	27.80	*BSk*
Van Horn	4050	108	1951	− 7	1962	44.3	80.4	62.8	†1942-63	9.52	1939-63	27.63	*BWk*
El Paso	3918	109	1960	− 8	1962	43.9	81.4	63.6	WBN	7.89	WBN	27.98	*BWk*
Balmorhea	3225	112	1939	− 9	1933	47.3	81.1	65.1	WBN	12.68	WBN	28.64	*BWh*
Ft. Stockton	2995	114	1907 1934	− 7	1911	47.6	82.2	66.1	†1931-60	16.45	†1931-60	29.08	*BSh*
Presidio	2582	117	1957 1960	+ 4	1962	49.8	86.5	69.5	WBN	8.31	WBN	30.58	*BWh*

*WBN: Weather Bureau normal for 1931-1960.
†: Some records missing.
Data sources. — Normals (WBN) from U.S. Weather Bureau (1962, p. 4); other means calculated from data in the office of the State Climatologist, Robert B. Mueller Airport, Austin, Texas.

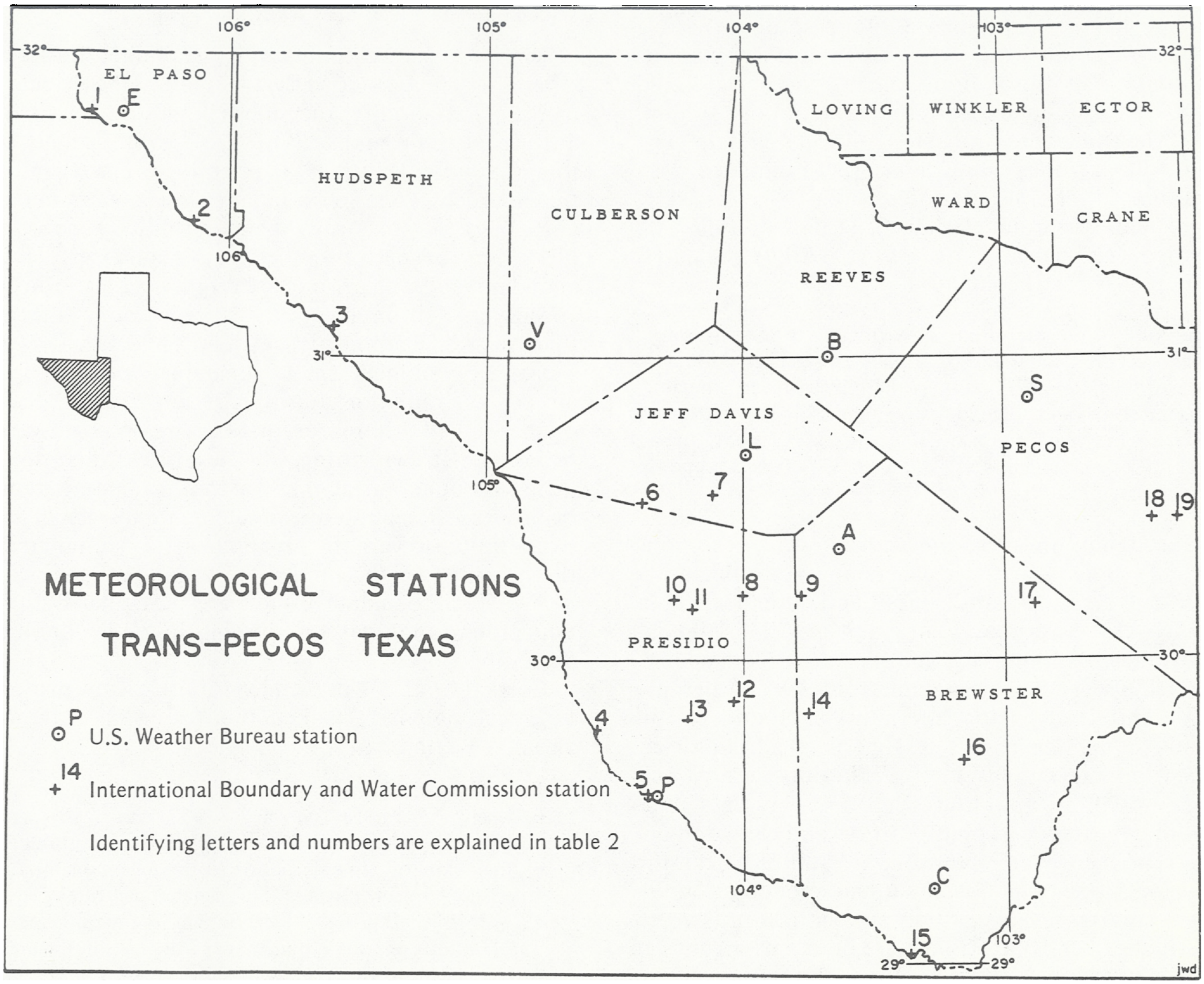


FIGURE 5

Twenty-seven selected meteorological stations in Trans-Pecos Texas. (From Dietrich 1965: Fig. 4)

emphasize the high degree of correlation between elevation and temperature. Mean annual precipitation increases from west to east at stations with comparable elevations and also increases with an increase in elevation. Dietrich (1965:16) applied the Koppen classification to each of these stations and concluded that they all have a dry climate. Four stations have a steppe (*BS*) climates. The three higher stations (Mount Locke, Chisos Basin, and Alpine) have a cold steppe (*BSk*) climate, and the easternmost station, Fort Stockton, has a hot steppe (*BSh*) climate. The other four stations have desert (*BW*) climates. Van Horn and El Paso are classified as having cold desert (*BWk*) climates, and Balmorhea and Presidio are classified as having hot desert (*BWh*) climates. Dietrich (1965:16) concludes:

> The steppe climate probably extends to the highest peaks in the mountains of Trans-Pecos Texas. Mount Locke (elevation 6790 ft) has the highest mean annual precipitation and the lowest boundary precipitation value of the eight stations. Its steppe (*BS*) classification would remain unchanged if the station received one-third more precipitation.

Data from those eight climatological stations (Table 1) show that the mean temperature decreases one to one and one-half degrees Centigrade per 100-m (two to three degrees Fahrenheit per 1000-ft) increase in elevation.

Dietrich also considers data from 19 weather stations maintained by the International Boundary and Water Commission (Table 2; Fig. 5) and has plotted the station elevation for all 27 stations against the mean annual precipitation (Fig. 6). This data indicates that both geographic position and elevation obviously influence precipitation. At stations near the same longitude, the mean annual precipitation increases five to seven centimeters per 100-m (two to three inches per 1000-ft) increase in elevation, and, at stations near the same elevation, the mean annual precipitation increases from west to east.

Dietrich (1965:21) calculates that with no change in the mean annual temperature, 85% increase (18 cm or seven in) in the mean annual precipitation at Presidio would be required to change the classification from hot desert climate (*BWh*) to steppe. He went on to approximate temperature gradients in the area from the regional data and calculated that the boundary between desert and steppe climate should occur about 1500 m (4900 ft) above mean sea level. If he is correct, then the desert-steppe boundary is near the tops of the higher peaks in the Bofecillos Mountains and the Solitario.

Dietrich (1965:22-23) also presents a good discussion of the effect of surface water:

> The U.S. Weather Bureau collects temperature data from a uniform height above the surface site selected to give data representative of large areas. These data accurately reflect the macroclimate, the climate above a thin boundary layer of air near the surface. The microclimate, the climate within the boundary layer a few inches to a few feet thick, is highly variable.

Where the macroclimate is near the borderline separating steppe and desert climates, the effects of factors that modify the microclimate are dramatic. Surface attitude and texture are two important factors that affect surface temperature, and therefore the microclimate. South-facing slopes, more nearly normal to the sun's rays than north-facing slopes, or the floors of narrow-walled canyons, receive more abundant energy per unit area and are a little hotter and dryer. Soil on an open surface is hotter and drier than the soil in pockets between large boulders because the boulders shield the small pockets from direct solar radiation during part of the day. Because of these small differences, grass grows on north-facing or boulder-strewn surfaces at elevations where south-facing or open surfaces are barren. A tank, a spring, or flowing stream modifies the climate in a small area. Evaporation lowers the air temperature and increases the humidity in the immediate vicinity of the water.

These microclimate effects are particularly important around the tinajas in the shutups which drain the Solitario.

Corry (1972:3), drawing on information provided by local ranchers, makes the following statement about the climate in the Solitario:

> Rainfall in the area averages about 40 cm but varies between 8 cm (during 1947-1957) and 100 cm (1974-1975). Most of the rainfall occurs in the summer in the form of violent thunderstorms occasionally accompanied by high winds. Summer temperatures often exceed 40°C. But nights are normally cool and breezy. The humidity is usually fairly low. The peaks in the area occasionally receive some light snow in the winter, and the annual mean temperature is about 16°C.

GEOLOGIC HISTORY

Paleozoic Stratigraphy

The complex of rocks exposed within the Solitario can conveniently be divided into four groups. The stratigraphic section is shown both on the legend for the geologic map of the Solitario which accompanies this report and in Table 3. The oldest and most complexly folded and faulted rocks are those exposed in the center of the Solitario that are of Paleozoic age (approximately 550 to 300 million years ago). The details of the Paleozoic stratigraphy are outlined in

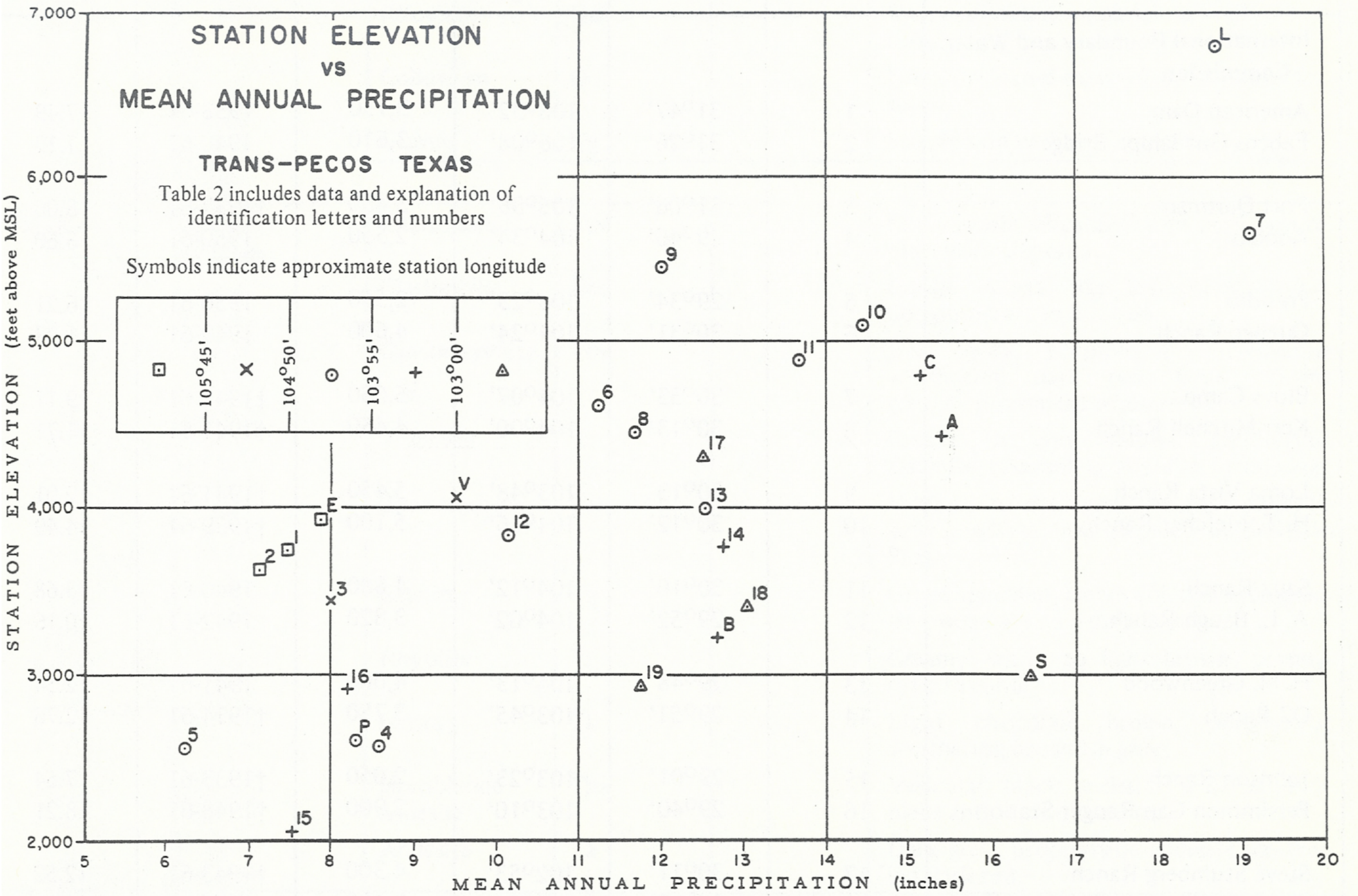


FIGURE 6

Station elevation versus mean annual precipitation at 27 stations in Trans-Pecos Texas. (From Dietrich 1965: Fig. 5)

Table 2 – Mean annual precipitation and geographic data, 27 stations in Trans Pecos Texas.
(from Dietrich 1965: Table 3)

STATION					PRECIPITATION	
Name	Symbol *	Location Lat.	Location Long.	Elevation (ft. above MSL)	Record period **	Mean annual (inches)
International Boundary and Water Commission						
American Dam	1	31°47'	106°32'	3,730	1938-61	7.49
Fabens-Guadalupe Bridge	2	31°26'	106°08'	3,610	1940-61	7.12
Fort Quitman	3	31°06'	105°36'	3,430	†1937-61	8.00
Adobes	4	29°46'	104°34'	2,550	1950-61	8.60
Presidio	5	29°34'	104°23'	2,550	1950-61	6.21
Quebec Ranch	6	30°31'	104°24'	4,600	1949-61	11.28
Bloys Camp	7	30°33'	104°07'	5,650	†1941-61	19.11
Kerr Mitchell Ranch	8	30°13'	104°00'	4,450	†1941-61	11.71
Loma Vista Ranch	9	30°13'	103°48'	5,450	†1941-61	12.01
H. T. Fletcher Ranch	10	30°12'	104°16'	5,100	†1939-61	14.49
Sauz Ranch	11	30°10'	104°12'	4,880	1940-61	13.68
A. L. Baugh Ranch	12	29°52'	104°02'	3,820	1942-61	10.16
H. M. Greenwood	13	29°48'	104°13'	4,000	1941-61	12.54
O2 Ranch	14	29°51'	103°45'	3,780	†1914-61	12.76
Johnson Ranch	15	29°01'	103°23'	2,050	†1933-61	7.54
Persimmon Gap Ranger Station	16	29°40'	103°10'	2,900	†1948-61	8.21
Steve Stumberg Ranch	17	30°11'	102°53'	4,300	†1943-61	12.52
Arvin and Harkins Header	18	30°27'	102°26'	3,400	1949-61	13.02
Arvin and Harkins Headquarters	19	30°27'	102°20'	2,930	1949-61	11.77
U.S. Weather Bureau						
El Paso	E	31°48'	106°24'	3,918	WBN	7.89
Van Horn	V	31°02'	104°51'	4,050	1939-63	9.52
Presidio	P	29°33'	104°24'	2,582	WBN	8.31
Mt. Locke	L	30°22'	104°00'	6,790	1945-63	18.72
Balmorhea	B	31°00'	103°41'	3,225	WBN	12.68
Alpine	A	30°22'	103°39'	4,433	WBN	15.42
Chisos Basin	C	29°16'	103°18'	5,300	1949-63	15.19
Fort Stockton	S	30°52'	102°55'	2,995	†1931-60	16.45

*Station identification on map (Fig. 2) and diagram (Fig. 3)
**WBN: Weather bureau normal for 1931-1960.
†: Some records missing.
Data sources. – International Boundary and Water Commission stations (I.B.C, 1961).
U.S. Weather Bureau stations: normals (WBN) from U.S. Weather Bureau (1962, p. 4); other means calculated from data in the office of the State Climatologist, Robert B. Mueller Airport, Austin, Texas.

Table 3 – Geologic Formations in The Solitario Quadrangle
(from Corry 1972: Table 4)

Age	Group	Formation or Rock Type	Map Symbol	Thickness, m.	Character
Quaternary		Alluvium	Qal		Unconsolidated material in valley bottoms.
		Colluvium	Qc		Unconsolidated material on flanks of features.
		Gravels	Qg		Stream and pediment gravels.
Unconformity					
Tertiary	Intrusive Igneous	Chalcedony	Tcv		Chalcedonic silica as fissure veins and replacement deposits.
		Clastic dike	Tcd		Clastic quartz dike resembling Shutup Conglomerate in outcrop.
		Olivine syenite	Tos		Dark grey, porphyrytic microsyenite weathering dark red. Green olivine crystals prominent when fresh.
		Trachyte	Tt		Cream to grey colored prophyrytic trachyte resembling rhyolite in outcrop.
		Soda trachyte	Tst		Medium to dark grey, microporphyrytic soda trachyte best exposed at Solitario Peak.
		Granite	Tg		Green speckled, cream colored microgranite, weathers to a dark brown.
		Rhyolite	Tr		Creamy white to light brown, porphyrytic rhyolite.
		Latite	Tl		Light chocolate brown, porphyrytic weathering brownish gray.
		Hornblende andesite	Tha		Vesicular black andesite with common blebs and veins of calcite.
		Andesite	Ta		Dark grey, prophyrytic andesite weathering dark red.
Miocene ?	Extrusive Igneous	Needle Peak Tuff	Tbn	10+	Light grey lithic tuff.
		Rawls Formation	Trf	~250	Undifferentiated tuff, ignimbrites, trachyandesite, trachyte, latite porphyry, basalt, trachybasalt porphyry (extrusive volcanics) with some associated sandstone and conglomerate.
		Santana Tuff	Ts	1.5	Non-welded tuffs to thoroughly welded vitric-crystal ignimbrites.
Oligocene ?		Fresno Formation	Tf	~300	Undifferentiated tuff, ignimbrites, trachyandestes, latite, latite porphyry, basalt, rhyolite, and lahars with some associated sandstone and conglomerate.
		Mitchell Mesa Tuff	Tmm	6 to 15	White to buff tuff grading upward into a thoroughly welded ignimbrite.
Eocene ?		Chisos Formation	Tc	150 to 250	Undifferentated tuffs and basalt with associated sandstone, conglomerate, and non-marine limestone.
		Jeff Conglomerate	Tj	1 to 6	Well rounded limestone cobble and boulder conglomerate in well cemented sandstone matrix.

Age	Group	Formation or Rock Type	Map Symbol	Thickness, m.	Character
Oldest Tertiary	Intrusive Igneous	Solitario Peak rhyolite	Tsp	25± (4.5 to 92)	Grey, porphyrytic intrusive rhyolite sill weathering to a dark brown or maroon.
Unconformity					
Upper Cretaceous	Terlingua	Boquillas Formation	Kbt	60	Slabby, sandy limestone and clay.
Disconformity					
Lower Cretaceous	Washita	Buda Limestone	Kb	30+	White, thick bedded limestone.
		Del Rio Clay	Kdr	98	Drab shale with sandy partings. Contains abundant gypsum.
		Santa Elena Limestone	Kse	250	Massive limestone with bedded chert.
		Sue Peaks Formation	Ksp	57	Marly limestone weathering yellowish.
	Fredricksburg	Del Carmen Limestone	Kdc	209	Massive hard cherty limestone, weathers brown and contains abundant rudistids.
		Telephone Canyon Formation	Ktc	58	Nodular limestone and marl.
	Trinity	Glen Rose Formation	Kgr	353	Alternating beds of massive limestones and highly fossiliferous marl.
		Yucca Formation	Ky	210	Sandy limestone and marl grading into massive grey limestone at top.
		Shutup Conglomerate	Kc	30	Chert boulder conglomerate, weathers deep purple.
Angular unconformity					
Mississippian-Pennsylvanian	Ouachita facies	Tensus Formation	IPt	1410+	Thick alternating beds of black siliceous shale and massive greenish brown quartzite.
Unconformity					
Devonian-Mississippian		Caballos Novaculite	Dc	84	White novaculite and dark bedded chert.
Unconformity					
Upper Ordovician		Maravillas Chert	Omv	58	Black bedded chert with a few grey limestone lenses.
		Woods Hollow Shale	Ow	118	Black shale with thin beds of brown sandstone.
Middle Ordovician		Fort Peña Formation	Op	122 ?	Massive buff sandstone, quartzite, quartzose limestone and chert.
Lower Ordovician		Marathon Formation	Omf	610	Black shale with some calcareous sandstone and limestone; flaggy blue limestone near middle.
Upper Cambrian	Ouachita facies	Dagger Flat Sandstone	Cd	183	Massive grey impure sandstone and dark shale.

Appendix 1. Briefly, from oldest to youngest, the section consists of the following: the Dagger Flat Sandstone of Cambrian age; the Marathon Formation (black siliceous shale, sandstone, sandy limestone, dark chert, and blue limestone), the Fort Peña Formation (limestones, sandy limestones, and cherts), the Woods Hollow Shale (fine-grained shale with some flaggy sandstones and siltstones), and the Maravillas Chert (black bedded chert with a few limestone lenses and some intraformational conglomerates), all of Ordovician age; and the Caballos Novaculite (white chert) of Devonian-Mississippi age. The two chert units (the Maravillas Chert and the Caballos Novaculite) are the prominent ridge formers within the Solitario. The total thickness of the measured Paleozoic section in the Solitario is approximately 2600 m

Late Paleozoic Mountain Building

A major series of mountain-building events followed the deposition of the Paleozoic rocks in Late Pennsylvanian-Early Permian time (Flawn and others 1961:188). These events were part of what is called the Ouachita Orogeny, a major and continuous band of folding that extended across much of the southern United States, comparable in age and type to the Appalachian Mountain structures of the eastern United States. The axis of the Ouachita fold belt extends northeastward from the Solitario to the Marathon Basin, then eastward and northward underneath the Edwards Plateau to the Ouachita Mountains in central Arkansas. The coastal plain sediments of the Mississippi Valley obscure the folded rocks in eastern Arkansas, western Tennessee and Mississippi. Since the rocks in the Ouachita Mountains are similar in age and structure to the Appalachian fold belt in the eastern United States, geologists traditionally have considered the Appalachian and Ouachita mountain building periods to be correlative. Recent information from drilling in Florida and investigations of the geology of north Africa (John Ferm, oral communication) suggests that the Ouachita Orogeny may be slightly older than the Appalachian Orogeny and that the Ouachita folds extend eastward beneath the Florida coastal plain and continue in the Atlas Mountains of Morocco. At that time the Atlantic Ocean had not yet come into existence; the east coast of Florida and the west coast of Africa were in contact. Continental drift, with the North American plate moving relatively westward and with spreading occurring along the length of the Mid-Atlantic Ridge, may subsequently have separated the once continuous fold belts.

The widely held view that the Ouachita and Appalachian Orogenies represent the same major mountain-building event has led to the common remark in introductory geology classes that the Big Bend area is "the place where the Appalachian and Rocky Mountains meet." More data is necessary before the larger associations of the Ouachita folding can be precisely determined. I admit to feeling a preference for thinking of Trans-Pecos Texas as being more closely related to the Sahara than to the humid and cool northeastern United States.

The Solitario contains the most southwestward good exposures of the Ouachita folds. Flawn and others (1961:Pl. 1) extend the Ouachita folds about 100 km further west from drill hole data and limited exposures in Mexico.

The axis of the Ouachita fold belt in the Solitario-Marathon region trends northeast to southwest with thrusting and compression from southeast to northwest. Flawn and others (1961:165) place the Solitario dome in the frontal zone of the Ouachita folds on the margin of a land mass that existed to the north and west. They found that the frontal zone in the Solitario, the Marathon area, and the Ouachita Mountains contains strongly folded strata which are commonly overturned toward the north and west. Thrust faults, reverse faults, and tear faults are common, and the older thrust faults are themselves folded by later compression. This is classically the type of structure that occurs in the Appalachian Mountains and has been interpreted as the product of several mountain-building periods, or intermittent orogenies, extending through a considerable span of late Paleozoic and early Mesozoic time. Corry (1972:51) concludes that in the Solitario the Ouachita Orogeny might have lasted from Early Permian (about 280 million years ago) to Jurassic (approximately 180 million years ago) time. King (1937:131), in mental exercise, "ironed out" the folded rocks in the Marathon Basin and restored rocks that had been displaced by thrust-faults to their original, undisturbed configurations. From his calculations he concluded that the crust of the earth in the vicinity of Marathon was shortened at least 24 km by northwestward thrusting and folding during the Ouachita Orogeny.

Many of the spectacular folds exposed in the Solitario are visually accentuated by the contrasting white and black cherts (Fig. 7, chevron fold). A detailed discussion of the effects of the Ouachita Orogeny observed within the Solitario is presented in Appendix 2.

Cretaceous Stratigraphy

Since the Ouachita orogenic period may have covered a very long span of time (possibly 100 million years), a considerable amount of erosion must

FIGURE 7

Chevron fold northwest of Tres Papalotes.
Black Maravillas Chert over the white Caballos Novaculite.
(Photo by Reagan Bradshaw)

have taken place during active mountain building. After the final termination of mountain building it is probable that another 50 million years of erosion took place prior to the invasion of the Cretaceous seas and the deposition of the Shutup Conglomerate. All of this erosion resulted in the development of nearly flat surface of low relief truncating the complexly folded and faulted Paleozoic sediments. The unconformity between these truncated, steeply dipping Paleozoic rocks and the sediments of Cretaceous age that were deposited horizontally above them forms a textbook example of an unconformity. As a result of later doming of the Solitario, the once-horizontal unconformity and the overlying Cretaceous conglomerates and limestones now dip everywhere away from the center of the Solitario. The unconformity is well exposed around the inner rim of the Solitario. The obvious discontinuity between the strike of the dipping Paleozoic rocks and the strike of the outward-dipping rim of the Solitario is obvious on aerial photographs.

Herrin (1958:73) found some indirect evidence indicating that some rocks of Permian age may have been deposited in the vicinity during the time represented by the unconformity in the Solitario. He found Permian fossils in small boulders of limestone included in the Needle Peak Tuff, the tuffaceous conglomerate exposed in the southern part of the central basin. Flawn and others (1961:188) suggest that the main mountain-building phase of the

Ouachita Orogeny migrated westward and reached the Marathon and Solitario region in Late Pennsylvanian to Early Permian time. As Corry (1972:88) points out, that suggestion would make it unlikely that Permian marine limestones were deposited here during that time. Cooper and others (1953:4) found Permian rocks in Pinto Canyon (northwest of Presidio); Udden (1904:24) described the Permian rocks in the vicinity of Shafter; Rix (1953:55-71; 1954) described 800 ft of Permian north of Presidio, and Dietrich (1965:27-34) described the Permian strata exposed in the Presidio area. King (1937:110) reported Triassic rocks in the Marathon Basin. The consensus is that from some time in the Permian the area stood high until the transgression of the Cretaceous seas, a period of time exceeding 100 million years.

The details of the Cretaceous stratigraphy are presented in Appendix 3. All the lower Cretaceous rocks are limestones and are beautifully exposed in the rim escarpment around the Solitario. Herrin (1958) divided the Lower Cretaceous into seven formations. His stratigraphic names were informal, and later work by Maxwell and others (1967) has formally named the rock units in Big Bend National Park. Smith (1970) further defined the Lower Cretaceous stratigraphy of northern Coahuila, Mexico. Corry (1972) in his work on the Solitario, correlated the work of Maxwell and others (1967) and Smith (1970) with Herrin's (1958) mapping, and applied the current terminology to the rocks exposed in the Solitario. A correlation of the Cretaceous rocks in the Solitario, Big Bend National Park, southwest Texas, and central Texas is shown in Table 4. A correlation of the Lower Cretaceous fossils in the Solitario, Big Bend National Park, and northern Coahuila, Mexico, is shown in Table 5.

The Shutup Conglomerate is beautifully exposed in many parts of the Solitario. It is a 15-to-30-m thick

Table 4 – Regional Correlation Table for Cretaceous Formations (after Maxwell and others 1967)

System	Series	Stage		Group	Solitario	Big Bend National Park Area	Southwest Texas	Central Texas
Cretaceous	Gulfian	Turonian		Terlingua	Boquillas Formation	Boquillas Formation	Eagle Ford Formation	Eagle Ford Formation
	Comanchean	Cenomanian		Washita	Disconformity	Disconformity	Disconformity	Pepper Formation
					Buda Limestone	Buda Limestone	Buda Limestone	Buda Limestone
					Del Rio Clay	Del Rio Clay	Del Rio Clay	Grayson Formation
		Albian	Upper		Santa Elena Limestone	Santa Elena Limestone	Georgetown Limestone	Georgetown Limestone
			Middle				Duck Creek Formation	
					Sue Peaks Formation	Sue Peaks Formation	Kiamichi Formation	Kiamichi Formation
				Fredericksburg	Del Carmen Limestone	Del Carmen Limestone	Fredericksburg Formation	Edwards Limestone
								Comanche Peak Limestone
					Telephone Canyon Formation	Telephone Canyon Formation		Walnut Clay
						Maxon Sandstone		Paluxy
			Lower	Trinity	Glen Rose Formation	Glen Rose Formation	Glen Rose Formation	Glen Rose Formation
		Aptian			Yucca Formation			
					Shutup Conglomerate			

Table 5 — Lower Cretaceous Formation Fossil Correlation — Comanchean Series
(from Corry 1972: 80-83)

Stage	Formation	Solitario (Herrin 1958)	Big Bend National Park (Maxwell and others 1967)	Northern Coahuila, Mexico (Smith 1970)
Upper Albian	Santa Elena Limestone (Georgetown equivalent)	*Enallaster texanus* (Roemer) *Gryphaea washitaenis* (Hill) *Gryphaea* sp. + *Hamites* *Holaster simplex* (Shumard) *Kingena wacoenis* (Roemer) *Pecten (Neithea) bellula* (?) Cragin *Pecten (Neithea) texanus* (Roemer) *Turrilites brazoensis* (Roemer)	*Eoradiolites* cf. *E. quadratus* *Gryphaea* sp. +	*Toucasia* sp. *Gryphaea* sp.+ *Chondrodonta* sp.
Middle Albian	Sue Peaks Formation		See Maxwell and others 1967: p. 44, for listing	Pelecypoda-19 species Gastropoda-9 species Echinodermata-3 species Ammonidea-3 species (see Smith 1970: p. 41-42 for complete listing)
	Del Carmen Limestone	*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Lima (Mantellum) wacoensis* (Roemer) *Nerinea* sp. + *Pecten* sp. *Pleurotomaria* (?) + *Turrilites brazoensis* (Roemer)	*Exogyra texana* (Roemer) *Protocardia texana* (Roemer) *Pholadomya sanctisabae* (Roemer) *Aporrhais tarrantensis* (Stanton) *Eoradiolites* cf. *E. dayidson* (Hill) *Gryphea* sp. *Tapes* sp. *Cardium* sp. *Protocardium* sp. *Turritella* sp. *Tylostoma* sp. *Radiolites* sp.	*Toucasia* sp. *Monopleura* sp. *Gryphaea* sp.
	Telephone Canyon Formation		*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Aporrhais tarrentensis* (Stanton) *Tapes chihuahuensis* (Bose) *Metengonoceras* cf. *M. ambiguum* (Hyatt) *Neithea irregularis* (Bose) *Cardium* sp. *Protocardium* sp. *Tylostoma* sp. *Enallaster* sp. *Gyrphaea* sp. *Engonoceras* sp.	*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Ostrea* sp. *Pecten subalpinus* (Bose) *P. occidentalis* (Conrad) *Cyprimeria texana* *Cardium* cf. *C. congestum* (Bose) *Lima* sp. *Pteria pedernalis* (Roemer) *Tapes aldamensis* (Bose) *T. quadalupae* (Bose) *Anchura* (?) +

Stage	Formation	Solitario (Herrin, 1958)	Big Bend National Park (Maxwell and others, 1967)	Northern Coahuila, Mexico (Smith, 1970)
			Gyrodes sp. *Amauropsis* sp. *Cyprimeria* sp. *Trigonia* sp. *Phyoadomya* sp. *Turritella* sp. *Nerinea* sp.	*Astarte* (?) + *Pholadmya* sp. cf. *P. sanctisabae* (Roemer) *P. shattucki* (Bose) *Protocardia texana* (Conrad) *Cucullaea* sp. *Nucula* (?) sp. cf. *N. fortworthensis* (Perkins) *Tylostoma* sp. aff. *T. regina* (Cragin) *Turritella* sp. *Nerinea* (?) sp. + *Pleurotomaria* sp. + *Kingena* sp. *Phymosoma texana* (Roemer)
Lower to Middle Albian	Glen Rose Formation	*Exogyra quitmanensis** (Cragin) *E. texana* (Roemer) *Hemiaster comanchei* (Clark) *Pecten occidentalis* (Conrad) *Plicatula* sp. *Nerinea roemeri* (Whitney) *Salenia texana* (Credner) *Lima* (?) sp. *Lunatia* (?) sp. *Orbitolina texana** (Roemer) *Pecten* sp. *Protocardia* sp.	*Exogyra quitmanensis** (Cragin) *Exogyra texana** (Roemer) *Douvilleiceras* cf. *D. mammilatum* (Schlotheim) *Inoperna* aff. *I. concentriccostellata* (Roemer) *Orbitolina texana** (Roemer) *Porocystis globularis** (Giebel)	*Exogyra quitmanensis** (Cragin) *Cymatoceras* sp. *Parahopilites* n. sp. *Hypacanthoplites mayfieldensis* (Scott) *Hypacanthoplites* n. sp. *Gryphea mucronata* (Gabb) *Douvilleiceras* sp. cf. *D. spathi* (Scott) *Hemiaster* sp. *H. Comanchei** (Clark) *Kingena* (?) sp. *Tylostoma* sp. *Knemiceras* (?) sp. *Nerinea* sp. *Enallaster obliquatus* (Clark) *Porocystis globularis** (Giebel) *Homomya* sp. *Pecten* sp. *Gryphaea wardi* (Hill and Vaughan) *Arctica* n. sp. *Cardium* n. sp. *Tapes* n. sp. *Protocardia* n. sp. *Liopista* *Liopistha* spp. *Lucina* sp. *Cucullaea* n. sp. *Luathia* (?) *praegrandis* (Roemer) *Orbitolina texana** (Roemer)

* indicates correlation of both genus and species
+ indicates correlation of species only

unit resting unconformably directly on the intensely deformed and eroded Paleozoic rocks. The type locality is at the entrance to the Lefthand Shutup. It contains pebbles and boulders of chert and novaculite, fragments of limestone, sand-size material, interstial clay, and is cemented by silica. A sequence of moderately resistant to very resistant limestones overlie the Shutup Conglomerate: the Yucca Formation, Glen Rose Formation, Telephone Canyon Formation, Del Carmen Limestone, Sue Peaks Formation, and Santa Elena Limestone. The Telephone Canyon Formation and Sue Peaks Formation tend to form breaks in the sheer cliffs as they are less resistant to erosion. The Del Carmen Limestone and Santa Elena Limestone are the two massive cliff-forming units seen in the canyons of the Rio Grande in Big Bend National Park (Santa Elena, Mariscal, and Boquillas Canyons).

The soft Del Rio Clay overlies the Santa Elena Limestone and is exposed southwest of the Solitario in drainages leading to Fresno Creek. The resistant Buda Limestone is also exposed along the drainage of Fresno Creek. Overlying the Buda is the Boquillas Formation of Upper Cretaceous age, also exposed along Fresno Creek. These last three formations (Del Rio Clay, Buda Limestone, and the Boquillas Formation) are described in more detail in the companion volume to this report, discussing the geology along Fresno Creek (Deal 1976a).

Laramide Mountain Building

After the termination of the Ouachita Orogeny, the area in the vicinity of the Solitario remained high until the beginning of the Cretaceous time. The encroaching Cretaceous seas deposited approximately 1.2 km of thick, flat-lying beds of limestone. The Laramide Orogeny, which followed the deposition of those rocks, is the major upper Cretaceous and lower Tertiary mountain-building period that formed the structures of the American Cordillera which stretch from Alaska to South America. In the vicinity of the Solitario, the axis of the Laramide folds tends approximately northwest to the southeast. Therefore, in the vicinity of the Solitario, the Laramide folds are nearly at right angles (King 1965) to the older Ouachita fold belt. As the Laramide Orogeny continued, it caused the folding and faulting of the already complexly folded and faulted Paleozoic rocks.

Doming of the Solitario

The Laramide mountain-building period was followed by a series of igneous intrusions, in turn followed by a series of volcanic eruptions which buried the older limestones beneath a sequence of ash deposits and lava flows.

The first indication of volcanic activity in the Solitario area was an intrusion of magma into the base of the Cretaceous limestone sequence in Early to Middle Tertiary (probably Eocene or Miocene) time (possibly 20 to 45 million years ago) (Fred McDowell, oral communication, March 1976). Then, as the orogeny progressed, the Solitario dome was formed. Corry (1972:58) was primarily concerned with the origin of the Solitario and concluded that "an intrusive laccolithic origin of the Solitario would seem unquestionable." His discussion of the structure of the Solitario is presented in Appendix 4.

It also has been argued that the Solitario formed in association with the vent of an active volcano (Lonsdale 1940) or that it might have originated from the impact of a large meteor.

Lonsdale actually proposed doming of the Solitario by an intrusive laccolith but believed that magma reached the surface early in the history of the Solitario and erupted explosively. This would require that a large volcano with a structural relief of about 4.6 km existed at the site (Corry 1972:58). Much of Lonsdale's interpretation was based on his identification of the "vent agglomerate" he mapped in the southern part of the interior basin of the Solitario. Closer examination of this material by Corry (1972:135-140; see Appendix 8, this paper) indicates that this rock unit is a lithic tuff, eliminating any requirement that magma from the Solitario erupted early in its history.

When Powers (1921) mapped the Solitario, he compared it to the Wells Creek Basin in Tennessee. This is now known to be an impact structure (Bunch and Short 1968) and led Corry (1972) to consider meteoritic impact as a possible origin for the Solitario. Meteor impact scars are known to exist in west Texas (meteor crater near Odessa and the Sierra Madera structure between Marathon and Fort Stockton). In addition, the description of the so-called "vent agglomerate" by Lonsdale (1940) and Herrin (1958) coincides closely with the descriptions of fallback breccia, commonly occurring at known impact structures. In a continuation of this work, Corry and Wilson (unpublished manuscript) further refine the discussion of whether the Solitario originated as a result of the intrusion of a large laccolith or from meteoric impact. Their arguments and conclusions are presented in Appendix 5.

Regardless of what mechanism actually formed the Solitario dome, it is clear that the dome was formed during early to mid Tertiary. McKnight (1970:8) has mapped the Chisos Formation and finds that in Fresno Canyon it pinches out against the flanks of the Solitario dome and the Terlingua-Solitario anticline (Fig. 8). This means that both structures must have been topographically high at that time and had formed prior to the deposition of the Chisos beds. Maxwell and others (1967:136-137) have dated the Chisos Formation by fossils and radiometric determinations as middle to upper Eocene (28 to 44 million years ago), but ongoing work at The University of Texas may well revise these dates (McDowell, oral communication, March 1976).

Shortly after the development of the Solitario Dome, and prior to the deposition of the Chisos beds, the structure known as the Terlingua-Solitario Monocline (Maxwell and others 1967) or the Terlingua-Solitario Anticline (Corry 1972) was formed. This structure extends southward and then eastward from the Solitario (Fig. 5), and has been the site of extensive geologic investigations and the commercial production of cinnabar (mercury ore). A more detailed description of this structure is presented in Appendix 6.

Rocks of Tertiary Age

As indicated above, rocks formed from the solidification of magmas which intruded the area during the Laramide Orogeny. The age relationship of some of these intrusions is difficult to determine and Corry's (1972:141-149) description of these intrusions (differing somewhat from Herrin 1958) is included as Appendix 7.

The Eocene also marked the onset of extensive extrusive volcanic activity in the area surrounding the Solitario, and this activity continued until the end of the Miocene. The field relationships of these rocks were carefully traced on the western and southern flanks of the Solitario by McKnight (1968), and a summary of their relationships, as applied to the Solitario, was prepared by Corry (1972:127-140) and is presented in Appendix 8.

The oldest exposed Tertiary igneous rocks in the Solitario are those of the "rim sill" (see Appendix 7) exposed in many places around the inner rim of the

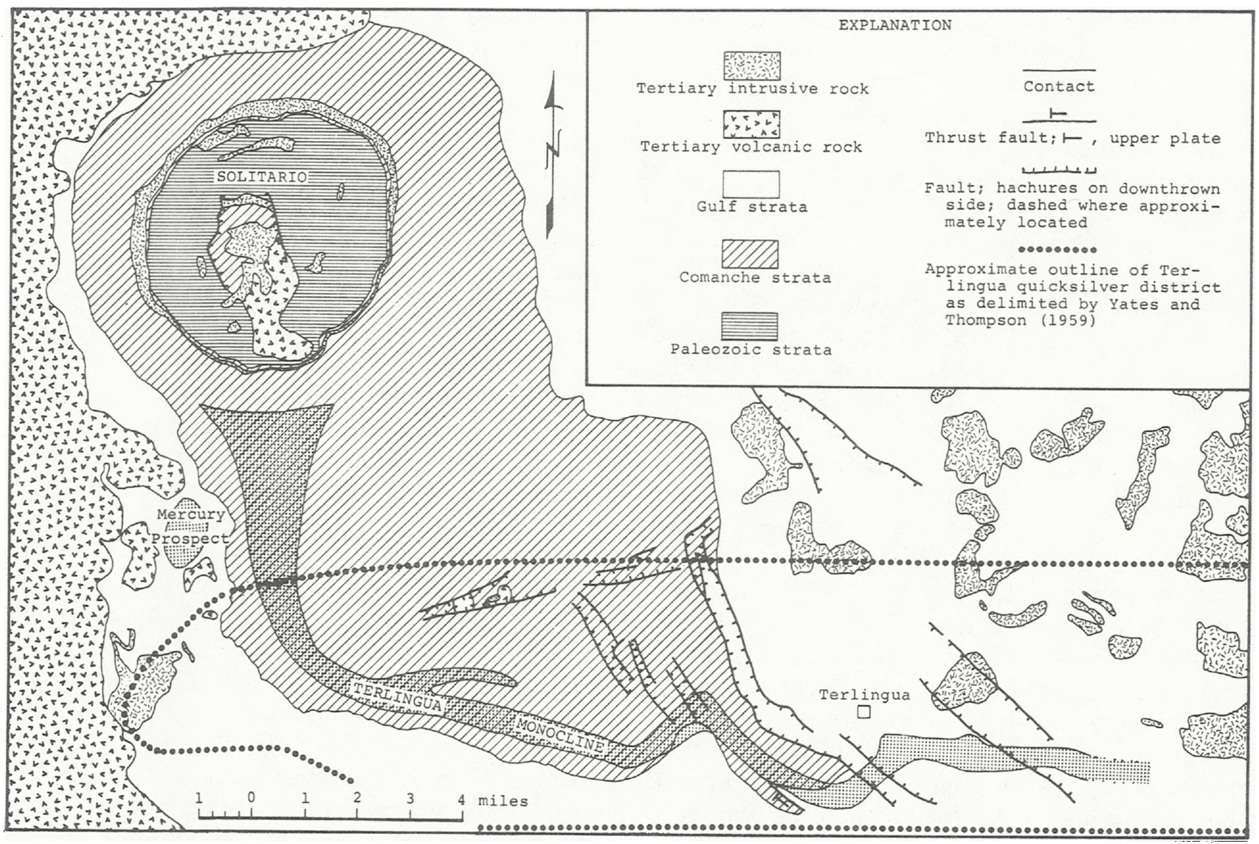


FIGURE 8

Generalized geologic map of Terlinqua-Solitario area, showing the mercury prospect on east side of the Bofecillos Mountain Area. Modified from Lonsdale (1950) and Yates and Thompson (1958) by McKnight (1968: Fig. 20)

Solitario. The rim sill is a white rhyolite with a type location at the entrance to the Lefthand Shutup. It was intruded prior to the doming of the Solitario as a sill, generally located between the underlying Shutup Conglomerate (the basal conglomerate of the Cretaceous sequence) and the overlying limestones of the Yucca Formation. It commonly displays prominent columnar jointing and has been tilted so that it dips in all directions away from the Solitario dome, parallel to the dip of the Cretaceous limestones in rim escarpment. Corry (1972) has suggested the name "Solitario Peak Rhyolite" for this unit. I feel this was an unfortunate choice of names. Solitario Peak (Fig. 4) is a distinctive volcanic neck on the northwestern rim of the Solitario that has intruded through the rim sill and is composed of soda trachyte, not rhyolite.

Prior to the eruption of the main volcanic phase, a conglomerate consisting mostly of well-rounded cobbles or boulders of limestone was deposited in the area. In a few places in Fresno Canyon it contains weathered, rounded, vesicular pebbles of igneous rock up to six inches in diameter (McKnight 1968:25-31). The formation also locally contains scattered, angular pebble- to boulder-sized fragments of petrified wood. The dominant limestone boulders and pebbles in the conglomerate are from the Del Carmen, Santa Elena, and Buda Limestones that are exposed on the Terlingua-Solitario Monocline and in the Solitario, but, since they are so uniformly well-rounded, they may have been transported from some fairly distant source. The name Jeff Conglomerate has been used for this unit.

Overlying the conglomerate is a sequence of soft, light-colored, easily-eroded beds of the Chisos Formation. They are formed largely from volcanic ash falls with associated stream deposits (conglomerate and sandstone), mud flows, and lake deposits (nonmarine limestone). McKnight (1968) has shown that this unit thins and pinches out against the flanks of both the Solitario Dome and the Solitario-Terlingua Monocline. The Chisos Formation was probably erupted from vents southeast of the Solitario, in the vicinity of what is now Big Bend National Park.

The Mitchell Mesa Tuff overlies the Chisos beds. It is a distinctive and interesting rock unit which usually forms a very resistant layer that the nongeologist would probably mistake for a solidified lava flow. It is not, however, an ancient lava flow but originated from what was either a single violent eruption or a series of closely related violent eruptions of large quantities of very hot volcanic ash. The particles of ash were so hot when they came to rest that in most places they fused together and "welded" themselves into this very hard and resistant unit. A deposit of this type is referred to as an "ignimbrite" or "welded tuff" and is about the closest thing to instant rock that one can find in the geologic record. Instead of being deposited over a span of millions of years, as is common for most sedimentary units, ignimbrites usually record a single event or a series of very closely spaced events.

The top of the Mitchell Mesa Tuff is one of the most useful horizons for stratigraphic correlation of the volcanic rocks in the Big Bend region of Texas. Not only does it form a hard, resistant, and distinctive unit, it covers an immense area. Known occurrences extend from the area of Big Bend National Park northward to the Davis Mountains (north of Alpine) and westward (where it is called the Brite Ignimbrite) to the rimrock country south of Van Horn. Dietrich (1965) estimated a minimum areal extent of four million hectares (2500 square miles) in the United States and Haenggi (1966) estimates a minimum of an additional one million hectares (700 square miles) in Mexico, west of Presidio.

The Mitchell Mesa Tuff also thins against the flanks of the Solitario. In Fresno Canyon, south of the Smith Ranch ruins, it pinches out and is often not thoroughly welded. (For more detailed discussion of this area, see the discussion in a companion volume on Fresno Canyon, Deal 1976a.)

Following the deposition of the Mitchell Mesa Tuff, the Bofecillos volcano, west of the Solitario, began its main eruptive phase (McKnight 1968). This resulted in the deposition of the Fresno Formation, a complex of units containing ash falls and lava flows, also described in more detail in a companion report on Fresno Canyon (Deal 1976b). The most important thing about the Fresno Formation, in reference to the discussion of the Solitario, is that the sedimentary units between the flows contain fragments of lower Paleozoic rocks that were undoubtedly derived from the center of the Solitario. There is therefore no question but that the erosion of the Solitario, which had been underway for some time, had resulted in the breaching of the Cretaceous cover over the dome, allowing Paleozoic rock fragments to be supplied to the Fresno Formation in Oligocene(?) time (McKnight 1970).

Eruption of volcanic debris, probably from the Bofecillos Volcano during Fresno time, filled the eroded central basin of the Solitario and mixed with rubble from within the dome to form a lithic tuff. This is the material previously described by Lonsdale (1940) and Herrin (1958) as a "vent agglomerate." Corry (1972:135-140) used the name "Black Needle Tuff" (now revised to "Needle Peak Tuff") for this unit. Since the unit is not a "vent agglomerate" (see discussion elsewhere in this report), it is wise to abandon that terminology. The name "Needle Peak Tuff" is no great improvement for, although the tuff does occur in the vicinity of what has been formally named Needle Peak on the new USGS topographic maps in the southern part of the central basin of the Solitario, there are the following objections to the use of that name for this unit: (1) Needle Peak (Black Needle Peak) is itself a rhyolite intrusion and is not made up of the material under discussion, and (2) the source of the formation is probably outside of the Solitario and not from Needle Peak itself.

This material is described in more detail in Appendix 8 but appears in the field as a mixture of fragments of novaculite, chert, limestone, and miscellaneous igneous rocks in a light-colored, fine-grained matrix. Although someone without geological training might easily mistake the material for a sedimentary conglomerate, most of the fragments were probably blown out of a volcanic vent along with the associated ash which forms the matrix. Local boulders and fragments, probably carried in part by mud flows caused by rains associated with the eruption, and channels and lenses of stream-deposited material are also included in the formation.

The total amount of volcanic rubble that accumulated within the Solitario is unknown, but it is quite probable that most of the central basin was filled with this material. Before the central basin was filled with this tuff, the topography of the interior of the Solitario may have been very similar to the topography we see today.

Following the eruption of the Fresno Formation, another remarkable welded tuff, the Santana Tuff, was erupted from a vent somewhere toward the south or southwest of the Solitario, probably in Mexico. The Santana probably covered less area than the Mitchell Mesa Tuff, but is also highly useful in correlating units in the volcanic stratigraphy of region.

Rhyolitic magma intruded and partially covered the lithic tuff within the Solitario, locally metamorphosing it. By Miocene time the rhyolitic lava flows from the Bofecillos (the Rawls Formation, overlying the Santana Tuff) had spread over a considerable portion of the eroded rim of the Solitario (Erickson 1953). The uplift of the Solitario appears to have continued after the highest Rawls flows erupted as indicated by the tilting of those flows along the flanks of the dome (McKnight 1968). There are also several thrust faults on the outside rim of the Solitario that are interpreted as gravity sliding down the flanks of the dome. (See companion volume on Fresno Canyon, Deal 1976a).

Post-Volcanic Block-Faulting and Erosion

Following the cessation of volcanic activity, considerable block faulting occurred south of the Solitario. Many of those movements probably took place along rejuvenated Laramide structural trends (see discussion in companion volume on Colorado Canyon, Deal 1976c). For a while the area had no through-flowing drainage to the sea, and large, undrained desert basins (as are today typical of Nevada and eastern California) occurred in the area. General uplift of western North America occurred. The ancestral Rio Conchos and Rio Grande, fed by increased precipitation in their now more elevated headwaters, filled basins to the southwest and northwest with temporary lakes. When those basins overflowed, the water moved to progressively lower basins and eventually one of the two ancestral rivers spilled into the Presidio bolson. It is likely that the Rio Conchos arrived long before the Rio Grande. (See more detailed discussion in the companion volume on Colorado Canyon, Deal 1976c.) The ancestral drainage of the Rio Grande probably proceeded in this fashion to spill across the divide between Redford and Lajitas (now the location of Colorado Canyon) and work its way eastward until it finally spilled into the headwaters of some tributary of the ancestral lower Rio Grande, somewhere east of what is now Big Bend National Park.

Once the ancestral Rio Grande (or Rio Conchos) spilled into lower basins to the east, the upstream portions of the river south of the Solitario began to downcut. At this time the ancestral Colorado Canyon began to form and tributaries, both north and south of the Rio Grande, also began to downcut. As a result, Fresno Creek began to more rapidly incise Fresno Canyon, and its tributaries accelerated the draining and dissection of the Solitario dome through the Righthand Shutup, the Lower Shutup, and Los Portales Shutup. A similar dissection occurred along Terlingua Creek where one of its tributaries incised the Lefthand Shutup.

This acceleration of erosion caused the relief that we see today to develop on the rim escarpment of the Solitario and removed much of the once thick filling of tuffaceous agglomerate ("Needle Peak Tuff") from the central basin. It is quite likely that much of the topography we see today in the central basin is largely exhumed from the topography that was buried beneath that tuff during early Fresno time.

MINERAL RESOURCES

Any area as unusually complex as the Solitario, with its many different ages and types of geologic events, will be intensively prospected for possible occurrences of mineral wealth. The diverse chemical composition of the rocks, the many different types of known igneous intrusive activity in the area, and the certainty that chemically active fluids from these intrusions have passed through many of the rocks in the Solitario make it an obvious area for consideration when searching for ores. The Solitario has been prospected for a number of resources: mercury, manganese, uranium, copper, flourspar, and a multiplicity of other minerals. The intense and often repeated physical deformation of the area make it unlikely that ancient fluid accumulations of petroleum or natural gas would have remained intact, even if they had once occurred in the area.

Water is probably the most important fluid mineral resource in the area, as the availability of water is the limiting factor on most of the biological resources.

Mercury

The Terlingua Quicksilver District (Fig. 8) adjoins the southern part of the mapped area and extends eastward for about 35 kilometers. A good history of the development of the Terlingua Mercury District was prepared by Daugherty (1972) and is reproduced as Appendix 3 to the companion report on Fresno Canyon (Deal 1976a).

According to Chester (1965), the Fresno Mine and the low-grade mineralization on the Contrabando Dome, just south of the Solitario, were discovered in 1935. This extended the known belt of mineralization about 10 km to the west. Most of the development in the Terlingua District is along a marked east-west trend. This also roughly parallels the axis of the Terlingua Monocline. Metallization of the Terlingua District may extend along established trends in either of two directions from the Fresno Mine: (1) westward—along the same trend as to the east or (2) northward—paralleling the trend of the Terlingua Monocline—toward the Solitario. North of the vicinity of the Fresno Mine, volcanic strata are mostly stripped off the beds known to be most favorable host rocks in the Terlingua District (McKnight 1968:137). McKnight continues:

> The area of interest extends from the Fresno Mine north to where the monocline abuts against the Solitario and perhaps along the west—and even east—side of the Solitario. Silicious fissure veins and replacement mantos are common in parts of Fresno Canyon along this general trend. Furthermore, calcite veins are common in Cretaceous strata; although many were probably deposited by ground water, hematite staining in some suggests hydrothermal activity. A prospect along this trend is a dome about three miles northwest of the Fresno Mine and a mile southwest of the abandoned Smith Ranch in Fresno Canyon. At this place, numerous faults cut three southeast-trending anticlines that expose the lower part of the Boquillas Formation. A few of the faults are hematite-stained; the faults trend southeast to east but bear approximately the same angular relationship to the monocline—here trending north to northwest—as do the mineralized fractures in the quicksilver district. The basal flow breccia of the lowest lava flow contains abundant chalcedonic silica of probable hydrothermal origin, and such silica also abounds in the float. After careful mapping of the area—about three and one-half miles across—one might be able to determine the depth of the Del Rio-Santa Elena contact and define targets by projecting mineralized faults to the surface. Mercury vapor detection apparatus might be useful in locating more subtle targets in this area.

Fluorspar

Fluorspar is a basic raw material in the chemical, metallurgical, and ceramic industries. The numerous deposits of fluorspar that exist in Trans-Pecos Texas have been described by McAnulty (1974). Several occurrences are known south of the Solitario, on the east side of Fresno Creek (McAnulty 1974:12).

Fluorine is a characteristic constituent of some alkaline magmas, and almost all commercial deposits appear to have formed directly or indirectly from fluids of magmatic origin. Commercial deposits are known in all types of host rocks as void fillings; as replacement veins along faults, fractures, sheaf zones, breccia pipes, and other brecciated areas; as irregular-shaped replacement bodies in contact zones; and as extensive concordant replacement deposits (mantos) in limestones and calcareous shales. Weathering of primary deposits sometimes results in residual deposits of gravel spar (McAnulty 1974:2-3).

Since most of the commercial deposits of fluorite in the Big Bend occur in limestones, the most favorable areas to prospect are in the limestone outcrops in the immediate vicinity of igneous intrusions in the Solitario and the Contrabando Lowland along Fresno Creek. Ore bodies may also exist in the limestones beneath the volcanic rocks of the Bofecillos Mountains.

Manganese

Numerous prospect pits for manganese occur within the Solitario. Hydrothermal solutions, rising from intrusions, have coated many fissures with black manganese minerals. In the vicinity of Tres Papalotes, manganese mineralization commonly occurs in the Caballos Novaculite, frequently causing introductory geology students to confuse some of these white cherts with the Maravillas Formation. None of the prospects are known to have had commercial production.

Water

Water is probably the most important mineral resource in the vicinity of the Solitario; it supports agricultural economy on the Rio Grande floodplain to the south and west and ranching in the Bofecillos Mountains to the west and creates numerous oases along the western side of Fresno Canyon. Surface water is scarce to absent within the Solitario and, as a result, the Solitario has long contrasted with the land to the west.

Streams run in the Solitario only during and immediately after rains, which usually occur catastrophically in July, August, and early September. Springs are undependable, and, although several run for a few days to a few weeks after the summer rains, they usually dry up quickly. Surface water also occurs in tinajas, water-filled bedrock depressions, occurring in the narrow canyon floors of the shutups. The tinajas attract and nourish animals, but, because of their often precipitous sides, sometimes become deadly traps (see the zoology report in this volume). The most dependable surface water occurs in two tinajas in the Lower Shutup which may contain water year-round.

Numerous attempts to artificially increase surface water availability have been made within the Solitario. A number of artificial catch tanks have been constructed, but for many years they were not adequately maintained and became washed out or filled with debris. The Big Bend Ranch has recently invested considerable effort in making these usable again. The spring at Burnt Camp (in the headwaters of the drainage leading through Los Portales Shutup) has been deepened and often contains water, although it is rarely usable by livestock.

Until recently, the only producing water well within the Solitario was at Tres Papalotes. It produces water from the base of the Tesnus Formation in the center of a tightly folded syncline. Sulfide minerals in the shale cause the water to contain dissolved sulfides and hydrogen sulfide gas, the latter giving it an unpleasant odor. The Foulkes brothers had constructed an elaborate system of pipelines and pumping windmills that distributed water within the Solitario, and up over the rim to exterior pastures. The most extensive lift carried the water over the eastern and southeastern rims of the Solitario, along the crest of the Blue Range, and into pastures now incorporated in a neighboring land development. Almost all of this system of pipelines and all the pumping windmills have fallen into disrepair.

The prospect of finding additional sites for good wells within the Solitario is small. One exception is the area of large and deep synclines developed in the Tesnus Formation, a similar geologic setting to the Tres Papalotes area, in the southwest corner of the Solitario. Corry (1972:98) pointed out that future wells in that area probably would be successful, although they would be expected to yield water with significant hydrogen sulfide content.

Exploration drilling by Pioneer Nuclear, investigating the mineral resources in the vicinity of the intrusion beneath the central graben, has shown that at least limited quantities of groundwater are available there. At least two of their wells produced significant quantities of water (Corry, personal communication, May 1976).

SUMMARY COMMENTS

The Solitario is without question one of the most unique and interesting geologic areas of North America. It is an exceptional natural outdoor laboratory and classroom. This fact is well-known throughout the geologic profession and is evidenced by the general efforts of university and industrial groups to visit this remote and rugged area.

Although the possibility remains that mineral wealth in commercial quantities might be found in and around the Solitario, the greatest geologic value of the area today is as a place to come and look, and to see and observe. If the State of Texas were ever to establish a system of outdoor laboratories for educational purposes or designate a series of geologic landmark areas, the Solitario should be one of the first to be considered. Not only is the Solitario a significant geologic landmark when considered in reference to other areas within the state, but it is probably of both regional and national significance as well. I feel that the Solitario probably qualifies for recognition as a national geologic Natural Landmark area.

ACKNOWLEDGEMENTS

The preservation of the natural state of the Solitario is a result of the wise management practices of Big Bend Ranch and the Diamond A Cattle Company, who not only allowed but encouraged our study of the area. They have taken great pride in the uniqueness of this area, and have recognized the exceptional value of the Solitario as a natural outdoor laboratory. Many geologists and geology students have been warmly welcomed on the ranch in the past, and on numerous occasions the Big Bend Ranch has expended considerable effort to facilitate the study of the area and the use of the ranch for educational purposes. This has included, but not been limited to, the preparation of many miles of rough ranch roads to allow ingress by Greyhound buses and, in the case of our study, bulldozed and repaired the Fresno Canyon road prior to our work.

The assistance of all those involved with the ranch, R. R. Anderson, R. B. Anderson, Joe Mims, Mark Davis, numerous ranch hands, and especially Ralph Hager, the ranch foreman, was greatly appreciated. Ralph was particularly generous with his help. He not only provided a great deal of information about the area, but supplied occasional equipment and assistance at times of vehicle malfunction and was a source of good fellowship as well. Ralph additionally spent several days with the field team assisting with the data gathering and the acquisition of field collections. I think that all of the members of the Natural Areas Survey field party learned to share the love and appreciation of this area held by the owners and workers on the Big Bend Ranch. We are grateful to have had the opportunity.

I additionally want to thank the staff and students from the Biology Department at Sul Ross State University that assisted in the program, especially Dr. A. Michael Powell. Jack Burns and Bob Walters, science teachers at the Alpine High School, also provided significant field assistance. Rick Sohl and Bill Sohl, of Alpine, helped by making available a 4-wheel drive vehicle and radio communications that proved invaluable when the field team had two immobile field vehicles at Tres Papalotes. Jack Burns also made available his 4-wheel drive truck, which turned out to be the major work-horse for our crew. Chuck Corry was especially helpful by letting us freely use his geological data. Jim Weedin, of the Chihuahuan Desert Research Institute in Alpine, provided invaluable aid in revising the terminology of the Lower Cretaceous fossils presented in Table 5, and his wife, Terry Weedin, typed and edited much of this manuscript.

Our study was a major group effort and many helped make it a success. We thank all of you.

REFERENCES CITED

Anderson E. M. 1951. *The dynamics of faulting and dyke formation with application to Britain.* London: Oliver and Boyd, 2nd rev. ed., 206 p.

Baker, C. L. and W. F. Bowman. 1917. *Geologic exploration of the southeastern front range of Trans-Pecos Texas.* Austin: Bur. Econ. Geol., Univ. Texas Bull. No. 1753, 114 p.

Baker, C. L. 1935. Major structural features of Trans-Pecos Texas, *in* The Geology of Texas, Vol. II, *Structural and economic geology.* Austin: Univ. Texas Bull., 3401, p. 137-214.

Beals, C. S., C. S. Innes, and J. A. Rottenberg. 1963. Fossil meteorite craters, *in* Middlehurst, B. M., and Kuiper, S. P., ed., *The solar system IV, the moon, meteorites and comets.* Chicago: Univ. of Chicago Press, p. 235-284.

Bunch, T. E. and N. M. Short. 1968. A worldwide inventory of features characteristic of rocks associated with presumed meteorite impact structures, *in* French, B. M., and Short, N. M., ed., *Shock metamorphism of natural materials.* Baltimore: Mono Book, p. 255-266.

Carter, N. L. 1965. Basal quartz deformation lamelae—a criterion for recognition of impactites. *Am. Jour. Sci.*, v. 263, p. 786-806.

Chester, J. W. 1965. Mercury in Texas, in *Mercury potential of the United States.* U.S. Bureau of Mines Information Circular 8252, Ch. 10, p. 337-351.

Cooper G., A. K. Miller, C. C. Rix, and others. 1953. *Guidebook, 1953 spring field trip to Chinati Mountains, Presidio County, Texas.* West Texas Geol. Soc., 85 p.

Corry C. E. 1972. *The origin of the Solitario, Trans-Pecos, Texas*: Univ. Utah, MS thesis, 151 p.

Corry C. E., and R. C. Wilson. Unpublished manuscript. The origin of the Solitario, Trans-Pecos, Texas.

Daugherty, F. W. 1972. The Terlingua mercury district. In *Geology of the Big Bend area, Texas: field trip guidebook with road logs.* West Texas Geological Society Pub. No. 72-59, p. 227-231.

Deal, D. E. 1976a. Geologic environment of the Fresno Canyon, southeastern Presidio County, Texas. Univ. Texas, Austin: Center for Natural Resources and Environment, *Natural Areas Survey. Report.*

———. 1976b. Geologic environment of the Bofecillos Mountains, southeastern Presidio County, Texas. Univ. Texas, Austin: Center for Natural Resources and Environment, *Natural Areas Survey Report.*

———. 1976c. Geologic environment of Colorado Canyon of the Rio Grande, Presidio County, Texas. Univ. Texas. Austin: Center for Natural Resources and Environment, *Natural Areas Survey Report.*

Dietrich, J. W. 1965. *Geology of Presidio area, Presidio County, Texas.* Univ. Texas, Austin: Ph.D. dissertation, 313 p.

Dietz, R. S. 1959. Shatter cones in crypto-explosion structures (meteorite impact?): *Jour. Geol.*, v. 67, p. 496-507.

Eifler, G. K., Jr. 1951. Geology of the Barrilla Mountains, Texas. *Geol. Soc. Am. Bull.*, v. 62, p. 339-354.

Erickson, R. L. 1953. Stratigraphy and petrology of the

Tascotal Mesa Quadrangle, Texas. *Geol. Soc. Am. Bull.*, v. 64, p. 1353-1386.

Flawn, P. T., A. Goldstein, Jr., P. B. King, and C. E. Weaver. *The Ouachita System.* Univ. Texas, Austin: Bur. Econ. Geol., Pub. 6120, 401 p.

Folk, Robert L. 1973. Evidence for Peritical Deposition of Devonian Caballos Novaculite, Marathon Basin, Texas. *Bulletin A.A.P.G.*, v. 57, p. 702-725.

Gary, M., R. McAfee, Jr., and C. L. Wolf, eds. 1972. *Glossary of geology:* American Geological Institute, 805 p.

Gilbert, G. K. 1877. *Report of the geology of the Henry Mountains.* U.S. Geol. and Geol. Survey of the Rocky Mountain Region, 170 p.

Goldich, S. S. and M. A. Elms. 1949. Stratigraphy and petrology of the Buck Hill Quadrangle, Texas. *Geol. Soc. Am. Bull.*, v. 60, p. 1133-1182.

Gretener, P. E. 1969. On the mechanics of intrusion of sills. *Can. Jour. Earth Sci.*, v. 6, 1415.

Haenggi, W. T. 1966. *Stratigraphy and structure of El Cuervo area, Chihuahua, Mexico.* Univ. Texas, Austin: Ph.D. dissertation, 403 p.

Herrin, E. T. 1958. *Geology of the Solitario area, Trans-Pecos, Texas.* Harvard Univ., Ph.D. dissertation, 162 p.

Hill, R. T. 1891. The Comanche series of the Texas-Arkansas region. *Geol. Soc. Am. Bull.*, v. 2, p. 503-528.

Huffington, R. M. 1943. Geology of the northern Quitman Mountains, Trans-Pecos, Texas. *Geol. Soc. Am. Bull.*, v. 54, p. 987-1048.

Johnson, A. M. 1970. *Physical processes in geology.* San Francisco, Freeman, Cooper, and Co., 577 p.

King, P. B. 1937. *Geology of the Marathon region,* Texas: U.S. Geol. Survey Prof. Paper 187, 148 p.

———. 1965. *The tectonics of North America—A discussion to accompany the tectonic map of North America, scale 1:5,000,000.* U.S. Geol. Survey Prof. Paper 628, 94 p.

Lonsdale, J. T. 1940. Igneous rocks of the Terlingua-Solitario region, Texas. *Geol. Soc. Am. Bull.*, v. 51, p. 1539-1629.

Maxwell, R. A., J. T. Lonsdale, R. T. Hazzard, and J. A. Wilson. 1967. *Geology of the Big Bend National Park, Brewster County, Texas.* Univ. Texas, Austin: Bur. Econ. Geol., Pub. 6711, 320 p.

MacCarthy, G. R. 1925. Some facts and theories concerning laccoliths. *Jour. Geol.*, v. 33.

McAnulty, W. N., Sr. 1974. *Fluorspar in Texas.* Univ. Texas at Austin, Bureau of Eco. Geo. Handbook 3, 31 p.

McKann, M. H., P. J. Harwood, E. Anderson, M. J. Smith, and R. A. Rowlett. 1973. *The Solitario-Fresno Creek area, Presidio County, Texas*: Texas General Land Office, Environmental Planning Division, Significant Natural Areas File Report No. 4, 132 p.

McKnight, J. F. 1968, *Geology of Bofecillos Mountains area, Trans-Pecos, Texas.* Univ. Texas, Austin: Ph.D. dissertation, 199 p.

———. 1970. *Geology of the Bofecillos Mountains Area. Trans-Pecos, Texas.* Univ. Texas, Austin: Bur. Econ. Geol., Geol. Quad. Map 37 with text, 36 p.

Moon, C. G. 1953. Geology of the Agua Fria Quadrangle, Brewster County, Texas. *Geol. Soc. Am. Bull.*, v. 64, p. 151-196.

Pettijohn, F. J. 1957. *Sedimentary rocks.* New York: Harper and Row, 2nd ed. 718 p.

Powers, S. 1921. Solitario uplift, Presidio-Brewster Counties, Texas. *Geol. Soc. Am. Bull.*, v. 32, p. 417-428.

Rix, C. C. 1953. *Geology of Chinati Peak Quadrangle, Trans-Pecos, Texas.* Univ. Texas, Austin: Ph.D. dissertation, 188 p.

Sellard, E. H. 1932. Overthrusting in the Solitario region of Texas (*abs*). *Geol. Soc. Am. Bull.*, v. 43, p. 145-146.

Sellards, E. H., W. S. Adkins, and F. B. Plummer. 1933. *The geology of Texas,* Vol. 1, *Stratigraphy.* Univ. Texas, Austin: Bur. Econ. Geol., Univ. Texas Bull., 3232, 1007 p.

Short, N. M. 1966. Shock processes in geology. *Jour. Geol. Ed.*, v. 14, p. 149-166.

Smith, C. I. 1970. *Lower Cretaceous stratigraphy, northern Coahuila, Mexico.* Univ. Texas, Austin: Bur. Econ. Geol., Rept. Inv. 65, 101 p.

Stearns, D. W. 1971. Mechanisms of drape folding in the Wyoming Province. in *Wyoming Geol. Assoc. Guidebook No. 23,* p. 125-143.

Udden, J. A. 1904. *The geology of the Shafter silver mine district, Presidio County, Texas.* Univ. Texas, Austin: Mineral Survey Bull. 8, 60 p.

———. 1907a. Report on a geological survey of the lands belonging to the New York and Texas Land Company, Ltd., in the upper Rio Grande embayment in Texas. *Augustana Lib. Pub. No. 6,* p. 50-103.

———. 1907b. A sketch of the geology of the Chisos country, Brewster County, Texas. Univ. Texas, Austin: *Bull. No. 93* (Sci. Ser. Bull. 11), 101 p.

———. 1972. *Geology of the Big Bend area, Texas, field trip guidebook with road log.* West Texas Geol. Soc. Pub. 72-59, 248 p.

West Texas Geological Survey. 1965. *Geology of the Big Bend area, Texas, field trip guidebook with road log.* West Texas Geol. Soc. Pub. No. 65-51, 196 p.

Williams, H., F. J. Turner, and C. M. Gilbert. 1954. *Petrography: an introduction to the study of rocks in thin section.* San Francisco: W. J. Freeman and Co., 406 p.

Wilson, J. L. 1954. Ordovician stratigraphy in the Marathon folded belt. *Am. Assoc. Petrol. Geol. Bull.*, v. 38, p. 2455-2475.

Yates, R. G., and G. A. Thompson. 1959. *Geology and quicksilver deposits of the Terlingua district, Texas.* U.S. Geol. Sur. Prof. Paper 312.

APPENDIX 1

OUTLINE OF THE PALEOZOIC STRATIGRAPHY OF THE SOLITARIO QUADRANGLE
(from Corry 1972: Appendix 2)

CAMBRIAN SYSTEM

Dagger Flat Sandstone: The Dagger Flat Sandstone is the oldest unit exposed in the Solitario dome. It was named by King (1937:22) for exposures in Dagger Flat 21 km south of Marathon, Texas. King (1937:22) describes the Dagger Flat Sandstone as a buff sandstone interbedded with shale in thick ledges. These grade upward into shales and thin flaggy sandstones, with some calcareous beds containing a few Upper Cambrian fossils.

The formation is conformably overlain by the Marathon Formation of Ordovician age. Herrin (1958) measured 183 m of exposed section in the Solitario. The base of the formation is covered by the Solitario thrust fault. Correlation with the Dagger Flat Sandstone of the Marathon Basin was done by Herrin (1958) on the basis of fossils reported by Sellards and others (1933). The presence of secondary biotite in thin section indicates low grade metamorphism.

ORDOVICIAN SYSTEM

General: The Ordovician includes four formations in the Solitario: Marathon Formation, Fort Peña Formation, Woods Hollow Shale, and Maravillas Chert. All four formations contain graptolites from which their ages are well established. Approximately 1220 m of rocks of Ordovician age are exposed.

Marathon Formation: The Marathon Formation was extended by Herrin (1958) from King's (1937) Marathon Limestone, which outcrops in Marathon, Texas. In the Solitario the correlative unit consists of black siliceous shale, sandstone, sandy limestone, dark chert, and some slabby, blue limestone similar to the limestone exposed at Marathon.

The formation is approximately 610 m thick, but because the contact with the overlying Fort Peña Formation is covered in the Solitario, and the measured section is intensely deformed, Herrin (1958) gives a range of thickness of 458 m to 915 m. Herrin also divides this formation into four members: "Above Hightank," Hightank member, "Below Hightank," and the White Shale member. In the interest of simplicity these subdivisions were not used by Corry (1972) as they were of little value for his purposes. Secondary biotite in thin section indicates low grade metamorphism. The quartz grains in the sandstones of this formation contain abundant laths of rutile. An age of earliest Ordovician is assigned by Herrin (1958:33).

Fort Peña Formation: The Fort Peña Formation is the name given by King (1937:32) to limestones, sandy limestones and cherts which outcrop in hogbacks north of Fort Peña Colorado in the Marathon region. Rocks of similar lithology which correlate with King's Fort Peña crop out in several anticlines in the Solitario. The contact at the base of the Fort Peña Formation with the underlying Marathon Formation is covered, and the contact with the overlying Woods Hollow Shale is gradational. Herrin (1958) estimates the thickness at 122 m. The rocks are siliceous with silica replacing calcite in some rocks. An age of Middle Ordovician is assigned by Herrin (1958:37).

Woods Hollow Shale: Woods Hollow Shale is fissile, fine grained, and hard with some flaggy sandstones and siltstones included. Wilson (1954:2462) measured a section 118 m thick in the Solitario. The Woods Hollow is exposed in most of the anticlines in the central basin.

Corry (1972) found large (up to 2 cm x 1 cm) quartz crystals filling fractures in the shale. Flawn and others (1962:117) review the presence of veins in Ouachita facies rocks, and conclude that veins of calcite and quartz are usually present. However, no study of veins in the Ouachita facies in the Solitario has been made.

Herrin (1958) suggests an age of Middle Mohawkian for the Woods Hollow Shale. The contact with the underlying Fort Peña Formation is gradational over 10 to 15 m and is conformable. The contact with the overlying Maravillas Chert is sharp, but Herrin (1958:41) finds it conformable.

Maravillas Chert: Maravillas Chert was named by Baker and Bowman (1917:87) at Maravillas gap, south of Marathon near the entrance to Big Bend National Park. This formation, in conjunction with the overlying Caballos Novaculite, forms many prominent ridges in the Solitario.

The Maravillas Chert is lithologically distinctive, consisting almost entirely of black bedded chert. In the Solitario only a few limestone lenses and a few lenticular intraformational conglomerates are included. The Maravillas Chert is about 58 m thick in the Solitario. Herrin (1958:45) bases correlation with the Maravillas Chert in the Marathon Basin on similar lithology and stratigraphic position.

Herrin (1958) found no fossils in the Maravillas Chert, but King (1937:42) found extensive fossils in the lower part of the Maravillas Chert in the Marathon Basin from which he assigned an age of Upper Ordovician, probably Richmondian. Herrin (1958:45) believes the Maravillas Chert may represent the Upper Mohawkian and all of Cincinnatian time. The contact with the underlying Woods Hollow Shale is conformable though lithologically distinct. The contact with the overlying Devonian-Mississippian Caballos Novaculite is unconformable.

In a few exposures in the Solitario the Maravillas Chert is separated from the overlying Caballos Novaculite by 6 to 10 m of green or red shale. Herrin (1958:46) feels these beds are the equivalent of Wilson's (1954:2462) Persimmon Gap Formation. These beds are not sufficiently distinct in the Solitario to be mappable units.

Correlation: With the exception of the Alsate Shale, which Herrin (1958:47) did not recognize in the Solitario, all the Ordovician formations in the Solitario are directly correlative with units in the Marathon Basin and the formation names are those used by King (1937). The correlation of the Paleozoic sediments in the Solitario and Marathon Basin with the Ouachita system in general is done by Flawn and others (1962). King (1937:45) and Herrin (1958:50) believe that all the sediments, including the shales, are of shallow marine origin. The Ordovician seas in the area of the Solitario were shallow, with restricted circulation (Herrin 1958).

DEVONIAN – MISSISSIPPIAN SYSTEM

Caballos Novaculite: Caballos Novaculite was named by Baker and Bowman (1917) for exposures on Caballos (Horse) Mountain in the Marathon Basin. In conjunction with the underlying Maravillas Chert, the Caballos holds up most of the prominent ridges in the central basin of the Solitario. The white novaculite outcropping at the tops of these ridges makes them easily recognizable on the air photos. Herrin (1958:55) measured a section 84 m thick in the Solitario.

Correlation with the Caballos Novaculite in the Marathon Basin (King 1937) and with the Arkansas Novaculite in the Ouachita Mountains (Flawn and others 1961:179) is based on stratigraphy and lithology. The novaculite is a nearly pure silica with less than four percent other minerals (King 1937:51). Herrin (1958:56) could find no fossils in the Caballos Novaculite in the Solitario. A questionable age of Devonian-Mississippian is assigned on the basis of correlation with the Arkansas Novaculite. The Caballos Novaculite is unconformable with both the underlying Maravillas Chert and the overlying Tesnus Formation. Folk (1973), from microscopic studies in the Marathon Basin, feels that the novaculite may have originated in part as an evaporate deposit that was later replaced by silica.

MISSISSIPPIAN – PENNSYLVANIAN SYSTEM

Tesnus Formation: The Tesnus Formation consists of interbedded massive, brown siltstone, very fine sandstone, and dark green, somewhat siliceous shale. The Tesnus Formation is extensively exposed in the Solitario, usually as low basinal synclines, as at Tres Papalotes, or as a series of east-west trending synclines and anticlines, as near Black Peak. The Tesnus Formation is apparently the reservoir rock for the water well at Tres Papalotes, which is the only reliable water source in the Solitario. Herrin (1958:70) measured a section 1410 m thick though the top of the formation is not exposed. The Tesnus Formation is underlain unconformably by the Caballos Novaculite. It is overlain in angular unconformity by Cretaceous Shutup Conglomerate. Age and correlation are based on stratigraphic and lithologic comparisons with the Tesnus Formation in the Marathon Basin (King 1937). Herrin (1958:72) on that basis assigns a questionable age of upper Mississippian to lower Pennsylvanian.

APPENDIX 2

OUACHITA OROGENIC STRUCTURES WITHIN THE SOLITARIO
(from Corry 1972:51-56)

GENERAL

The following discussion of the Ouachita structure, exposed in the Solitario, is based on the work by Herrin (1958), and, to a much more limited extent, on Flawn and others (1961) who base their work on Herrin also, but put the Solitario into the broad perspective of the Ouachita system.

The onset of the Ouachita orogeny in Middle Pennsylvania time was not felt in the Solitario area until Late Pennsylvanian or Early Permian as the orogeny migrated westward (Flawn and others 1961:188). From Permian to Cretaceous the area stood high as a result of this orogeny. The Ouachita orogeny is recorded in the Paleozoic sediments by severe folding, including Z-folds, boundinage structures, and thrust faulting. Several small anticlines and synclines exposed in the central basin of the Solitario are the result of this deformation. The general axis of the folding and thrust faulting is northeast to southwest. The direction of thrusting is from southeast to northwest in all exposed Ouachita structures. Herrin (1958) describes the following major Ouachita structures in the central basin of the Solitario. The structures can be followed on Corry's geologic map from the outlines below.

TRES PAPALOTES FOLDED AREA

Herrin (1958:125) found an area of alternating anticlines and synclines occupying the eastern and northeastern central basin. The boundaries of the area are the Needle Peak Tuff and granite to the west; to the northwest, a northeasterly trending fault about 900 m northwest of Tres Papalotes; on the west and southwest by the Shutup Conglomerate from the Lefthand Shutup to the Needle Peak Tuff in the south.

The valley in which Tres Papalotes lies is a syncline filled with Tesnus Formation, the axis of which passes through Tres Papalotes. This syncline can be traced from the Lefthand Shutup, in the northeast, southwest for about five km to where it is covered by Needle Peak Tuff. The southwest limb of the syncline is terminated by a series of normal faults. In general, the road in the vicinity of Tres Papalotes follows the axis of the syncline.

To the southeast of these faults, but northwest of the associated thrust fault, Herrin (1958:126) describes a small southwesterly plunging anticline. The relation between this anticline and the syncline to the northwest is obscured by the series of normal faults. The syncline to the southeast is obscured by a thrust fault.

The thrust fault near the southeast margin of the central basin is exposed for about five km. Herrin (1958:126) finds the fault dipping 30° to 45° with a net slip on the order of 300 m. The structures to the southeast of the thrust fault are complex.

TESNUS MONOCLINE

In the southwestern corner of the central basin are a series of beds of Tesnus Formation. These beds are obvious in the air photos as a series of east-west striking ridges. About 1400 m of Tesnus Formation is exposed, with a generally uniform dip of 40° to 50° to the south. Herrin (1958:127) has called this the Tesnus monocline, but feels it may be a southwestward extension of the northwest limb of the Tres Papalotes syncline.

RIGHTHAND SHUTUP FOLDED AREA

To the north of the Tesnus monocline, in the western central basin, there is a sequence of three anticlines and two synclines. The folds trend northeast, plunge to the southwest, and are asymmetric or overturned to the northwest (Herrin 1958:127). Intense folding, with drag folds, disharmonic folds, and small thrust faults, are characteristic of the area. In the northern portion of this area the Solitario thrust fault is exposed in a small fenster (not mapped) just to the north of the road at the entrance to the Righthand Shutup.

SOLITARIO THRUST FAULT

Herrin (1958:128) traces the Solitario thrust fault for about 6.6 km in the northwest quadrant of the central basin. The structural relations are complex, but Herrin (1958:128) believes the stratigraphic throw exceeds 900 m. In general, younger rocks have been thrust over Lower Ordovician and Cambrian rocks. The strata in the vicinity of the Solitario thrust fault are highly folded and broken. Many strata are vertical or overturned, and the rocks of the overthrust sheet are also folded.

Herrin (1958:129) suggests a minimum net slip along the fault of about one km, with a dip of 5° to 10° to the southeast.

NORTHERN FOLDED AREA

In the northeast corner of the central basin, bounded essentially to the south by the Solitario thrust fault, and ringed by normal faults, lies what Herrin (1958:132) calls the northern folded area. In general, the area is a broad anticline plunging to the northeast. The structure in this area has been made more complex by faulting associated with the doming. In the southwestern part of the area near the Solitario thrust fault the strata are highly folded and faulted.

APPENDIX 3

CRETACEOUS STRATIGRAPHY IN THE SOLITARIO QUADRANGLE
(from Corry 1972:88-91, 119-126)

LOWER CRETACEOUS (COMANCHEAN) SYSTEM

Trinity Group

The Trinity Group was extended by Corry (1972) to include the Shutup Conglomerate, Yucca Formation, and the Glen Rose Formation. As used by Maxwell and others (1967) and Smith (1970), the Trinity Group only included the Glen Rose Formation. Maxwell and others (1967) frequently refer to a basal conglomerate beneath the Glen Rose Formation but do not give it a formation rank. Corry (1972), therefore, retained Herrin's (1958) name, Shutup Conglomerate. The Yucca Formation (Smith 1940; Herrin 1958:88) may be the equivalent of the La Peña Formation of Coahuila, Mexico (Smith 1970:24). The described lithologies are roughly similar, and stratigraphic positions agree, but unfortunately only one identifiable fossil, *Exogyra quitmanesis* Cragan (Herrin 1958:87), has been found in the Solitario in this formation. The Trinity Group is Upper Aptian to Lower Albian in age.

Shutup Conglomerate: The Shutup Conglomerate (Herrin 1958:77) is the basal unit of the Cretaceous rocks in the Solitario and is the only Cretaceous rock unit which is not calcareous. The conglomerate is composed of poorly sorted, subrounded material derived from the Ouachita facies rocks exposed in the central basin.

The Shutup Conglomerate consists of pebbles and boulders of chert and novaculite, a few fragments of limestone, sand-sized detritus, interstitial clay, and a siliceous cement. In this section the cementing matrix is quartz with about five percent magnetite and hematite included in the cementing matrix. There is no obvious bedding. The rock weathers a characteristic deep purple hue which makes field identification a simple matter. The unit is best exposed at the entrances of the shutups. Herrin (1958:77) measured a section 30 m thick at the type locality, the entrance to the Lefthand Shutup. The unit thickens and thins over the buried Paleozoic topography from a maximum of about 30 m to a minimum of about 15 m.

The Shutup Conglomerate is underlain by the angularly unconformable Tesnus Formation, and overlain conformably by the Yucca Formation. The Shutup Conglomerate was undoubtedly laid down as a result of the encroachment of the Cretaceous sea across the Coahuila Platform. Herrin (1958:78) found no fossils, but assigns it an age based on its stratigraphic position of Middle to Upper Aptian.

Yucca Formation: The Yucca formation was named by Smith (1940) in the Devils Ridge area, and extended by Huffington (1943) to the Quitman Mountains. Herrin (1958:88) extends the formation to the Solitario area based on lithology as a transitional unit between basal conglomerate and overlying normal marine limestones.

Herrin's (1958:86) measured section is 210 m thick. In the lower 46 m of the section the Yucca Formation is dolomitized, and these are the only rocks in the Solitario which have significant magnesium content. Although it is predominantly calcareous, the limestone and dolomites contain more detrital material, sand and clay than limestones higher in the section. The Yucca contains a few beds of shale, some yellow marl, and numerous beds of calcareous sandstone and dolomite, particularly in the lower part. In the upper part of the unit, limestones, some of which are oolitic, contain less detrital material. The formation tends to weather yellow or dark red with cross-bedded sandstones showing distinctive color banding.

Herrin (1958:87) assigns an age of Upper Aptian to lower Albian. The Yucca Formation overlies the Shutup Conglomerate conformably and is conformably overlain by the Glen Rose Formation.

Glen Rose Formation: The Glen Rose Formation was first mapped in the Solitario by Sellards and others in 1931. Lonsdale (1940) and Erickson (1953) also used Glen Rose for Comanchian limestones in the Solitario. Herrin (1958) called it the Solitario Formation, but the fossil correlation in Table 4, particularly the distinctive foraminifera, *Orbitolina texana,* conclusively shows this to be the Glen Rose Formation.

Herrin (1958:92) measured a section 353 m thick. The Glen Rose Formation in the Solitario consists of alternating massive bedded limestones and more thinly bedded marly limestones. The formation is generally fossiliferous with shell beds and coquinoid layers. The Glen Rose is conformably overlain by the Telephone Canyon Formation which may be distinguished from Glen Rose by the presence of nodular and bedded chert. The Glen Rose conformably overlies the Yucca Formation.

The Glen Rose Formation was named by Hill (1891:504) from exposures along the Paluxy River near the town of Glen Rose, Texas. The Glen Rose occurs widely in Texas and northern Mexico. Smith (1970:25) provides a good recent review of its occurrence. The Glen Rose Formation is lower Albian in age and is the youngest member of the Trinity group in the Solitario.

Fredricksburg Group

The Fredricksburg Group in the Solitario is used as defined by Maxwell and others (1967:31) with the exception of the Maxon Sandstone which has no equivalent in the Solitario. This group includes the Telephone Canyon Formation and the Del Carmen Limestone. The Telephone Canyon Formation includes the upper 58 m of Herrin's (1958) Solitario Formation. The Del Carmen Limestone is the lower unnamed member of Herrin's (1958) Fresno Peak Formation. Correlation is based on the lithologies and stratigraphic position of the formations. The Fredricksburg is Middle Albian in age.

Telephone Canyon Formation: The Telephone Canyon Formation in the Solitario consists of alternating one m thick beds of grey fossiliferous limestone, and grey, marly limestone which weathers yellow to reddish brown. Red stains are common. The Telephone Canyon Formation is the same as the upper 58 m of Herrin's (1958:89) Solitario formation.

The Telephone Canyon Formation was named by Maxwell and others (1967:35) for exposures in Telephone Canyon in Big Bend National Park. Smith (1970:39) assigns an age of middle Albian, and the formation is generally correlative with the Walnut Clay of central Texas.

The formation is conformably underlain by the Glen Rose Formation and overlain by the Del Carmen Limestone.

Del Carmen Limestone: The Del Carmen Limestone is named from the sheer escarpment of the Sierra del Carmen by Maxwell and others (1967:36). In the Solitario it is represented by the lower unnamed member of Herrin's (1958) Fresno Peak Formation, and it is 209 m thick.

The Del Carmen Limestone is a massive grey limestone which weathers to shades of brown. Large chert nodules and lenticular bodies are common. Rudistids are common. The Del Carmen Formation is conformably underlain by the Telephone Canyon Formation and overlain by the Sue Peaks Formation. The age is indeterminate, but the Del Carmen is probably middle Albian in age.

Washita Group

The Washita Group in the Solitario is defined as outlined by Maxwell and others (1967). Four formations are included in this group in the Solitario. The Sue Peaks Formation, Santa Elena Limestone, Del Rio Clay, and Buda Limestone. Correlations of the Buda Limestone and the Del Rio Clay are well established. Correlations between Herrin's (1958) Blue Range Formation and Maxwell and others (1967) Santa Elena Limestone are based on stratigraphic position, lithology, and the fact that both authors refer to the formation as the local Georgetown equivalent. An attempt at fossil correlation by Corry (1972:Table 7; Table 5) was inconclusive due to incomplete collections from the separate areas. The Sue Peaks Formation was represented by the Marley Member of Herrin's (1958) Fresno Peak Formation. The Washita Group ranges in age from Middle Albian to Lower Cenomanian.

Sue Peaks Formation: The Sue Peaks Formation was named by Maxwell and others (1967:40) from the Sue Peaks in the Sierra del Carmen. This is the Marly Member of Herrin's (1958) Fresno Peak Formation, and is approximately 57 m thick in the Solitario.

The rock is marly and weathers a characteristic yellow. The base of the Sue Peaks Formation is gradational into the Del Carmen Limestone. It is conformably overlain by the Santa Elena Limestone. Smith (1970:42) assigns an age of uppermost middle Albian to the Sue Peaks Formation.

Santa Elena Limestone: The Santa Elena Limestone was named by Maxwell and others (1967) from the rocks forming the upper half of the sheer canyon walls at the mouth of Santa Elena Canyon in Big Bend National Park. The Santa Elena is the local equivalent of the Georgetown Limestone of central and southwest Texas. Herrin (1958) called this the Blue Range Formation and measured a section 250 m thick in the Solitario.

The formation is characterized, in the Solitario, by massive limestone beds, rudisted bioherms, and thin bedded chert. A distinctive marker bed of interbedded chert and sandy limestone occurs from 64 to 76 m above the base of the Santa Elena Limestone, and can be recognized in all exposures in the rim of the Solitario.

The Santa Elena Limestone rests conformably on the Sue Peaks Formation, and is conformably overlain by the Del Rio Clay which represents a sharp lithologic break at the contact. The age of the Santa Elena Limestone is upper Albian.

Del Rio Clay: The Del Rio Clay in the Solitario is similar in stratigraphic position, lithology, thickness, and fossil content to the Del Rio at its type locality. Herrin (1958) measured a section 98 m thick in the Lefthand Shupup of the Solitario.

The Del Rio Clay consists of grey to green marl and shale which weathers greyish yellow. Thin flaggy beds of red sandstone and siltstone are common, as well as pyrite and gypsum.

The Del Rio is conformably underlain by the Santa Elena Limestone, and overlain by the Buda Limestone. The age of the Del Rio Clay is Lower Cenomanian.

Buda Limestone: The Buda Limestone was correlated in the Solitario by Moon (1953) with the type locality (Shoal Creek in Austin, Texas). The Buda outcrops discontinuously around the extreme periphery of the Solitario and along the flanks of the Terlingua-Solitario anticline.

The Buda Limestone is cream colored to yellow nodular limestone in beds one cm to one m thick. Marly partings separate the beds. Herrin (1958) measured a section of 30+ m in the Solitario. Because of its light color, the unit is fairly distinctive on the aerial photographs. McKnight (1968) measured about 21 m west of the Solitario, in Fresno Canyon.

The Buda Limestone is conformably underlain by the Del Rio Clay and unconformably overlain by Upper Cretaceous Boquillas Formation. The age of the Buda Limestone is lower Cenomanian.

UPPER CRETACEOUS (GULF) SYSTEM

Terlingua Group

Boquillas Formation: The Terlingua Group (Maxwell and others 1967) is represented in the Solitario area only by the Boquillas Formation. The Boquillas Flags were named by Udden (1907a:29-33) from the old Boquillas postoffice on Tornillo Creek. Maxwell and others (1967:55) have expanded Udden's (1907a) classification.

Approximately 60 m of flaggy, buff, sandy limestone with a wavy bedding is exposed in the Solitario quadrangle in Fresno Creek. These outcrops represent the Ernst member of Maxwell and others (1967:55). In the Solitario area, however, the formation is mapped undifferentiated. The Boquillas is unconformably overlain by Tertiary sediments and volcanics of the Bofecillos group. The age of the Boquillas Formation in the Solitario area is probably Turonian.

APPENDIX 4

STRUCTURE OF THE SOLITARIO
(from Corry 1972:58-66)

INTRODUCTION

An intrusive laccolith origin of the Solitario would seem unquestionable. Lonsdale (1940) and Herrin (1958) have proposed an intrusive laccolith origin, but several points have been questioned in their interpretation. The principal difference is the amount of structural relief required in the two different models. Lonsdale (1940) required essentially a large volcano with a structural relief of 4.6 km. He believed that magma reached the surface early in the history of the Solitario and erupted explosively. He interpreted the Needle Peak Tuff as a vent agglomerate resulting from this early eruption. Herrin (1958:143), however, was unable to find any evidence for such early volcanic activity from the central cone. Herrin (1958) did support the structural interpretation of Lonsdale's (1940) "vent agglomerate" in the field and in thin section it was determined that this formation is actually a lithic tuff which is informally called Needle Peak Tuff by Corry (1972) (see Appendix 8). This reinterpretation eliminates any requirement that magma from the Solitario erupted early in its history. A closer look at the form of laccoliths suggests that the structural relief of the Solitario is on the order of 1.6 to 1.8 km.

STRATIGRAPHIC DISPLACEMENT

In Fresno Canyon near Shelter Thrust is a bench mark (BM3692) located on top of gently westward dipping (9°W) Buda Limestone. This exposure is sufficiently far away from the dome that it can be taken as nearly representative of the pre-Solitario surface. Inside the central basin the base of the Shutup Conglomerate is presently exposed at about the 1350-m (4400-ft) contour. The displacement at the base of the Shutup Conglomerate is then equal to the thickness of the Cretaceous section beneath the Buda Limestone plus the difference in elevation of the two exposures (stratigraphic throw). From Table 3 the thickness of the Cretaceous section is about 1.2 km and the difference in elevation is approximately 220 m so that the displacement of the Solitario is about 1.42 km. Since the elevation in the central basin is measured at the outer rim rather than at the center where displacement would be maximum and the reference bench mark is on the upthrust side of the nearby fault, the value of 1.42 km vertical displacement is considered to be a minimum.

FORMATION OF THE RIM ESCARPMENT

The formation of prominent flations in the southwest rim and the abrupt change in dip at the top and bottom of the rim indicate that the Cretaceous section has been deformed inelastically by drape-folding (Stearns 1971). Corry (1975) has suggested, from fracture studies of the roofs of other laccoliths, that proto-laccoliths spread to their full diameter as thin sheets and then thicken in a manner analogous to a circular, or cylindrical, punch. Powers (1921) originally suggested this type of behavior during formation of the Solitario dome. As the intrusion thickened, the overburden was put in radial extension and bent elastically over the edge of the cylinder. Stearns (1971) has shown that, as uplift continued, failure occurred in hinge zones and that the inelastic deformation produced a pattern of rigid blocks draped over the margin of the uplift. This concept is illustrated in Figures 9 and 10.

Analysis of the direction of movements indicates that both rotation and extension of the blocks occur. Stearns (1971:129) finds that uplift, or folding, is the dominant mechanism of deformation in monoclines. The presumption is that the tension normal to the fold axis is equal in either direction across the decollement surface. In a circular feature, such as the Solitario, the tension is not equal but pulls radially outward from the center. The results are illustrated in Figure 9. Between blocks 3 and 4 and blocks 4 and 5, reverse faults will result after the initial rotation. Since the extension must all occur away from the center, rotation of blocks 2, 3, and 3 continues, and normal faults form.

The beds in the base of blocks 3 and 4 have been deformed elastically to the point of failure. The sense of motion on the fracture has then been reversed so that reverse drag folds would be expected along these

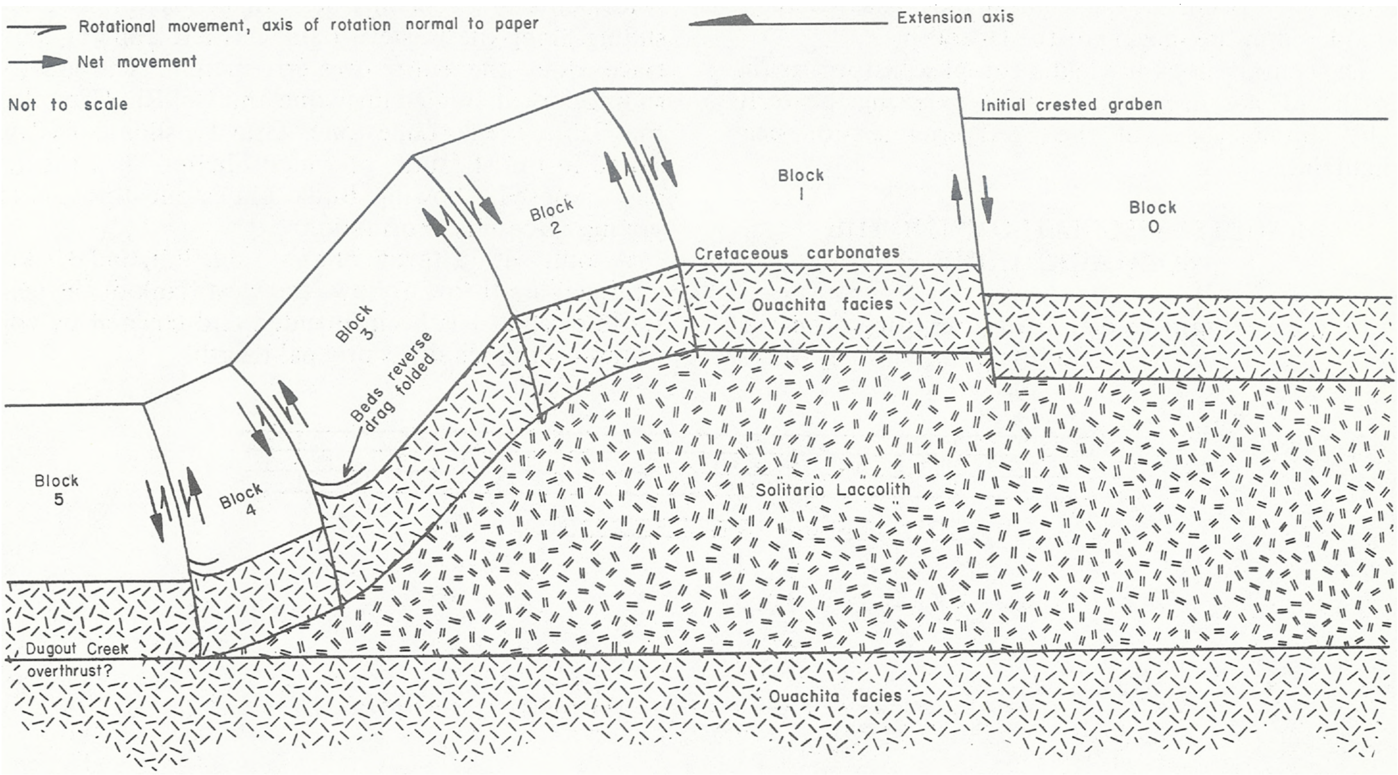


FIGURE 9

Drape folding in the Solitario.
(Redrawn from Corry and Wilson, unpublished manuscript: Fig. 6)

blocks at their basal hinge zones. These hinge zones are not exposed to substantiate this hypothesis. Subsequent erosion has developed the present rim.

FORMATION OF THE CENTRAL GRABEN

In the preceding section it is implied that in a circular (or anticlinal) feature extension is limited to the elastic limits of the rocks involved. Stearns (1971) has found that in a monocline beds tend to drape themselves over the basement rocks by a combination of elastic and cataclastic deformation in hinge zones. However, as uplift continues, draping can no longer accommodate the extension. In a circular feature, or at the crest of an anticline, this point will be reached much sooner, as uplift proceeds, than in a monocline. This point is illustrated (Figs. 9 and 10) by the initiation of a crestal graben, or block 0. Presuming block 1 continues to act with blocks 2, 3, and 4, a gap will develop between blocks 0 and 1. Using elementary trigonometry, the approximate dimensions of this gap can be calculated. Assuming the uplift has a radius of 6.5 km (4 miles) and has been uplifted 1.6 km (5250 ft), then the maximum extension is approximately 0.7 km (2300 ft), or 1.4 km (4600 ft) extension over the diameter of the Solitario. It is also obvious that, if the tension is radial outward, block 0 will be approximately circular. The western boundary fault of the central block on the geologic map indicates the central block may once have been roughly circular. The distance, however, from the boundary fault of the central block to the inside edge of the present rim is approximately 1.6 km (1 mile). This is nearly 1.0 km (3300 ft) greater than the maximum of 0.7 km. This difference is so large that no extensional geometry can account for it, and it must be explained by differential erosion. Needle Peak Tuff, or an earlier bolson fill, undoubtedly filled and protected the central graben while the rim stood high and was subject to severe erosion.

An approximate estimate of the amount the central block has been downdropped can be made by using BM3692 as a reference level for the pre-Solitario surface. Near the south end of the central block, the top of the Del Carmen Limestone is exposed, with nearly horizontal bedding. Using the elevation of these beds, plus the thickness of the missing beds between the Del Carmen Limestone and the Buda Limestone at BM3692, it is evident that the central graben has been downdropped at least one km to its present position. This amount of downdropping could only occur if the central block has partially foundered in the magma of the laccolith.

The central block has had a complex history, as the north end has been rotated 90°, exposing the vertically dipping base of the Cretaceous section near Hightank.

FAULTS ASSOCIATED WITH THE SOLITARIO DOME

In the Solitario, radial faults, resulting from the uplift, are evident at several locations in the rim. Displacements are generally less than 100 m. Gravity sliding along the western flank has left a major fault trace along the entire western margin. The gravity sliding was of Buda Limestone and Del Rio Clay over the Santa Elena Limestone. Gravity sliding has resulted in thrust faults, of which Shelter Thrust is the best exposed, showing Buda Limestone thrust into younger Boquillas Formation.

A fault with a throw of about one km, and 3.1 km stratigraphic throw, follows the west flank of the central block but has been intruded and covered by volcanics over much of its original length.

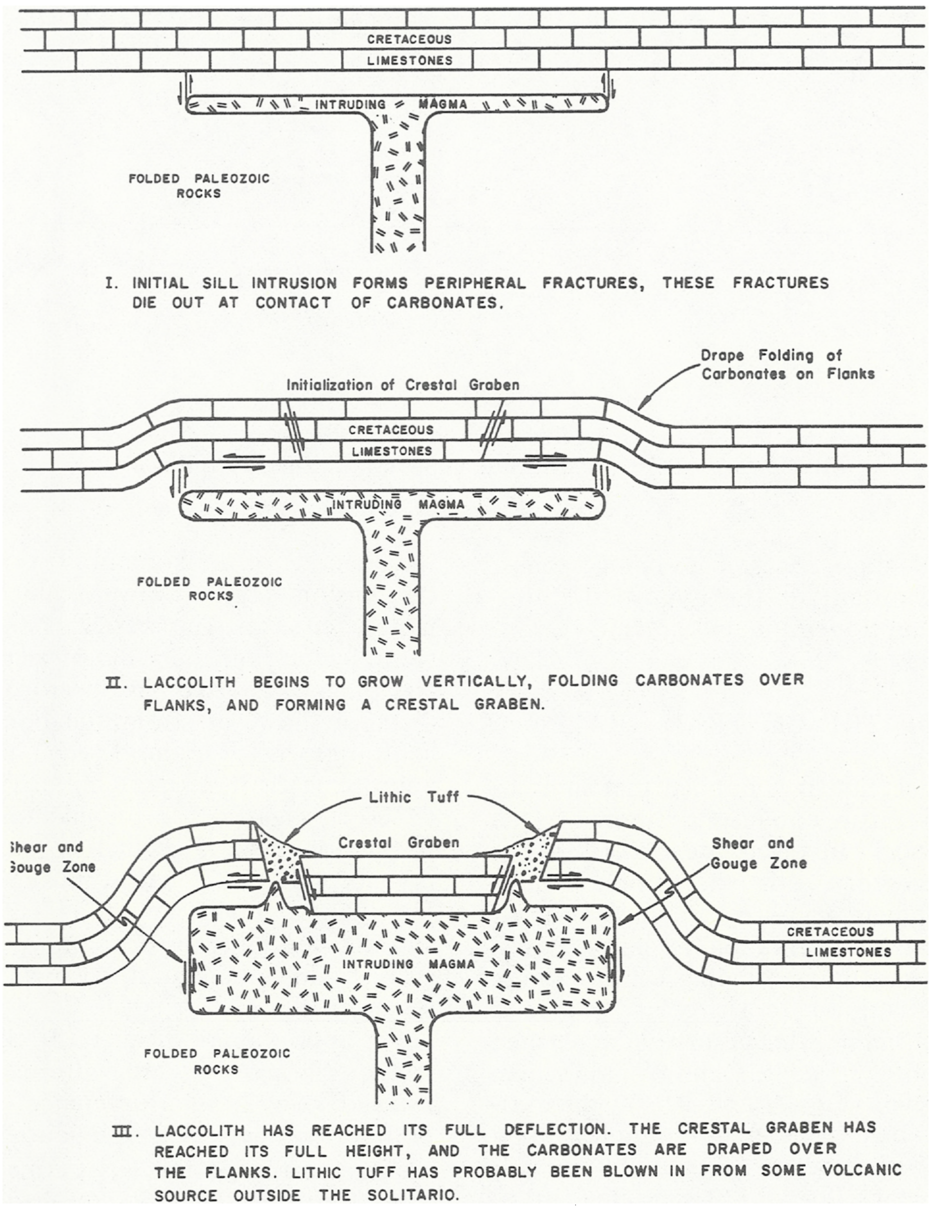


FIGURE 10

Diagramatic cross sections illustrating a probable origin of the Solitario Dome. (Redrawn from Corry and Wilson, unpublished manuscript: Fig. 8)

APPENDIX 5

THE ORIGIN OF THE SOLITARIO
(from Corry and Wilson unpublished manuscript)

IMPACT ORIGIN

The criteria for recognition of impact structures have been outlined by Short (1966). The evidence in support of an impact origin is summarized as: (1) the circular shape with raised rim and depressed central basin; (2) the supposed lack of an exposed igneous core (Lonsdale 1940; Herrin 1958); (3) the similarity between the "vent agglomerate" of Lonsdale (1940) and a fallback breccia. Also Powers (1921) compared the origin of the Solitario with the origin of Wells Creek basin in Tennessee, now a known impact structure (Bunch and Short 1968).

A field search for shock features, such as shatter cones (Dietz 1959), yielded negative results. A detailed examination of the "vent agglomerate" (Lonsdale 1940) in the field and in thin section convinced Corry and Wilson (unpublished manuscript) that this formation is the erosional remnant of a lithic tuff which filled the central basin after the feature was unroofed. An outcrop of microgranite, discovered in the central basin, is the top of a large pluton.

Impact craters will have a net reduction in density in the target rocks surrounding the impact point due to fragmentation, dilatation, and other mechanisms inherent in the cratering process. As Beals and others (1963) have pointed out, impact craters may be associated with anomalous gravity lows. In contrast, a gravity survey of the Solitario, as subsequently discussed, indicates a small positive anomaly.

Carter (1965) has shown that over 60% of shock induced lamellae in quartz are alligned parallel with the optic axis. No such relation was found in a petrofabric study of sandstones from the Marathon formation in the central basin.

The absence of shock features, such as shatter cones, the lack of dominant basal lamellae in quartz, and the absence of a negative gravity anomaly are taken as proof that the Solitario is not an impact site.

LACCOLITHIC ORIGIN

A laccolithic origin for the Solitario was originally proposed by Lonsdale (1940). Lonsdale (1940) and Herrin (1958) proposed a model for the development of the Solitario from which they inferred that: (1) magma reached the surface early in the evolution; (2) a vent agglomerate was formed; (3) the magma retreated; (4) the pluton was primarily basaltic, and (5) the deflection of the roof was between three and five km. Corry and Wilson (unpublished manuscript) found no evidence to support these inferences; however, they agreed that the feature is laccolithic in origin.

Some features of the structure are not, however, in accord with conventional descriptions of laccoliths. For example: (1) the laccolith is intruded into previously deformed Ouachita facies sediments; (2) the Ouachita structures have not been quaquaversally refolded and are well preserved despite a minimum of 1.5 km vertical uplift beneath a cover of 1.2 km of Cretaceous carbonates; (3) the overlying carbonates have responded to the uplift by drape folding around the flanks, and (4) the remnant of a crestal graben occurs in the central basin.

By measuring the stratigraphic throw of the Cretaceous carbonates Corry and Wilson (unpublished manuscript) determined that the deflection of the roof, hence the thickness of the laccolith, was between 1.5 and 2 km. The igneous rocks of the Solitario range in composition from andesite to olivine syenite, with rhyolite and granite by far the most abundant. The assumption of Lonsdale (1940) and Herrin (1958) that the intrusion was primarily basaltic at depth is not supported by the gravity data. No evidence that the magma reached the surface before the dome was unroofed has been found. Corry and Wilson (unpublished manuscript) did not require the magma to retreat since the top of the laccolith is almost certainly exposed now.

Since the frontal zone of the Ouachita system is a thick sedimentary mass (Flawn and others 1961), and because observed field relations suggest that the laccolith intruded approximately 0.5 km beneath the Cretaceous contact, Corry and Wilson (unpublished manuscript) inferred that the laccolith is exposed approximately 0.5 km below the Cretaceous contact and with a total thickness of 1.2 km of Cretaceous carbonates. They concluded that the depth of intrusion was approximately 2 km below the Paleocene surface.

In order to account for the nearly perfect circular outlines of the Solitario, they suggested that lateral spreading of the intrusion may have occurred along a horizontal plane of weakness such as a decollement surface within the Ouachita facies, possibly a southward continuation of the Dugout Creek Overthrust (Flawn and others 1961). However, no evidence for a large thrust sheet has yet been found.

Gravity Survey

In order to obtain further information about the dimensions of the intrusive body Corry (1972) made a gravity survey. The complete Bouguer anomaly map indicates two structural trends. The first strikes northwest-southeast along the crest of the Terlingua-Solitario anticline and continues south into Mexico. This trend also continues north beyond the map limits. The second trend strikes northeast-southwest and probably marks the eastern flank of basin-range block faulting to the southwest.

To construct a gravity model of the pluton, Corry (1972) measured rock densities in the area. From these data Corry and Wilson (unpublished manuscript) used a weighted mean average of 2.6 gm/cm^3 (grams per cubic centimeter) for the sedimentary rocks and 2.5 gm/cm^3 for the exposed igneous rocks. Using these densities, a two-dimensional model of a laccolith was calculated using the thickness obtained from the stratigraphic throw. From this model a maximum anomaly of -6.0 mgal was obtained for the Solitario. After the removal of the anomalies associated with the orthogonal regional trends, the maximum residual anomaly related to the pluton is +2 to +4 mgal. This small positive anomaly is in contrast with the predicted anomaly of -6 mgal. Further, the wavelengths of the anomalies do not correlate with the diameter for the Solitario. Therefore, the residual anomalies are the result of small, near-surface density variations and are only indirectly associated with the pluton. From this evidence Corry and Wilson (unpublished manuscript) concluded that the bulk density contrast between the pluton and the country is approximately zero. Since the approximate margins of the pluton are defined by surface topography it is possible to determine unambiguously from the gravity data that the Solitario is a shallow, floored, granitic pluton like a laccolith. For a stock to meet the condition of zero density contrast requires that, on the average, density of the stock remain equal to the density of the country rock over the entire column, and this is a physically unrealistic model. It is also physically unrealistic to assume a basic composition for the laccolith since the country rock density, hence the laccolith density, is only 2.6 gm/cm^3.

CONCLUSIONS

Of necessity Corry and Wilson (unpublished manuscript) simplified some aspects of the problem and ignored others. They considered the mere existence of the crestal graben to be more significant than the fact that it is a complex collapse structure. The preservation of the Ouachita structures has been emphasized, and the relatively small distortions associated with the uplift largely ignored. The igneous rocks have been characterized as simply "granitic" in the Solitario 7.5-minute quadrangle where in fact one can map 10 intrusive rock types and at least 8 extrusive formations.

An impact origin for the Solitario is ruled out by a lack of shock features, no associated negative gravity anomaly, and the absence of dominant basal deformation lamellae in quartz from the central basin.

The Solitario is the result of a granitic intrusion of early to mid-Tertiary age. The intrusion formed a circular laccolith eight to nine km in diameter and 1.6 to 1.8 km thick that is not concordant with the overlying sediments. From stratigraphic and structural evidence the depth of intrusion was approximately two km below the surface. The drape-folded carbonates extend the apparent radius of the laccolith to 13 km.

The laccolithic intrusion was probably diapiric, and the level of intrusion was determined by the density contrast between the ascending magma and the intruded sediments as proposed by Gilbert (1877). This hypothesis is supported by the available gravity data.

APPENDIX 6

ORIGIN OF THE TERLINGUA-SOLITARIO UPLIFT
(from Corry 1972:74-78)

INTRODUCTION

The Terlingua Uplift is a northwest trending, asymmetrical anticline bounded on the west and south by the Terlingua Monocline and on the east by the Long Draw Graben. The axis of the uplift is characterized by normal faults which strike perpendicular to the anticline axis. These faults bound at least one graben whose axis is also perpendicular to the axis of the anticline. This graben is obviously the result of longitudinal extension of the anticline. With the conjunctive relation of the anticline to the Solitario, two hypotheses can be advanced to explain the origin. The first hypothesis is an anticlinal laccolith, and the second a broad, open-folded, doubly-plunging anticline, resulting from compression from the southwest as a result of Laramide deformation. In either case Corry (1972) believed that the formation of the anticline postdates the formation of the Solitario dome. This conclusion is based on the circular shape of the Solitario. If the broad anticline had predated the Solitario, the zone of weakness in the anticline would have made the Solitario a more elliptical feature. In addition, it appears that intrusive and extrusive phases of the Laramide predate the compressive phase in this area.

Observed Stratigraphic Displacement

By reference to BM3692 and Table 3 for stratigraphic thicknesses, a minimum estimate of the uplift of the anticline can be made, since the crest of the anticline now exposes what must be nearly the top of the Santa Elena Limestone (see the geologic map). On this basis the total structural relief of the Terlingua-Solitario uplift is estimated at about 0.5 km in the Solitario quadrangle. Yates and Thompson (1959) found 980 m near Terlingua.

The anticline is certainly larger than the Solitario, being approximately 20 km long by 12.5 km wide. These dimensions are more typical of compressive deformation, which would be associated with late Laramide activity. Without further evidence, the interpretation of the anticline as a compressional feature of late Laramide deformation would be unquestioned. However, the presence of extensive cinnabar deposits associated with the formation of the anticline and which are of definite magmatic origin (Baker 1935) makes it unlikely that the uplift is of purely compressive origin. In view of the cinnabar deposits, which occur throughout the anticline, it is believed that an intrusive laccolithic body must be responsible for the anticline. The literature in general (Daugherty 1972) has long favored an intrusive body beneath the anticline for the reasons cited above.

The depth of the intrusive body must be on the same order as the body forming the Solitario, namely 1.5 km to 2.0 km. The Cretaceous beds acted, apparently, as the resistant beds during intrusion. The steep flanks are apparently formed by the same process of drape folding (Stearns 1971) that formed the flanks of the Solitario. Because deflection was only on the order of 0.5 km, extensional effects have not played as important a role as in the Solitario. Crestal grabens have formed perpendicular to the axis of the anticline, as a result of the doubly plunging shape of the domed strata above the laccolith.

Laramide Faults Associated with the Terlingua-Solitario Uplift

The crest of the anticline is marked by faults striking perpendicular to the axis of the anticline. Only one of these faults is shown on the geologic map, but similar faults continue to the south and are clearly visible on the air photos. These faults are normal faults resulting from extension due to the doubly plunging nature of the anticline. The throw on these faults is probably less than 100 m. In at least one instance this faulting has resulted in a crestal graben, whose axis is perpendicular to the axis of the anticline. The extension across the axis apparently has been largely elastic with strain energy released in the hinge areas of the drape folds on the margins. Deflections were not of sufficient amplitude to cause formation of a crestal graben parallel to the axis of the anticline. The crestal graben which formed perpendicular to the axis of the anticline would seem to be unique to the Terlingua-Solitario uplift, and is undoubtedly due to the laccolithic origin of the anticline.

APPENDIX 7

INTRUSIVE ROCKS IN THE SOLITARIO QUADRANGLE
(from Corry 1971:127-130, 141-149)

Andesite: Herrin (1958:122) found a dark grey, porphyrytic, fine-grained groundmass rock, weathering deep red, which he termed andesite. The rock is highly altered and is the most basic rock found in the Solitario.

Herrin (1958:122) describes the andesite in thin section as composed of phenocrysts of zoned labradorite to oligoclase feldspar commonly mantled by orthoclase. Some epidote is associated with the more mafic centers in zoned phenocrysts. Hematite after magnetite is common. Augite, biotite, and apatite are accessory minerals. The andesite is compositionally gradational into latite.

Corry (1972) did not sample the andesite. An outcrop mapped as andesite by Herrin (1958), sampled and examined in thin section by Corry, turned out to be an olivine syenite.

Hornblende andesite: An intrusive dike is exposed in the Righthand Shutup where it is crossed by the bounding fault on the west flank of the Solitario. The dike or small flow, as presently exposed, is about 10 m wide and 500 m long. In outcrop and hand specimens the rock has the appearance of a vesicular basalt with blebs and veins of coarsely crystalline calcite common throughout. The calcite is apparently limestone that was mobilized and recrystallized as the dike intruded through the Cretaceous section. No inclusions of the deeper Ouachita facies rocks have yet been found in this dike.

The distinctive feature in thin section of this rock is the presence of a deep orange mineral identified by Corry as lamprobolite or basaltic hornblende. The groundmass is composed of microlites of plagioclase feldspar and minute crystals of lamprobiolite. Phenocrysts of lamprobolite, shattered microcline, andesine, zircon, and xenoliths of calcite are present. Phenocrysts are commonly shattered and invaded by the groundmass.

The approximate composition of the rock is calcite 25%, lamprobolite 20%, microcline $<$ 5%, andesine 45%, magnetite 5%, zircon $<$ 5%. This composition best fits the classification hornblende andesite (Williams and others 1954:95).

Latite (Trachyandesite-Syenodiorite): Lonsdale (1940: 1587) compiles rocks of intermediate composition under the group classification, trachyandesite-syenodiorite. Herrin (1958:121) uses the term latite for the same rock, and has mapped four outcrops in the south central basin. Herrin (1958:121) describes latite as intermediate between trachyte and andesite.

In hand specimen these rocks are porphyrytic, brown-grey when weathered, and a light chocolate-brown when fresh. One thin section was examined by Corry, who deferred to Lonsdale (1940:1590) and Herrin (1958:121-122) for detailed descriptions of the rock. Corry (1972) followed Herrin's (1958) classification.

Solitario Peak Rhyolite: The oldest exposed Tertiary igneous rock in the Solitario quadrangle is the Solitario Peak Rhyolite. Powers (1921), Sellards and others (1931), Lonsdale (1940), and Herrin (1958) have referred to this unit as simply the "rim sill." Because of its stratigraphic significance, it has been named and elevated to formation rank by Corry (1972). The Solitario Peak Rhyolite is exposed around the northwestern half of the inner rim of the Solitario basin, usually in the form of a low cuesta. The Solitario Peak Rhyolite is also poorly exposed near Hightank on the north end of the central limestone hills.

The type area for the Solitario Peak Rhyolite is at the entrance to the Lefthand Shutup where about 25 m of section is beautifully exposed. Lonsdale (1940) found a range in thickness from 4.5 m to 92 m. Sellards and others (1931) and Lonsdale (1940) have mapped the Solitario Peak Rhyolite completely around the inner rim. However, Herrin (1958) and Corry could find no outcrops in the southeastern half of the rim.

Lonsdale (1940:1548) describes the Solitario Peak Rhyolite as a

> . . . white rhyolite varying from spherulitic, partly glassy, to aphanitic; in some places it is slightly porphyritic. The very fine texture prohibits precise classification, but judging from the feldspars in coarser specimens the composition appears to vary somewhat. Most determinable specimens are sodipotassic, but a few may be potassic.

In the type section the Solitario Peak is a fine-grained grey rhyolite which weathers to a dark brown or maroon. A thin section from the type locality contained porphyrytic crystals of sanidine veined with calcite and quartz in a very fine-grained groundmass of (plagioclase to oligoclase) feldspar. Magnetite comprises about 5% of the rock, and zircon is present as a trace mineral. Minute biotite crystals are present.

The Solitario Peak Rhyolite was intruded, prior to the formation of the dome, as a sill, generally between the underlying Shutup Conglomerate and the overlying Yucca Formation. In the type section the rhyolite displays magnificent vertical columnar jointing. The tilting of these once vertical columnar joints to their present attitude of about 30° from vertical, together with the presence of the Solitario Peak Rhyolite near Hightank in the central basin, indicates that the intrusion of this rhyolite preceded the formation of the dome. This interpretation does not preclude the formation of the sill as a subsidiary of a deeper incipient laccolith. It does require injection and cooling of the sill prior to fracturing the roof rock.

Other Rhyolite Intrusions: Lonsdale (1940: 1565-1566) distinguished two types of rhyolite in the Solitario: potassic rhyolite and sodipotassic rhyolite. Herrin (1958) dropped this distinction, and since the types cannot be differentiated easily in the field, Corry (1972) continued Herrin's practice. It should be emphasized that rhyolite is a very common rock type in the central basin of the Solitario, and the geologic map by no means shows all the outcrops. Only the more prominent dikes have been mapped. Lonsdale (1940:1564-1578) gives analyses and descriptions of the different rhyolites found in the Solitario. Herrin (1958:117, 119) provides several more thin-section descriptions in the central basin. Corry examined three thin sections, two of which are described below.

One specimen was taken from a dike in the drainage of the Lower Shutup. In hand specimen, this rhyolite is a creamy white, porphyrytic rhyolite with dendrites of pyrolusite on the surface. In thin section, quartz and hematite crystals are readily identifiable. Occasional weathered phenocrysts of orthoclase feldspar are recognizable. The very fine-grained groundmass has been weathered, largely to chlorite.

The second section Corry examined was from an outcrop at the abandoned mine at the south end of the central block of Cretaceous limestone. In hand specimen, this rhyolite is a light brown, porphyrytic rhyolite which weathers to a dark brown. The specimen examined has small vesicles, and some small lithophysae. In thin section the rock is conspicuously veined with hematite. The phenocrysts are quartz and orthoclase feldspar, with some zircon. The groundmass has been partly altered to clay, probably mommorillonite, in the vesicles.

The third thin section examined was texturally a microgranite, and has been reclassified as such.

Granite: A prominent igneous peak about 2.5 km east of Tres Papalotes was found to be an intrusive body of microgranite. In hand specimens, the rock is a green speckled cream color where fresh, and weathers to a dark brown. The texture is that of a microgranite. Quartz, biotite, hornblende, and an orthoclase feldspar are recognizable by eye, or with the hand lens.

In thin section the groundmass is crystalline, with crystals about 0.1 m in diameter. The rock is composed of quartz, biotite, hornblende, sanidine (30%), and zoned plagioclase (andesine to oligoclase) feldspar. Magnetite, apatite, and zircon are accessory minerals.

Soda trachyte: Solitario Peak (Fig. 4) is a distinctive volcanic neck on the western rim of the Solitario. This is described by Lonsdale (1940:1586) as

> . . . typical soda trachyte . . . rock is medium to dark gray with many minute specks of mafic minerals . . . Microporphyrytic with laths and tablets of feldspar. . . .

Herrin (1958:120) found the groundmass consisted primarily of orthoclose laths. He also found altered biotite, magnetite, and augite with rims of aegerine-augite, as well as some interstitial quartz. The feldspar laths were preferentially oriented and produced a well-developed flow structure.

Herrin (1958) mapped this rock as aegerine-augite trachyte, but used soda trachyte in the text (Herrin 1958:119-120), Corry (1972) used the term soda trachyte.

Trachyte: The trachyte rocks exposed in the Solitario have been well described by Lonsdale (1940:1580) and Herrin (1958:119). Herrin divided the trachytic rocks in the Solitario into three types: soda trachyte, plagioclase bearing trachyte, and trachyte. Corry (1972) only retained two of these terms since plagioclase-bearing trachytes cannot be distinguished in the field.

All trachytic rocks in the Solitario contain quartz and grade into sodipotassic rhyolites which they resemble in being cream-colored to grey. One thin section of soda trachyte was examined by Corry but did not differ significantly from the description given by Herrin (1958:119). In thin section, the rock contains plagioclase (albite or oligoclase) feldspar. Potassium-rich orthoclase feldspars are microcline or orthoclase with some microperthite. The groundmass is composed of microlites of orthoclase feldspars. Magnetite and apatite are accessory minerals. Nash (1972, personal communication as referenced by Corry 1972) has also identified aenigmatite and an alkaline amphibole (arfvedsinite or riebeckite) in thin section.

Olivine syenite: This is the rock classified by Lonsdale (1940:1693) as analcite syenite. However, Herrin (1958:123) and Corry (1972) did not identify analcite in thin section. Lonsdale (1940:1604) lists the percentage of analcite as only 3.4% by volume in an analysis of analcite syenite in the Solitario. Because analcite is so rare, and the olivine in the rock so distinctive in hand specimens, Corry (1972) called this rock olivine syenite. This is the only rock containing olivine within the Solitario dome.

Lonsdale (1940) and Herrin (1958) mapped only one exposure of this rock in the Solitario. Corry (1972) discovered a second outcrop about 2 km southeast of the original outcrop. In hand specimen, the rock is a dark grey porphyrytic rock with possible phenocrysts of plagioclase feldspar and olivine. The olivine forms distinctive green blebs in the otherwise grey rock. The outcrops weathers a dark red.

In thin section the groundmass is composed principally of orthoclase feldspar. The texture is that of a microsyenite with a finely crystalline groundmass. The rock is composed of olivine, iddingsite after olivine, plagioclase (andesine and oligoclase), orthoclase, hornblende, biotite, apatite, and magnetite. The magnetite usually occurs as small clusters within the olivine crystals, and the olivine is fayalitic.

Chalcedony: Chalcedony occurs commonly throughout the Solitario quadrangle. McKnight (1970) has mapped one prominent vein of it below the Bogles domes in Fresno Canyon. Other deposits are not mapped, but chalcedony is a common associate of many of the extrusives and intrusives in the area.

APPENDIX 8

TERTIARY STRATIGRAPHY IN THE SOLITARIO QUADRANGLE (from Corry 1972:127-140)

Jeff Conglomerate: The Jeff Conglomerate was named by Eifler (1951) as a member of the Huelster Formation in the Barilla Mountains about 160 km to the north. McKnight (1970:6) correlated the Jeff Conglomerate and gives it formation rank, with exposures in the southwest corner of the Solitario quadrangle. The rock is a conglomerate of well-rounded limestone cobbles and boulders up to 34 cm in diameter. Lenses of sandstone occur, and the matrix of the conglomerate is a sandstone so well cemented that McKnight (1970:6) finds the rock breaks across the boulders rather than around them.

The Jeff Conglomerate lies with angular unconformity over the Cretaceous Boquillas Formation. The Jeff is overlain by volcanic Chisos Formation. McKnight (1970:6) finds the thickness varying from about one m to six m. The age of the Jeff Conglomerate is given by Eifler (1951:342) as probably lower Eocene.

Chisos Formation: The Chisos Formation was named by Udden (1970b:60) from outcrops in the Chisos Mountains, southern Brewster County, Texas, where the formation is approximately one km thick. The formation is composed of massive conglomerate, coarse-grained sandstone, fine-to-medium-grained tuffaceous sandstone, tuffaceous clay and mudstone, tuff, indurated tuff, and lava with considerable variation in thickness and lithology in the various outcrops. Maxwell and others (1967:112-137) essentially redefine the type section, dividing the Chisos Formation into five members—Tule Mountain Trachyandesite, Mule Ear Spring Tuff, Bee Mountain Basalt, Ash Spring Basalt, and the Alamo Creek Basalt—plus two informal units, undifferentiated tuff, and sedimentary rocks. McKnight (1970:7) correlates and maps all but the Ash Spring Basalt of the formal members in the Bofecillos Mountains area and divides the informal units into undifferentiated tuff, conglomerate, sandstone, and "mud rock," and a unit of nonmarine limestone. Corry (1972) mapped the entire formation as undifferentiated.

In the Solitario quadrangle the formation thins and pinches out in Fresno Canyon against the flanks of the Solitario dome and the Terlingua-Solitario anticline (McKnight 1970:8). Over most of the Bofecillos Mountains area the Chisos Formation is from 150 to 250 m thick. The Chisos overlies the Jeff Conglomerate and underlies the Mitchell Mesa Tuff. Maxwell and others (1967:136-137) have dated the Chisos Formation by fossils and radiometric determinations as middle to upper Eocene.

Mitchell Mesa Tuff: The Mitchell Mesa Tuff was named and described by Goldich and Elms (1949) in the Buck Hill quadrangle. McKnight (1970) correlates and traces the Mitchell Mesa over a large area to the north and west of the Bofecillos Mountains.

McKnight (1970) describes it in the map area as a white buff tuff at the base grading upward into the thoroughly welded resistant ignimbrite characteristic of the formation. The thickness varies generally from 6 to 11 m with a maximum of 15 m. The age of the Mitchell Mesa Tuff has not been determined. The Mitchell Mesa is exposed only at one outcrop in the southwestern corner of the Solitario quadrangle.

Fresno Formation: McKnight (1970:13) defines the Fresno Formation as the main extrusive event of the Bofecillos volcano to the west of the Solitario dome. The upper flows of the Fresno Formation contain conglomerate with rock fragments of Ouachita facies derived from within the Solitario (McKnight 1970:13) indicating advanced erosion of the dome by Fresno time. Volcanic activity within the dome was probably also renewed at this time.

In the Solitario quadrangle the Fresno Formation is principally composed of tuff, ignimbrites, and a latite porphyry (McKnight 1970). Some mafic trachyandesite, rhyolite breccia, sandstone, and conglomerate are also found.

The maximum thickness exposed is about 300 m though the total thickness is estimated at 460 m. The Fresno Formation overlies the Mitchell Mesa Tuff and underlies the Santana Tuff. Its age is approximately Oligocene based on stratigraphic position.

Santana Tuff: As defined by McKnight (1970:16) the Santana Tuff is composed of at least four partly welded ashflows, or ignimbrites. In the area of Fresno

Canyon the tuff has a thickness of about 1.5 m, but reaches a thickness of 168 m at the mouth of Panther Canyon, southwest of the Solitario quadrangle.

The Santana Tuff forms distinctive orange cliffs in Panther Canyon, but in the Solitario quadrangle it is visible only as a trace on the west walls of Fresno Canyon. The tuff overlies Fresno Formation and underlies the Rawls Formation. The formation is probably early Miocene in age.

Rawls Formation: The Rawls Formation was named by Goldich and Seward (1948) and comprises the lava flow capping Tascotal Mesa which overlies the Fresno equivalent Tascotal Formation. The name Rawls Basalt was used more formally by Erickson (1953). As used by McKnight (1970), the Rawls Formation comprises everything younger than Santana Tuff, or Fresno Formation if Santana Tuff is missing.

According to McKnight (1970), the Rawls Formation is the result of a second and final eruptive period of the volcanoes of the Bofecillos Mountains. The extrusives of this period become more complex, and McKnight lists nine formal members which are in turn subdivided into 25 submembers. The rock types forming the Rawls Formation are extremely varied. The formation contains tuffs, volcanic mud-flows or lahars, basalt, trachybasalt porphyry, latite porphyry, trachyandesite, trachyte, ignimbrites, conglomerate, sandstone, and bolson fill. Not all of these rock types are exposed in the Solitario quadrangle. Corry (1972) made no attempt to map individual members. Future workers on the stratigraphy of the completely interfingered flows may well choose to make several formations out of the present Rawls Formation and elevate the Rawls name to group status.

The thickness of the Rawls Formation is slightly less than the older Fresno Formation. McKnight (1970:17) estimates a maximum thickness of about 370 m. The Rawls Formation forms the caprock of the mesa west of Fresno Canyon and onlaps the previously eroded Solitario dome as far as Telephone Canyon Formation in the northwest. The Rawls Formation is underlain by Santana Tuff in most exposures and is the youngest Tertiary extrusive rock in the Solitario quadrangle. Erickson (1953) tentatively assigns a Miocene age to the formation.

Needle Peak Tuff: The Needle Peak Tuff was named by Corry (1972) after Needle Peak in the southern central basin of the Solitario. The Needle Peak Tuff occupies most of the lowlands in the central basin. Lonsdale (1940) and Herrin (1958) refer to this formation as "vent agglomerate." Their descriptions of "vent agglomerate" coincide so closely with descriptions of fallback brecia at known impact structures that its presence was considered a strong argument for an impact origin. As a result considerable effort was expended by Corry (1972) in analysis of this problem. The unit was elevated to formation status by him, because the Needle Peak Tuff does not correlate with formations outside the Solitario but is a melange of rock types both pyroclastic and sedimentary in origin. Unfortunately that peak is *not* composed of the tuff formation under discussion.

The Needle Peak Tuff is a lithic tuff (Pettijohn 1957:332) or a volcanic wacke (Williams and others 1954:303). The tuff is distinguished in the field by the large number of inclusions, or pseudomorphs of inclusions, of novaculite, chert, limestones, and miscellaneous igneous rocks. These inclusions are in general subangular to rounded, and their appearance is that of stream worked pebbles. The inclusions compose from 50% to 90% of the rock, depending apparently on the amount of stream reworking of the tuff after deposition. The formation exhibits considerable variation, both laterally and vertically, due to amount and kind of postdepositional metamorphism. For convenience of classification, Corry subdivided the formation into three types, or members, based on amount and type of metamorphism.

Type 1 Needle Peak Tuff is essentially a lithic tuff which has undergone limited or no alteration. The great majority of the exposed section is of type 1 composition, and it is believed that type 1 is the parent rock from which types 2 and 3 are derived by hydrothermal and thermal metamorphism respectively. The present exposure of Needle Peak Tuff is an erosional remnant of a much larger body which once covered and partially filled the central basin of the Solitario. In three thin sections of type 1 examined by Corry (1972), the inclusions appear poorly cemented in a clay matrix which comprises up to 50% of the rock fraction. The inclusions are usually coated with hematite, which precludes optical identification of the clay minerals. In all type 1 thin sections, devitrified glass shards are recognizable in the matrix, and comprise as much as 25% of the rock fraction, or 60% of the matrix. Some chlorite is present, but, in general, the minerals are remarkably fresh and unaltered. Reaction rims on the inclusions are absent or very weakly developed. Some secondary biotite may be present and some secondary calcite. Most of the biotite is, however, detrital. Detrital orthoclase, sanidine, and microcline, as well as detrital plagioclase are present in significant (10% of rock fraction) quantities. Quartz is present both as sand grains in the matrix and as included sandstone fragments, but is not as common as the feldspar grains. No secondary quartz is present.

Type 2 Needle Peak Tuff is the apparent result of hydrothermal alteration of type 1. Type 2 is characterized by large quartz crystals which may be as much as several centimeters in length. In two thin sections examined by Corry (1972), the matrix was primarily crystalline quartz and magnetite, or hematite after magnetite. Reaction rims are prominent on the inclusions, and generally inclusions less than one cm in diameter have disappeared into the groundmass except for faint outlines. In one of the hand specimens, bands of rhyolite were visible. Type 2 may grade into quartz veins or into type 3. The rock is porous, with about 5% of the surface occupied by visible pores.

Type 3 Needle Peak Tuff differs only from associated rhyolites, which it grades into, by the presence of large inclusions. Inclusions less than 10 cm in diameter are visible only as broken pseudomorphs. Apparently inclusions of less than several centimeters in diameter have been thermally reworked into the groundmass. The replacement minerals in the pseudomorphs are generally sanidine and calcite. The groundmass is a porphyrytic rhyolite similar in composition and appearance to the Solitario Peak rhyolite. Quartz, plagioclase feldspar, biotite, and zircon are recognizable phenocrysts within the groundmass. Type 3 is best exposed at "Three Springs" north of the entrance to the Lower Shutup.

The origin of the tuff in the central basin of the Solitario is as an accumulation of pyroclastics found in the Fresno Formation, Santana Tuff, and the Rawls Formation from outside the dome, and possibly from sources within the basin or on the eroded rim. These pyroclastic rocks were mixed by stream action with rock fragments of the Ouachita facies and central Cretaceous limestone block. When intrusive and extrusive activity was initiated within the eroded dome, possibly late in Eocene time in conjunction with Fresno Formation activity, the Needle Peak Tuff was in part metamorphosed by rhyolites which cut the tuff and in places overlay it. Circulation of hydrothermal fluids in other sections caused the formation of type 2 tuff. Erosion has selectively removed most of the less resistant type 1 tuff leaving the present configuration.

Because of poor vertical exposures, less than 10 m anywhere, no type section was designated by Corry (1972). Type 1 can best be seen where the road, travelling southwest from Tres Papalotes, goes into the stream bed of the Lower Shutup. Type 2 has only been found in isolated patches. One exposure is near the abandoned mine, where the road rounds the southern tip of the central Cretaceous limestone block. Type 3 is best seen at "Three Springs."

A VEGETATIONAL SURVEY OF THE SOLITARIO

Mary Butterwick and Stuart Strong

INTRODUCTION

The plant life of the Solitario is characterized by the sotol-lechugilla vegetational zone typical of the Trans-Pecos region (Tharp 1939). Although the plants of the Solitario may be found elsewhere throughout west Texas, the dramatic geological diversity of the Solitario permits a corresponding diversity of plants rarely found in an area of comparable size. The contrasting geological formations that characterize the Solitario also serve to segregate the flora into distinguishable subgroups.

Along the steep rim of the circular limestone outcrops around the Solitario one finds ocotillo (*Fouquieria splendens*), agave (*Agave lechegilla*), sotol (*Dasylirion leiophyllum*), and resin-bush (*Viguiera stenoloba*), and numerous cacti. Similar plant associations also inhabit the steep chert slopes, igneous peaks, and sandstone ridges found within the Solitario. The lowland interior of the Solitario is comprised of two basic units that are diverse geologically; the northern unit is composed of sedimentary sandstone and shale while the southern unit is volcanic in origin. Both lowland areas support desert flat-land shrubs such as creosote (*Larrea tridentata*), mesquite (*Prosopis glandulosa*), catclaw acacia (*Acacia greggii*), tarbush (*Flourensia cernua*), guayacan (*Porlieria angustifolia*), wolfberry (*Lycium berlandieri*), and beebush (*Aloysia gratissima*). The four main canyons that drain the Solitario show the benefits of a relatively persistent water supply in the stands of water-loving trees such as Gregg ash (*Fraxinus greggii*), western soapberry (*Sapindus saponaria*), little walnut (*Juglans microcarpa*), Mexican buckeye (*Ungnadia speciosa*), and scrub oak (*Quercus pungens*). Canyon shrubs also normally found in a higher or wetter area include the mescal bean (*Sophora secundiflora*), toothed service-berry (*Amelanchier denticulata*), Havard plum (*Prunus havardii*), evergreen sumac (*Rhus virens*), rough mortonia (*Mortonia scabrella*), and seepwillow (*Baccharis glutinosa*).

Numerous herbaceous annuals and perennials comprise a significant part of the ground cover. Some of the more prevalent taxa are desert baileya (*Baileya multiradiata*), bluntscale bahia (*Bahia pedata*), hairyseed bahia (*Bahia absinthifolia*), *Machaeranthera scabrella*, and Wright verbain (*Verbena wrightii*).

Grasses frequenting the Solitario include sideoat gramas (*Bouteloua curtipendula*), chino grama (*Bouteloua ramosa*), Wright three-awn (*Aristida wrightii*), silver bluestem (*Bothriochloa saccharoides*), fluffgrass (*Erioneuron pulchellum*), bush muhly (*Muhlenbergia porteri*), and alkali sacatan (*Sporobolus airoides*), all of which are typical of a desert grassland.

METHODS

This report is based on field studies undertaken during June and July of 1975.

The plants of the Solitario were surveyed by two methods. First, the qualitative nature of the flora was determined by a collection of plant specimens throughout the major areas of the Solitario. Identifications of the species were made according to the *Manual of the Vascular Plants of Texas* (Correll & Johnston 1970) and the *Manual of the Grasses of the United States* (Hitchcock 1950), with the exception of the oaks which were annotated by Dr. C. H. Muller. Specimens collected have been stored at the University of Texas herbarium for future reference.

Secondly, the composition of the vegetation was measured quantitatively. Nine areas were chosen to be a representative sample of the different environmental forms in the Solitario: ridge tops, igneous and limestone slopes of various orientation to the sun, and alluvial flats and stream beds. In eight of the sample areas, the quadrat plot method was used according to the procedure described by Curtis and Cottam (1963). A 0.1-m quadrat (a rectangular metal frame) was placed along a 100-m tape at 10-m intervals. At each interval, the number of species falling within the quadrat and the percentage of ground covered by each plant species was recorded. The 100-m tape was then moved 10 m to the side to form a parallel line and the procedure was repeated. Additional lines were run until no new species were found. From this data it was possible to calculate the numerical frequency of each species, ground area covered by all plants, and relative frequency and relative dominance among the species (Appendix 2).

The streambed association required a different method of quantitative measurement. This association generally occurred as a narrow band of plants crowded at the edge of the streambed, making repeated quadrat transects impossible. Therefore a line transect was employed, and a record was made of the number of individual plants of each species and the area along a 100-m tape covered by each individual. This process yields similar information, i.e., relative density, total coverage and relative dominance of the species encountered as does the quadrat plot method.

DISCUSSION

The Big Bend country with its unique and unusual life forms has attracted the attention of botanists since the middle of the 19th century. Charles Wright made extensive botanical collections throughout the Southwest between 1849 and 1852, thus becoming the first contributor to our knowledge of the vegetation of this region. Shortly afterwards, John Torrey (1858) wrote the "Botany of the Boundary" in conjunction with the United States-Mexican boundary survey. Following the turn of the century, William Bray (1905) and Mary S. Young (1914), both professors at the University of Texas, wrote descriptions of the ecology and botany of the area. A recent botanical treatment of the Big Bend area has been produced by Barton Warnock (1970), a professor of Botany at Sul Ross University and an authority on West Texas flora.

Little botanical work has been done specifically on the Solitario except for incidental collections and a preliminary survey by the Texas State Land Office done in 1973.

Climatic conditions found here reflect those typically found in a desert environment. Water is limited, with a mean annual precipitation of about 20-30 cm (8-12 in) and an evaporation rate of about 2.3 m (90 in) a year which is the highest rate in the state. Mean annual temperatures are about 18°-19°C, and the warm season (number of days in which temperature is above freezing) extends from 230 to 245 days out of the year. The intensity of sunlight is indicated by a mean annual possible sunshine of 70-80% (Arbingast 1973).

These severe climatic conditions found in the Solitario, as in desert regions in general, produce a harsh environment for any form of life. In contrast to animals, the inability of plants to improve their situation by moving to a better area makes the survival of desert plants especially difficult. Consequently, the plants' survival and geographical distribution is dependent upon having characteristics that facilitate their ability to cope with demanding environmental conditions, of which climate is the most important. The predominant plants of the desert are those that have successfully met the challenge of living in a water-scarce land. A well-known adaption is the presence of water-storage tissue. Cacti are noted for their fleshy stems which store water and food. The agave and Spanish dagger store food and water in their leaf bases while sotol and bear grass use their roots and woody base for storage. Herbaceous perennials such as umbrella-wort (*Allionia choisya*), rain-lilly (*Cooperia* sp.), and angel-trumpets (*Aceisanthes longiflora*) have tuberous roots or bulbs for storage and stems which arise only under favorable conditions. ocotillo, which stores food reserves in its woody stems, drops its small leaves during dry periods in order to retard water loss by transpiration. The presence of very small leaves among desert plants is also thought to be a method of reducing possible water-loss by transpiration through the leaves; this pattern is exemplified by the acacias, cat's claw mimosa (*Mimosa biuncifera*), mesquite, white ratany (*Krameria grayi*), and dalea (*Dalea formosa*). Creosote, tarbush, and resin-bush have resinous coatings on their leaves which may reduce the rate of water loss. Similarly the presence of leaf hairs is considered to be a device to retard water loss; this is seen in the silver leaf and species of *Croton*. Annual plants are able to remain in dormancy as a seed until the proper conditions of moisture and temperature exist to stimulate germination; this phenomenon is seen in bladderpod (*Lesquerella fendleri*), gilia (*Gilia rigidula*), name (*Nama hispida*), and desert baileya. Ferns and selaginella possess the ability to roll up their fronds to reduce exposure to the heat.

In contrast to the harsh conditons of the dry mountain slopes and plains, the canyons enjoy more water and protection from the desiccating winds and intense sunlight. As a result, the relatively hospitable conditions in the canyons facilitate the growth of plants that have not undergone adaptations to severe desert conditions; these plants frequently are the same ones that are normally found in more favorable climates. It is assumed that they are relics from a time when the region had a wetter climate.

The information gathered in this study indicated that four major plant associations existed in the Solitario, each corresponding to one of the major types of terrain—mountain slopes, alluvial gravel, riparian regions, and canyons. It was found that any one of these topographic areas tended to support a distinctive group of plants that was different in type and proportion from the others. This is not to say that within any one of the four areas there was a homogeneity of plants throughout. In fact, the combinations of plants in two adjoining places frequently varied noticeably. This type of local variation in plant composition has suggested to some that each homogeneous local association of plants comprises a separate association. Our data suggested otherwise. Although local variations did occur, there was a persistent ubiquity of some species. The local variations that did occur within a single type of terrain were reasonably attributable to the random ebb and flow of plants over time. It is probable that each of the four major terrain types is capable of supporting many changing combinations of its favored plants. Since the data was consistent with this assumption, a conclusion of this report is that the major plant associations were dependent upon and generally contiguous with the four major types of terrain to be discussed below. It must be pointed out that plants characteristic of one of the four regions were not necessarily found there exclusively, but they were notably more likely to be there than elsewhere. The exception to this rule was a group of plants that was ubiquitous throughout the Solitario. Among them were resin-bush, creosote, mesquite, bee bush, and prickly pear. Their presence constituted a point of overlap between the associations.

A map illustrating distributions of the recognized plant associations accompanies this report.

THE SLOPE ASSOCIATION

The Slope Association, distinguished by the presence of lechugilla, sotol, and ocotillo, is the most widespread of the plant associations recognized in this study. Known for its geological uniqueness and complexity, the Solitario features both igneous and limestone slopes. One of the purposes of the transects is to determine whether or not a correlation between the two basic soil types and the vegetation exists. With a few exceptions, the data did not suggest such a relationship. A transect run on a limestone slope shows *Coldenia greggii,* a known calciphile, to be the dominant shrub, accounting for about 18% of the total area covered (Table 8, Fig. 7). *Linum rupestre* and *Leucophyllum minus* are also found exclusively on calcareous soils. However, the majority of species encountered has a more general distribution, irrespective of these edaphic factors. The ubiquitous taxa include shrubs such as mesquite, resin-bush, cat's claw mimosa, desert olive (*Forestiera angustifolia*), and red-berry juniper (*Juniperus pinchotii*). Lechuguilla and sotol, in addition to Wright vervain, bluntscale bahia, hairyseed bahia and *Machaeranthera scabrella*, various cacti, and a majority of the grasses, inhabit both igneous and limestone areas (Tables 1, 2, 6, 7, 8; Figs 1, 2, 6, and 7).

Considerable quantitative and qualitative variation in plant composition exists within the Slope Association. As a result, each transect site shows a distinct array of dominant shrubs, herbs, and grasses. For instance, the dominant shrubs on one slope are bee bush, resin-bush, and Engelmann prickly pear (*Opuntia phaeacantha* var. *discata*), while on another slope resin-bush, cat's claw mimosa, red-berry juniper, and tatalencho (*Gymnosperma glutinosum*) dominate (Tables 1, 8). Although resin-bush is a common element at both sites its relative dominance varies considerably from 16.73% to 6.55%. Similar relationships can likewise be drawn among the other components of this plant association.

Another characteristic of the Slope Association is the degree of grass development which accounts for from 17.1% to 55.5% of the total coverage. As with the herbs and shrubs, the dominant grasses vary from one transect site to another. The most prevalent grasses include chino grama, silver bluestem, Wright three-awn, and side-oats grama. Less frequently encountered species are fluffgrass, mesa muhly, purple three-awn, southwestern needle grass (*Stipa eminens*), and vine-mesquite (*Panicum obtusum*). Dominance of chino grama, silver bluestem, side oats grama, and three-awn, all of which make fair to good grazing for wildlife and livestock, is indicative of an area that is relatively undisturbed. However, the abundance of shrubs such as resin-bush, which competes poorly with a well-developed grass cover, probably is the result of a previously deteriorated grassland that has only recently been allowed to rejuvenate. The greater percentages of grass cover that characterize the higher elevations may also be due to this area's inaccessibility to livestock as compared to the plains of the Solitario.

Although often the least conspicuous components of a plant association, the herbaceous species account for a great deal of the diversity found on the slopes of the Solitario. In addition to the more widespread species mentioned previously, milkwort (*Polygala scoparioides*), showy menodora (*Menodora longiflora*), plains fleabane (*Erigeron modestus*), Drummond hedeoma (*Hedeoma drummondii*), and angel's trumpets frequent many of the slopes. A significant percentage of the ground cover, ranging from 16.19% to 65.45%, is composed of herbs (Table 1, 7).

THE ALLUVIAL-GRAVEL ASSOCIATION

Alluvial gravels, composed of material that has been washed down from the neighboring slopes, are characterized by a fine-textured soil and a fairly level terrain. Situated among the numerous drainages within the Solitario, this association has access to varying quantities of water. The substrate allows for considerable root development and thus supports typical desert shrubs, such as creosote, mesquite, tarbush, wolfberry, littleleaf sumac (*Rhus microphylla*), bee bush, and Engelmann prickly pear. Minor shrub associates include white ratany, guayacan, lotebush (*Ziziphus obtusifolia*), and tatalencho. That the shrubs are a prominent feature is exemplified in three transects which show relative dominance values of 53.54%, 67.81%, and 73.27% of the total area covered (Tables 3, 4, 5; Figs. 3, 4, 5).

Grasses play a minor role in the composition of this plant association. Relative dominance of all the grass species ranges from 2.22% to 6.79%. Although fluffgrass is the most frequently encountered species, Bermuda grass (*Cynodon dactylon*) and side oats grama are found in local abundance at two sites (Tables 3, 4). Other minor grass constituents include Wright three-awn, mesa muhly, and bristlegrass (*Setaria leucopila*). Man's impact on this association, as a result of grazing practices, is evidenced by the paucity of grass cover and by the relative abundance of fluffgrass which is recognized as a typical invader of overgrazed areas.

The understory of herbaceous species is a diverse and at times a prevalent element within the Alluvial-Gravel Association. For instance, in one quadrat transect desert baileya accounts for 36.83% of the total area covered (Table 5). Milkwort (*Polygala longa*), nama, Lindheimer senna (*Cassia lindheimeriana*), tasajillo (*Opuntia leptocaulis*), *Machaeranthera scabrella*, mesa greggia (*Nerisyrenia camporum*), and New Mexico vervain (*Verbena neomexicana*) are some of the more common herbaceous species found in this association.

THE RIPARIAN ASSOCIATION

Limited in its distribution, the Riparian Association encompasses the streambed itself and a narrow band of dense vegetation along the stream banks. This association is distinguished by such water-loving species as seepwillow, desert willow (*Chilopsis linearis*), burro-bush (*Hymenoclea monogyra*), and apache plume (*Fallugia paradoxa*). A line transect run along the bank of a dry streambed shows cat claw acacia and apache plume to be the dominant shrubs (Table 9; Fig. 3). Minor shrub components are mesquite, burro-bush, littleleaf sumac, and resin-bush. Several of the shrubs are draped with the twining growth of alpine clematis (*Clematis alpina*). Scattered individuals of side oats grama, vine-mesquite, bristlegrass, and silver bluestem occupy occasional breaks in the dense shrub border. Establishment of herbaceous species within the streambed is seldom observed, thus indicating the force with which water flows through these drainages during the rainy season. The convergency of these ephemeral streams with major drainages leading out of the Solitario results in a certain amount of overlap in vegetation between the Riparian and Canyon Associations.

THE CANYON ASSOCIATION

The Solitario canyons, consisting of narrow vertical cuts through the outside rim of the formation, are the passages through which water drains out of the Solitario to the lower surrounding land. As the recipient of more abundant water, the canyons have many of the vegetative elements characterizing the riparian association Apache plume, seepwillow, burro brush, and desert willow are found in all of the drainages.

The stark vastness and majesty of the canyons form one of the more impressive sights of the Solitario. The towering walls and often narrow canyons result in partial shade, lower temperatures, and reduced evaporation rates in comparison with the surrounding dry, exposed slopes and plains. As a result of these environmental factors, the canyons support an assemblage of plants that are characteristic of other canyon areas in the Trans-Pecos region. Common trees and shrubs include scrub oak, Gregg ash, toothed service-berry, rough mortonia, Mexican buckeye, Western soapberry, little walnut, and Havard plum (Fig. 9).

A significant number of species representing the slope and alluvial gravel associations are also present. Mesquite, catclaw acacia, bee bush, lotebush, littleleaf sumac, resin-bush, guayacan, desert olive and spiny hackberry (*Celtis pallida*) are frequently encountered. As a result of the more mesic environment, individuals inhabiting the canyons often exhibit greater stature and more luxuriant foliage than those found on the drier slopes and lowlands.

Several of the exclusively canyon species are thought to have been more widely distributed when climatic conditions were cooler and wetter. The continuous warming trend since the pluvial periods of Pleistocene has restricted such populations to these desert oases. The Canyon Association would thus be considered relictual.

RARE PLANTS

Three rare species inhabit the Solitario. *Cereus greggi*, the desert night-blooming cactus, was collected from the rim of the Solitario. A rather inconspicuous plant with crest-ribbed stems, it produces lovely white nocturnal flowers. The range of this species extends into New Mexico, Chihuahua, and Zacatecas. However, in Texas, *Cereus greggii* is considered very rare and acutely endangered.

Northwest of Solitario Peak is a population of *Quercus hinckleyi*, an oak formerly known only from the Solitario. Another population has since been sited at Shafter. The Solitario population consisted of 40-50 individual clumps growing on limestone soil. The shrubs were only about two feet high with small leaves devoid of hairs and with a bluish-gray color. All the individuals were very similar in appearance and were uniformly in flower at this time. No seedlings were observed. However, acorns collected from both the Solitario and Shafter populations have successfully germinated. The paucity of seedlings may be due to predation pressure on the acorns or improper environmental conditions necessary for germination of the propagules. It has been suggested that the uniformity of the population coupled with the absence of any seedlings may be indicative of a clonal population which has reproduced vegetatively, by way of rhizomes, for an extended period of time, perhaps since Pleistocene (Muller 1975). Periodic observation of those oaks, in addition to germination studies, may be helpful in understanding the absence of seedling establishment within this population.

A third rare species, Fendler lipfern (*Cheilanthes fendleri*), was found in a shaded side canyon that drains into the Lefthand Shutup. Previously collected in the mountains of Hudspeth and Jeff Davis counties, with a third locality in Crosby County, this fern is considered to be scarce and endangered in Texas. The range of *Cheilanthes fendleri* extends northward into Colorado and Arizona.

SUMMARY AND COMPARISON OF THE SOLITARIO, FRESNO CREEK AND COLORADO CANYON STUDY AREA

The Solitario, as the name implies, remains distinct from the Fresno Creek and Colorado Canyon areas in a number of botanical features. Heath cliffrose (*Cowania cliffrose*), toothed service-berry, Gregg ash, Arizona oak (*Quercus arizonica*), Gray oak (*Quercus grisea*), redberry juniper (*Juniperus pinchotii*), and rough mortonia were collected only from the Solitario. The limestone rim around the Solitario forms a partial barrier to seed dispersal. Environmental factors such as temperature, edaphic properties, water supply, or altitude may also prohibit the establishment of these plants in the other areas.

Another distinquishing feature of the Solitario is the lack of a permanent water supply. All the drainages within the Solitario are ephemeral with surface water remaining for a short period after a significant rainfall. Fresno Canyon and Colorado Canyon, however, both feature perennial water sources along the banks of the Rio Grande and in the vicinity of springs scattered throughout the canyons. These moist areas nurture growths of sedges, rushes, ferns, numerous grasses, ash (*Fraxinus velutina*), and cottonwood (*Populus arizonica*).

The slope community is for the most part continuous throughout. Distribution of sotol appears to follow an altitudinal gradient. Sotol is a characteristic element in the Solitario and higher slopes along Fresno Creek but is conspicuously absent from the slopes of the Colorado Canyon area. Increased aridity and grazing pressures in these latter two areas may be responsible for the relative abundance of lechuguilla and leatherstem as compared to the slopes of the Solitario.

The alluvial gravel association is fairly consistent except that creosote is far more extensive in the Fresno Creek and Colorado Canyon areas than in the Solitario. Once again an altitudinal phenomenon may be involved, resulting in higher temperatures and increased water-loss at the lower elevations. Man may have had a strong impact on the vegetation of Fresno Creek and Colorado Canyon, resulting in further deterioration of grasslands followed by the invasion of creosote.

The isolation of the Solitario is reflected by the scarcity of introduced species. This is a sharp contrast to the Colorado Canyon reach of the Rio Grande where introductions such as salt cedar (*Tamarix gallica*), tree tobacco (*Nicotiana glauca*), and giant reed (*Arundo donax*) predominate.

LITERATURE CITED

Arbingast, S. A., et. al 1973. *Atlas of Texas.* University of Texas at Austin. Bureau of Business Research, p. 15-19.

Bray, W. L. 1905. Vegetation of the Sotol Country in Texas. *Texas Academy of Science Bulletin,* p. 60.

Correll, D. S. and M. C. Johnston. 1970. *Manual of the Vascular Plants of Texas.* Renner, Texas: Texas Research Foundation.

Curtis, J. T. and G. Cottam. 1965. *Plant Ecology Workbook.* Minneapols, Minnesota: Burgess, p. 66-82, 95-98.

Gould, F. W. 1969. *Texas Plants–A Checklist and Ecological Summary.* College Station, Texas: Texas A&M University.

Gray, A. 1850. *Plantae Wrightanae.* Smithsonian Institute. Washington, D.C.

Hitchcock, A. S. 1950. *Manual of the Grasses of the United States.* Washington, D.C.: U.S. Government Printing Office.

Muller, C. H. July, 1975. Personal communications.

Tharp, B. C. 1939. *Vegetation of Texas.* Houston, Texas: Texas Academy Publications in Natural History.

Torrey, J. 1858. Botany of the Boundary, *U.S.-Mexican Boundary Survey,* 2(1), p. 20-270.

Warnock, B. H. 1970. *Wildflowers of the Big Bend Country, Texas.* Alpine, Texas: Sul Ross State University.

Young, M. S. 1914. Journal of Botanical Explorations in Trans-Pecos Texas, August-September, 1919, edited by B.C. Tharp and C. V. Kielman. *Southwesten Historical Quarterly 65* (3 and 4).

APPENDIX I

Localities for quadrat transects presented in Tables 1-8.

Table 1—Northwest facing slope of peak 5014, Mine Hill, ca. .5 mi. south of Tres Papalotes (Solitario 7.5-minute quadrangle map).

Table 2—Ridge top of same peak at that of table 1.

Table 3—East of metal stock tank, about 1.5 mi. northwest of Prospect Mt. (Solitario 7.5-minute quadrangle map).

Table 4—East of jeep trail, ca. about .33 mi. north of Tres Papalotes (Solitario 7.5-minute quadrangle map).

Table 5—West of jeep trail, ca. about .5 m. south of McGuirks tank (Solitario 7.5-minute quadrangle map).

Table 6—East facing slope, just southwest of Eagle Mountain (Solitario 7.5-minute quadrangle map).

Table 7—Northwest part of Solitario rim. South-facing slope of peak 4786 (Solitario 7.5-minute quadrangle map).

Table 8—Northwest part of Solitario rim. North-facing slope of peak 4786 (Solitario 7.5-minute quadrangle map).

Locality for line presented in table 9.

Table 9—Bank of streambed, about .6 mi. west of Prospect Peak (Solitario 7.5-minute quadrangle map).

APPENDIX II

Explanation of symbols used in tables

Q = Total quadrats in which species occurred.

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

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

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

TI = Total Individuals

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

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

TA = Total area covered by species.

FIGURE 1
The Slope Association – site for Quadrat Transect 1.

FIGURE 2
The Slope Association – site for Quadrat Transect 2.

TABLE 1
Quadrat Transect I

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida wrightii	2	4	2	4	3.22	1.3	1.97	65
Bothriochloa sacchariodes	13	26	13	25	20.16	9.7	14.67	485
Setaria leucopila	3	6		4	3.22	.3	.45	15
HERBS								
Agave lecheguilla	3	6	3	5	4.03	2.5	3.78	125
Cheilanthes sp.	1	2	1	1	.8	1.4	2.12	70
Dasylirion texanum	3	6	3	3	2.42	3.2	4.84	160
Evax verna	2	4	2	2	1.61	.2	.3	10
Lepidium virginicum	4	8	4	4	3.22	.4	.6	20
Nolina erumpens	2	4	2	2	1.61	.5	.76	25
Notholaena sinuata	1	2	1	1	.8	.2	.3	10
Parthenium confertum	3	6	3	3	2.42	.4	.6	20
Selaginella wrightii	2	4	2	5	4.03	.7	1.06	35
Thelesperma longipes	1	2	1	1	.8	.3	.45	15
Verbascum thapsus	1	2	1	1	.8	.3	.45	15
Verbena wrightii	4	8	4	4	3.22	.56	.85	28
SHRUBS & TREES								
Acacia greggii	4	8	4	4	3.22	3.2	4.83	160
Aloysia gratissima	15	30	15	18	14.52	12.00	18.15	600
Celtis pallida	1	2	1	1	.8	2.00	3.00	100
Opuntia phaeacantha	18	36	18	18	14.52	11.4	17.24	510
Parthenium incanum	3	6	3	3	2.42	2.1	3.18	105
Prosopis glandulosa	1	2	1	1	.8	2.00	3.00	100
Viguiera stenoloba	11	22	11	12	9.68	11.06	16.73	553
Ziziphus obtusifolia	1	2	1	1	.8	.2	.3	10

TABLE 2
Quadrat Transect 2

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida wrightii	7	23.33	12.07	15	18.07	2.73	5.09	82
Bothriochloa sacharoides	9	30	15.52	14	16.87	6.67	12.41	200
Erioneuron pulchellum	4	13.33	6.9	7	8.43	1.5	2.79	45
Setaria leucopila	1	3.33	1.72	1	1.2	.17	.31	5
HERBS								
Agave lecheguilla	4	13.33	6.9	6	7.23	5	9.3	150
Boerhaavia linearifolia	1	3.33	1.72	1	1.2	1.67	.31	5
Brickellia laciniata	1	3.33	1.72	1	1.2	1.67	3.1	50
Cassia lindheimeriana	2	6.66	3.44	2	2.4	.6	1.12	18
Cynanchum barbigerum	1	3.33	1.72	1	1.2	.5	.93	15
Dasylirion texanum	1	3.33	1.72	1	1.2	2.67	4.96	80
Echinocereus stramineus	2	6.66	3.45	2	2.41	1.07	1.99	32
Mammillaria sp.	1	3.33	1.72	1	1.2	.33	.62	10
Orobanche cooperi	1	3.33	1.72	2	2.41	.33	.62	10
Selaginella wrightii	17	56.66	29.31	23	27.71	19.5	36.29	585
Yucca thompsoniana	1	3.33	1.72	1	1.2	3.33	6.2	100
SHRUBS								
Aloysia gratissima	1	3.33	1.72	1	1.2	.5	.93	15
Opuntia phaeacantha	1	3.33	1.72	1	1.2	.67	1.24	20
Prunus havardii	1	3.33	1.72	1	1.2	2.5	4.65	45
Viguiera stenoloba	2	6.66	3.45	2	2.41	3.83	7.13	115
TOTAL	**58**			**83**	**99.94%**	**53.73%**	**99.99%**	**1612%**

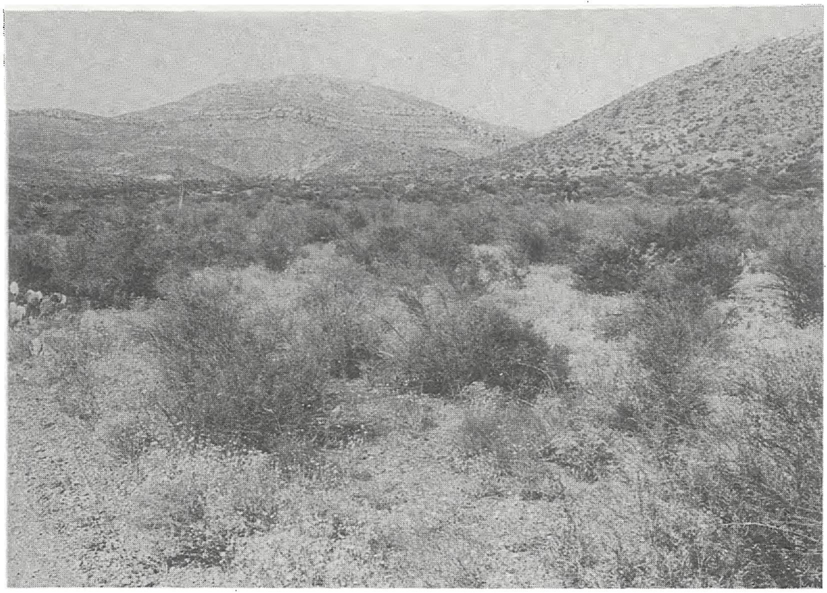


FIGURE 3

The Alluvial Gravel Association – site for Quadrat Transect 3.

TABLE 3
Quadrat Transect 3

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Cynodon dactylon	3	5	4.03	3	1.46	3.17	4.09	190
Erioneuron pulchellum	2	3.33	1.61	3	1.46	.25	.32	15
Muhlenbergia porteri	2	3.33	1.61	3	1.46	.5	.65	30
Setaria leucopila	3	5	2.42	5	2.44	.92	1.18	55
HERBS								
Atriplex obovata	1	1.66	.81	1	.49	.66	.86	40
Baileya multriadiata	3	5	2.42	3	1.46	.66	.86	40
Croton sancti-lazari	3	5	2.42	4	1.95	.5	2.58	120
Echinocereus triglochidatus	2	3.33	1.61	2	.98	.92	1.18	55
Euphorbia arizonica	3	5	2.42	5	2.55	.5	.64	30
Gaura boquillensis	2	1.66	.81	1	.49	.58	.75	35
Machaeranthera scabrella	15	25	12.1	59	28.78	4.25	5.49	255
Mentzelia multiflora	1	1.66	.81	1	.49	.75	.97	45
Nerisyrenia camporum	5	8.33	4.03	5	2.44	1.58	2.05	95
Opuntia leptocaulis	3	5	2.42	3	1.46	1.5	1.94	90
Parthenium confertum	3	5	2.42	6	2.93	.78	1.01	47
Phacelia congesta	1	1.66	.81	1	.49	.17	.21	10
Polygala scoparioides	5	8.33	4.03	12	5.85	.7	.9	42
Senecio douglasii var. *jamesii*	1	1.66	.81	3	1.46	.25	.32	15
Verbena neomexicana	3	5	2.42	3	1.46	.45	.58	27
Verbesina encelioides	1	1.66	.81	1	.49	.08	.11	5
SHRUBS & TREES								
Acacia constricta	3	5	2.42	1	.49	.92	1.18	55
Aloysia gratissima	1	1.66	.81	1	.49	.83	1.08	50
Flourensia cernua	6	10	4.84	6	2.93	5.75	7.43	345
Gymnosperma glutinosum	11	18.33	8.87	25	12.2	3.88	5.02	233
Larrea tridentata	7	11.66	5.64	9	4.39	7.17	9.26	430
Lycium berlandieri	13	23.33	11.29	15	7.32	14.5	18.73	870
Opuntia phaeacantha	3	5	2.42	3	1.46	3.83	4.95	230
Parthenium incanum	2	3.33	1.61	2	.98	2.5	3.23	150
Prosopis glandulosa	10	16.66	8.06	12	5.85	11.5	14.86	690
Rhus microphylla	2	3.33	1.61	2	.98	2	2.58	120
Ziziphus obtusifolia	4	6.66	3.23	5	2.44	3.83	4.95	230
TOTAL				205	102.93%	77.38%	99.96%	4644%

FIGURE 4

The Alluvial Gravel Association – site for Quadrat Transect 4.

TABLE 4
Quadrat Transect 4

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida wrightii	1	2	.96	3	1.96	1	1.52	50
Bouteloua curtipendula	2	4	1.92	2	1.31	2.3	3.5	115
Erioneuron pulchellum	8	16	7.69	19	12.42	1.16	1.77	58
HERBS								
Agave lecheguilla	1	2	.96	2	1.31	.5	.76	25
Bahia pedata	3	6	2.88	5	3.27	1	1.53	50
Baileya multiradiata	12	24	11.54	22	14.38	2.26	3.44	113
Cassia lindheimeriana	7	14	6.73	9	5.88	.9	1.37	45
Clematis alpina	1	2	.96	1	.65	1.5	2.29	75
Echinocereus sp.	1	2	.96	1	.65	.2	.3	10
Machaeranthera scabrella	9	18	8.65	17	11.11	2.12	3.23	106
Nama hispida	8	16	7.69	9	5.88	1.62	2.47	81
Opuntia leptocaulis	6	12	5.77	6	3.92	4.3	6.55	215
Parthenium confertum	1	2	.96	3	1.96	.4	.6	20
Phacelia congesta	1	2	.96	1	.65	.6	.91	30
Senecio douglasii var. *jamesii*	4	8	3.85	12	7.84	6.6	1.01	33
Verbena wrightii	3	6	2.88	3	1.96	.6	.91	30
SHRUBS & TREES								
Aloysia gratissima	12	24	11.54	14	9.15	15.3	23.32	765
Condalia hookeri	1	2	.96	1	.65	.4	.61	20
Fallugia paradoxa	1	2	.96	1	.65	2	3.05	100
Flourensia cernua	4	8	3.85	4	2.61	2	3.05	100
Koeberlinia spinosa	1	2	.96	1	.65	.2	.3	10
Krameria grayi	2	4	1.92	2	1.31	1.7	2.59	85
Lycium berlandieri	2	4	1.92	2	1.31	4	6.09	200
Opuntia phaeacantha	4	8	3.85	4	2.61	5.3	8.08	265
Porlieria angustifolia	2	4	1.92	2	1.31	3	4.57	150
Prosopis glandulosa	3	6	2.88	3	1.96	2.6	3.96	130
Rhus microphylla	3	6	2.88	3	1.96	6	9.14	300
Ziziphus obtusifolia	1	2	.96	1	.65	2	3.05	100
TOTAL				153	99.97%	65.62%	99.97%	3281%

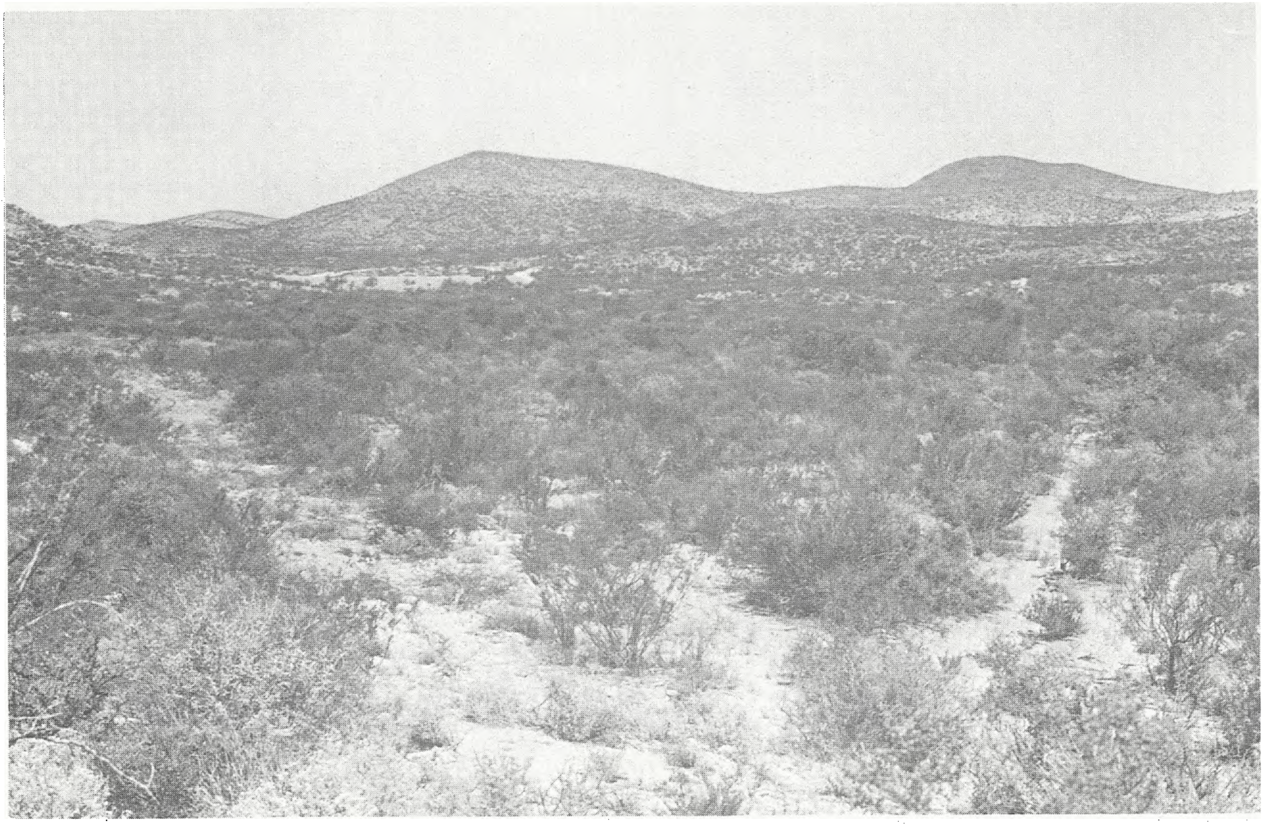


FIGURE 5

The Alluvial Gravel Association – site for Quadrat Transect 5.

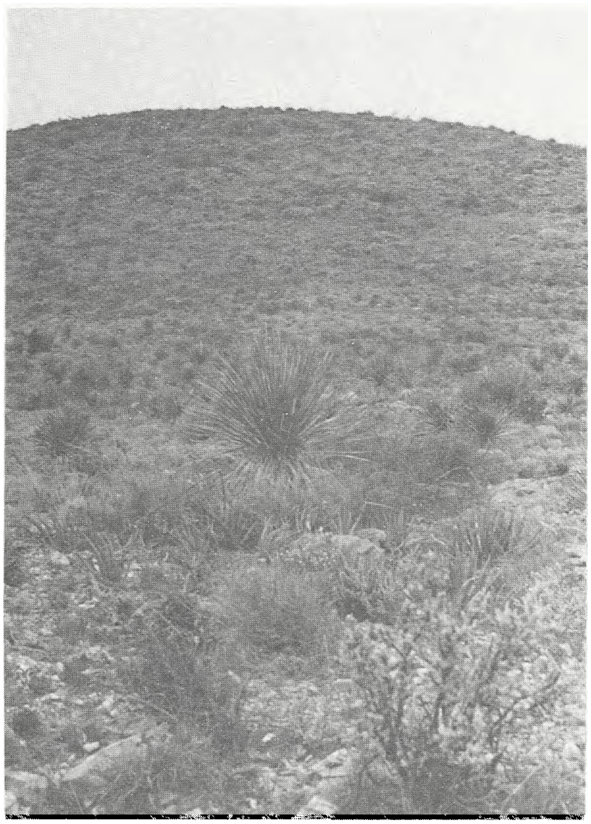


FIGURE 6

The Slope Association – site for Quadrat Transect 6.

TABLE 5
Quadrat Transect 5

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Erioneuron pulchellum	4	13.33	5.88	24	14.81	1.1	2.22	33
HERBS								
Baileya multiradiata	28	93.33	41.18	89	54.91	18.23	36.83	547
Dyssodia pentachaeta	2	6.66	2.94	2	1.23	.27	.54	8
Euphorbia fendleri	2	6.66	2.94	2	1.23	.5	1.10	15
Machaeranthera scabrella	2	6.66	2.94	4	2.47	.27	.54	8
Polygala scoparioides	7	23.33	10.29	9	5.55	.93	1.88	28
Senecio douglesii var. jamesii	7	23.33	10.29	13	8.02	1.2	2.42	36
Yucca torreyi	1	3.33	1.47	1	.62	.5	1.01	15
SHRUBS & TREES								
Larrea tridentata	12	40	17.64	15	9.26	20.83	42.09	625
Lycium berlandieri	1	3.33	1.47	1	.62	1.67	3.37	50
Poslieria angustifolia	1	3.33	1.47	1	.62	2	4.04	60
Prosopis glandulosa	1	3.33	1.47	1	.62	2	4.04	60
TOTAL				162	99.99%	49.5 %	99.99%	1485%

TABLE 6
Quadrat Transect 6

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida wrightii	5	25	8.77	7	6.48	1.9	3.26	38
Bouteloua ramosa	6	30	10.53	16	14.81	13.75	26.37	275
Erioneuron pulchellum	4	20	7.02	20	18.52	3.75	7.19	75
Muhlenbergia porteri	1	5	1.75	3	2.78	2	3.83	40
Panicum obtusum	1	5	1.75	4	3.7	.5	.96	10
Stipa eminens	1	5	1.75	5	4.63	1.5	2.88	30
HERBS								
Agave lecheguilla	4	20	7.02	6	5.56	5.75	11.03	115
Bahia absinthifolia	3	15	5.26	4	3.70	.75	1.44	15
Bahia pedata	9	45	15.79	16	14.81	2.4	4.6	48
Dasylirion texanum	1	5	1.75	1	.92	.5	.96	10
Echinocerous stramineus	1	5	1.75	1	.92	.5	.96	10
Gaura boquillensis	1	5	1.75	1	.92	.05	.01	1
Lepidium virginicum	1	5	1.75	1	.92	.15	.29	2
Machaeranthera scabrella	3	15	5.26	7	6.48	.25	.48	5
Opuntia leptocaulis	1	5	1.75	1	.92	.5	.96	10
Plantago patagonica	1	5	1.75	1	.92	.15	.29	3
Sida hederacea	1	5	1.75	1	.92	.1	.19	2
Verbena wrightii	1	5	1.75	1	.92	.15	.29	3
SHRUBS & TREES								
Forestiera angustifolia	1	5	1.75	1	.92	.25	.48	5
Mimosa biuncifera	3	15	5.26	3	2.78	8.5	16.3	170
Prosopis glandulosa	1	5	1.75	1	.92	.25	.479	50
Viguiera stenoloba	7	35	12.28	7	6.48	6.25	11.98	125
TOTAL	57			180	99.93%	49.9 %	99.6 %	1043%

FIGURE 7
The Slope Association – site for Quadrat Transect 8.

TABLE 7
Quadrat Transect 7

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida purpurea	1	2	.74	5	2.2	1	1.25	50
Aristida wrightii	13	26	9.63	34	14.98	6.66	8.35	333
Bouteloua ramosa	26	52	19.26	47	20.7	12.04	15.1	602
HERBS								
Acleisanthes longiflora	4	8	2.96	4	1.76	.9	1.63	65
Agave lecheguilla	12	24	8.89	25	11.01	8.7	10.91	435
Bahia absinthifolia	5	10	3.7	6	2.64	.6	.75	30
Baileya multiradiata	1	2	.74	5	2.2	7.76	9.73	388
Carlowrightia linearifolia	3	6	2.22	4	1.76	.32	1.13	45
Chamaesaracha villosa	6	12	4.44	8	3.52	.1	.12	5
Croton dioicus	1	2	.74	2	.88	.06	.08	3
Dasylirion texanum	7	14	5.19	8	3.52	7.4	9.28	370
Dyssodia acerosa	1	2	.74	1	.44	.3	.38	15
Euphorbia arizonica	1	2	.74	1	.44	.1	.12	5
Linum rupestre	2	4	1.48	2	.88	1.3	.1	4
Menodora longiflora	11	22	8.15	16	7.05	2.22	2.78	111
Polygala longa	10	20	7.41	19	8.37	10.6	13.29	530
Psilostrophe tagetina	1	2	.74	1	.44	.08	.1	4
Ruellia parryi	3	6	2.22	4	1.76	.6	.75	30
Thamnosma texana	1	2	.74	1	.44	.3	.38	15
Tragia ramosa	1	2	.74	2	.88	.1	.12	5
Verbena wrightii	1	2	.74	1	.44	.2	.25	10
Zinnia acerosa	1	2	.74	1	.44	.2	.25	10
TREES & SHRUBS								
Coldenia greggii	12	24	8.89	12	5.29	14.4	18.06	720
Leucophyllum minus	2	4	1.48	2	.88	.6	.75	30
Viguiera stenoloba	9	18	6.67	12	5.29	4.04	5.07	202
TOTAL				227	99.97%	79.68%	101.24%	3987%

FIGURE 8
The Riparian Association – site for Line Transect 1.

FIGURE 9
The Canyon Association – as represented by the Lower Shutup.

TABLE 8
Quadrat Transect 8

	Q	RFi	RFii	TI	RDi	RC	RDii	TA
GRASSES								
Aristida wrightii	3	2.72	7.5	6	2.45	.8	2.3	40
Bothriochloa saccharoides	19	17.27	47.5	37	15.1	7.65	17.59	306
Bouteloua curtipendula	28	25.45	70	85	34.69	14.75	33.91	590
Bouteloua ramosa	1	.9	2.5	2	.82	.25	.57	10
Muhlenbergia porteri	1	.9	2.5	2	.82	.5	1.15	20
HERBS								
Agave lecheguilla	2	1.81	5	5	2.04	2.25	5.17	90
Artemisia ludoviciana	1	.9	2.5	1	.4	.25	.57	10
Bahia absinthifolia	3	2.72	7.5	10	4.08	.42	.98	17
Baileya multiradiata	1	.9	2.5	1	.4	.07	.17	3
Cassia lindheimeriana	1	.9	2.5	10	4.08	.5	1.15	20
Dasylirion texanum	3	2.72	7.5	3	1.22	2.62	6.03	105
Erigeron modestus	12	10.91	30	30	12.24	1.07	2.47	43
Hedeoma drummondii	4	3.63	10	4	1.63	.1	.23	4
Lesquerella fendleri	1	.9	2.5	2	.82	.1	.29	5
Machaeranthera scabrella	1	.9	2.5	1	.4	.02	.06	1
Menodora scabra	1	.9	2.5	1	.4	.02	.06	1
Nolina erumpens	4	3.63	10	4	1.63	2.2	5.06	88
Polygala scoparioides	1	.9	2.5	1	.4	.05	.11	2
Selaginella wrightii	5	4.54	12.5	6	2.45	2.62	6.03	105
Verbena wrightii	4	3.63	10	5	2.04	.2	.46	8
SHRUBS & TREES								
Juniperus pinchottii	2	1.81	5	2	.82	2.62	6.03	105
Minosa biuncifera	2	1.81	5	2	.82	.75	1.72	30
Gymnosperma glutinosum	1	.9	2.5	1	.4	.5	1.15	20
Opuntia phaeacantha	1	.9	2.5	1	.4	.07	.17	3
Viguiera stenoloba	8	7.27	20	23	9.39	2.85	6.55	14
TOTAL				245	99.99%	43.14%	99.98%	1740%

TABLE 9
Line Transect 1

SPECIES	RFii	TI	RDii	TA
Acacia greggii	16.67	18	20.14	37.25
Aloysia gratissima	4.63	5	5.68	10.50
Atriplex canescens	7.41	8	4.73	8.75
Chilopsis linearis	5.56	6	11.22	20.75
Clematis alpina	13.89	15	8.38	15.50
Fallugia paradoxa	27.78	30	24.33	45.00
Gymnosperma glutinosum	2.78	3	.81	1.50
Prosopis glandulosa	2.78	4	5.41	10.00
Rhus microphylla	12.96	14	17.41	32.20
Viguiera stenoloba	4.63	5	1.89	3.50
TOTALS	100.01%	108	100.00%	184.95%

SOLITARIO SPECIES LIST

A—Annual
P—Perennial
I—Introduced
N—Native
*—Endemic

SCIENTIFIC NAME		COMMON NAME
Selaginellaceae		Spikemoss Family
Selaginella lepidophylla (Hook. & Grev.) Spring	NP	Resurrection Plant, Siempre Viva
Selaginella peruviana (Milde.) Hieron.	NP	
Selaginella wrightii Hieron.	NP	Wright Selaginella
Polypodiaceae		True Fern Family
Adiantum capillus-veneris L.	NP	Maidenhair Fern, Culantrillo
Bommeria hispida (Mett.) Underw.	NP	Hairy Bommaria
Cheilanthes fendleri Hook.	NP	Fendler Lipfern
Cheilanthes lindheimeri (Sm.) Hook.	NP	Fairy Swords
Cheilanthes wrightii Hook.	NP	Wright Lipfern
Notholaena sinuata (Lag.) Kaulf. var. *sinuata*	NP	Bulb Cloakfern
Notholaena sinuata (Lag.) Kaulf. var. *integerrima* Hook.	NP	
Notholaena sinuata (Lag.) Kaulf. var. *cochisensis* (Goodd.) Weath.	NP	Helechillo, Jimmyfern
Notholaena standleyi Maxon	NP	Star Cloakfern
Cupressaceae		Cypress Family
Juniperus pinchotii Sudw.	NP	Red-Berry Juniper
Ephedraceae		Ephedra Family
Ephedra antisyphilitica C. A. Mey	NP	Clapweed, Popote
Ephedra aspera Engelm.	NP	Boundary Ephedra Popotilla
Graminae		Grass Family
Aristida purpurea Nutt.	NP	Purple Three-Awn
Aristida wrightii Nash	NP	Wright Three-Awn
Bothriochloa saccharoides (Sw.) Rybd.	NP	Silver Beardgrass
Bouteloua curtipendula (Michx.) Torr.	NP	Side-Oats Grama
Boutelous ramosa Vasey	NP	Chino Grama
Cynodon dactylon (L.) Pers.	IP	Bermuda Grass, Rata de Gallo
Eragrostis neomexicana Vasey	NA	New Mexico Lovegrass
Erioneuron pulchellum (H.B.K.) Tateoka	NP	Fluffgrass
Heteropogon contortus (L.) R. & S.	NP	Tanglehead
Hilaria mutica (Buckl.) Benth.	NP	Tobosa
Lycurus phleoides H.B.K.	NP	Wolftail
Muhlenbergia monticola Buckl.	NP	Mesa Muhly
Muhlenbergia porteri Scribn.	NP	Bush Muhly
Panicum obtusum H.B.K.	NP	Vine-Mesquite
Pappophorum mucronulatum Nees	NP	Whiplash Pappusgrass
Setaria leucopila (Scribn. & Merr.) K. Schum.	NP	
Sporobolus airoides (Torr.) Torr.	NP	Alkali Sacaton
Sporobolus contractus Hitchc.	NP	Spike Dropseed
Stipa eminens Cav.	NP	Southwestern Needlegrass
Trichachne californica (Benth.) Chase	NP	Arizona Cottontop
Bromeliaceae		Pine-Apple Family
Hechtia scariosa L. B. Smith	NP	Rough False-Agave

Commelinaceae		Spiderwort Family
Commelina erecta L. var. *angustifolia* (Michx.) Fern.	NP	Hierba del Pollo
Liliaceae		Lily Family
Dasylirion leiophyllum Engelm.	NP	Smooth Sotol
Dasylirion texanum Scheele	NP	Texas Sotol
Nolina erumpens (Torr.) Wats.	NP	Bear-Grass
Yucca thompsoniana Trel.	NP	Thompson Yucca
Yucca torreyi Shafer	NP	Torrey Yucca
Amaryllidaceae		Amaryllis Family
Agave lecheguilla Torr.	NP	Lechugilla
Cooperia sp.		Rain-Lily
Salicaceae		Willow Family
Populus arizonica Sarg.	NP	Chopo, Arizona Cottonwood
Salix gooddingii Ball var. *variabilis* Ball	NP	Southern Black Willow
Juglandaceae		Walnut Family
Juglans microcarpa Berl.	NP	Little Walnut
Fagaceae		Beech Family
Quercus arizonica Sarg.	NP	Arizona White Oak
Quercus grisea Liebm.	NP	Gray Oak
**Quercus hinckleyi* C. H. Muell.	NP	Hinckley Oak
Quercus pungens Liebm.	NP	Scrub Oak
Quercus pungens Liebm. var. *vaseyana* (Buckl.) C. H. Muell.	NP	Vasey Shin Oak
Ulmaceae		Elm Family
Celtis pallida Torr.	NP	Granjeno, Desert Hackberry
Celtis reticulata Torr.	NP	Palo Blanco, Netleaf Hackberry
Ulmus pumila L.	IP	Siberian Elm
Moraceae		Mulberry Family
Ficus carica L.	IP	Common Fig, Higuera
Maclura pomifera (Raf.) Schneid.	NP	Osage Orange, Naranjo Chino
Viscaceae		Mistletoe Family
Phoradendron tomentosum (DC.) Gray	NP	Injerto
Aristolochiaceae		Birthwort Family
Aristolochia wrightii Seem.	NP	Wright Dutchman's-Pipe
Polygonaceae		Knotweed Family
Eriogonum abertianum Torr.	NA	Abert Wildbuckwheat
Eriogonum jamesii Benth.	NA	James Wildbuckwheat
Eriogonum rotundifolium Benth.	NA	Roundleaf Wildbuckwheat
Eriogonum tenellum Torr. var. *ramosissimum* Benth.	NP	
Chenopodiaceae		Goosefoot Family
Atriplex canescens (Pursh) Nutt.	NP	Four-Wing Saltbush
Atriplex obovata Moq.	NP	Silver Saltbush
Salsola kali L.	IA	Russian Thistle, Tumbleweed

Amaranthaceae		Amaranth Family
Dicraurus leptocladus Hook. F.	NP	
Froelichia arizonica Thornb.	NP	Arizona Snakecotton
Nyctaginaceae		Four-O'Clock Family
Acleisanthes longiflora Gray	NP	Angel Trumpets
Allionia incarnata L.	NP	Pink Windmills, Hierba de la Hormiga
Boerhaavia linearifolia Gray	NP	Narrowleaf Spiderling
Mirabilis linearis (Pursh) Heimerl.	NP	Linearleaf Four-O'Clock
Selinocarpus angustifolius Torr.	NP	Narrowleaf Moodpod
Portulacaceae		Purslane Family
Portulaca mundula I. M. Jonhst.	NA	Chisme, Shaggy Portulaca
Ranunculaceae		Crowfoot Family
Clematis alpina Mill.	NP	Alpine Clematis
Clematis drummondii T. & G.	NP	Texas Virgin's Bower, Barbas de Chivato
Berberidaceae		Barberry Family
Berberis trifoliolata Moric.	NP	Agarito, Curant-of-Texas
Papaveraceae		Poppy Family
Argemone chisosensis G. Ownbey	NA	Chisos Poppy
Cruciferae		Mustard Family
Lepidium virginicum L. var. *medium* (Greene) C. L. Hitchc.	NA	Virginia Pepperweed, Lente jilla
Lesquerella fendleri (Gray) Wats.	NP	Fendler Bladderpod
Lesquerella purpurea (Gray) Wats.	NP	Rose Bladderpod
Nerisyrenia camporum (Gray) Greene	NP	Mesa Greggia
Sisymbrium linearifolium (Gray) Pays.	NP	
Resedaceae		Mignonette Family
Oligomeris linifolia (Vahl) Macbr.	NA	
Saxifragaceae		Saxifrage Family
Fendlera rupicola Gray	NP	Cliff Fendlerbush
Rosaceae		Rose Family
Amelanchier denticulata (H.B.K.) Koch	NP	Toothed Serviceberry
Cowania ericifolia Torr.	NP	Heath Cliffrose
Fallugia paradoxa (D. Don) Endl.	NP	Apache-Plume
Prunus havardii (W. Wight) W. Wight	NP	Havard Plum
Leguminosae		Legume Family
Acacia constricta Gray	NP	Mescat Acacia
Acacia greggii Gray	NP	Catclaw
Acacia neovernicosa Isley	NP	
Astragalus emoryanus (Rydb.) Cory var. *terlinguensis* (Cory) Barneby	NA	
Cassia bauhinioides Gray	NP	Two-Leaved Senna
Cassia lindheimeriana Scheele	NP	Lindheimer Senna
Cassia wislizenli Gray	NP	Wislizenus Senna
Dalea aurea Nutt.	NP	Golden Dalea
Dalea formosa Torr.	NP	Feather Plume

Dalea neomexicana (Gray) Cory	NP	New Mexico Dalea
Dalea wrightii Gray	NP	Wright Dalea
Desmanthus velutinus Scheele	NP	Velvet Bundleflower
Lupinus havardii Wats.	NA	Chisos Bluebonnet
Mimosa biuncifera Benth.	NP	Cat's Claw Mimosa
Prosopis glandulosa Torr. var. *torreyana* (L. Benson) M. C. Johnst.	NP	Western Honey Mesquite
Rhynchosia texana T. & G.	NP	Texas Stoutbean
Sophora secundiflora (Ort.) DC.	NP	Texas Mountain Laurel, Frijolillo
Krameriaceae		Ratany Family
Krameria grayi Rose & Painter	NP	White Ratany
Krameria glandulosa Rose & Painter	NP	Range Ratany
Linaceae		Flax Family
Linum rigidum Pursh var. *berlandierei* (Hook.) T. & G.	NA	
Linum rupestre (Gray) Engelm.	NA	Rock Flax
Linum vernale (Woot.) Sm.	NA	Spring Flax
Zygophyllaceae		Caltrop Family
Larrea tridentata(DC.) Cov.	NP	Creosote Bush, Gobernadora
Porlieria angustifolia (Engelm.) Gray	NP	Guayacan, Soap-Bush
Tribulus terrestris L.	NA	Caltrop, Cadillo
Rutaceae		Citrus Family
Thamnosma texana (Gray) Torr.	NP	Dutchman's Britches, Ruda del Monte
Polygalaceae		Milkwort Family
Polygala longa Blake	NP	Narrowleaf Milkwort
Polygala macradenia Gray	NP	Glandleaf Milkwort
Polygala scoparioides Chod.	NP	Broom Milkwort
Euphorbiaceae		Spurge Family
Acalypha lindheimeri Muell. Arg.	NP	Lindheimer Copperleaf
Argythamnia neomexicana Muell. Arg.	NP	New Mexico Wildmercury
Bernardia obovata I. M. Johnst.	NP	Desert Myrtlecroton
Croton dioicus Cav.	NP	Rosval, Hierba del Gato
Croton fruticulosus Torr.	NP	Encinilla, Hierba Loca
Croton pottsii (Kl.) Muell. Arg.	NP	Leather-Weed
Croton sancti-lazari Croizat	NP	
Croton torreyanus Muell. Arg.	NP	Vara Blanca
Euphorbia antisyphilitica Zucc.	NP	Candelilla
Euphorbia arizonica Engelm.	NP	Arizona Euphorbia
Euphorbia fendleri T. & G.	NP	Fendler Euphorbia
Euphorbia pycnanthema Engelm.	NP	Head Euphorbia
Jatropha dioica Cerv. var. *graminae* McVaugh.	NP	Sangre de Drago, Leather Stem
Tragia ramosa Torr.	NP	Catnip Noseburn
Anacardiaceae		Sumac Family
Rhus microphylla Engelm.	NP	Littleleaf Sumac
Rhus virens Gray	NP	Evergreen Sumac, Lentisco
Celastraceae		Staff-Tree Family
Mortonia scabrella Gray	NP	Rough Mortonia

Sapindaceae		Soap-Berry Family
Sapindus saponaria L. var. *drummondii* (H. & A.) L. Benson	NP	Jaboncillo, Western Soapberry
Ungnadia speciosa Endl.	NP	Mexican Buckeye, Monilla
Rhamnaceae		Buckthorn Family
Adolphia infesta (H.B.K.) Meisn.	NP	Texas Adolphia
Condalia ericoides (Gray) M. C. Johnst.	NP	Javelina Bush, Tecomblate
Condalia warnockii M. C. Johnst.	NP	
Ziziphus obtusifolia (T. & G.) Gray	NP	Lotebush, Clepe
Vitaceae		Grape Family
Cissus incisa (Nutt.) Des Moul.	NP	Hierba del Buey, Ivy Treebine
Vitis arizonica Engelm. var. *arizonica*	NP	Canyon Grape
Vitis arizonica Engelm. var. *glabra* Munson	NP	Canyon Grape
Malvaceae		Mallow Family
Abutilon parvulum Gray	NP	Littleleaf Abutilon
Hibiscus coulteri Harv.	NP	Desert Rose-Mallow
Hibiscus denudatus Benth.	NP	Paleface Rose-Mallow
Sida hederacea (Hook.) Gray	NP	Dollar Weed, Alkali Mallow
Sida filicaulis T. & G.	NP	Spreading Sida
Sphaeralcea angustifolia (Cav.) D. Don var. *angustifolia*	NP	Narrowleaf Globemallow
Fouquieriaceae		Ocotillo Family
Fouquieria splendens Engelm.	NP	Ocotillo
Koeberliniaceae		Allthorn Family
Koeberlinia spinosa Zucc.	NP	Junco, Allthorn
Loasaceae		Stickleaf Family
Cevallia sinuata Lag.	NP	Stinging Cevallia
Eucnide bartonioides Zucc.	NA	Yellow Rocknettle
Mentzelia multiflora (Nutt.) Gray	NP	Desert Mentzelia
Mentzelia oligosperma Sims	NP	Chicken Thief, Stickleaf
Cactaceae		Cactus Family
Ariocarpus fissuratus (Engelm.) K. Schum.	NP	Living Rock
Cereus greggii Engelm.	NP	Desert Night-Blooming Cereus
Echinocactus horizonthalonius Lem.	NP	Turk's Head, Manca Caballo, Devil's Head
Echinocactus texensis Hopffer	NP	Horse Crippler, Devil's Pincushion
Echinocereus enneacanthus Engelm. var. *stramineus* (englem.) L. Benson	NP	Strawberry Cactus
Enchinocereus pectinatus (Scheidw.) Engelm. var. *neomexicanus* (Coult.) L. Benson	NP	Rainbow Cactus
Echinocereus triglochidiatus Engelm.	NP	Claret-cup
Epithelantha micromeris (Engelm.) Weber	NP	Button Cactus
Mammillaria pottsii Scheer	NP	Potts Mammillaria
Neolloydia conoidea (DC.) Britt. & Rose	NP	
Opuntia imbricata (Haw.) DC.	NP	Tree Cholla, Coyonostle
Opuntia leptocaulis DC.	NP	Christmas Cactus, Tasajillo
Opuntia phaeacantha Engelm. var. *discata* (Engelm.) L. Benson & Walkington	NP	Engelmann Prickly-Pear

Opuntia schottii Engelm.	NP	Clavellina
Opuntia rufida Engelm.	NP	Blind Prickly-Pear
Opuntia violacea Engelm. var. *macrocentra* (Engelm.) L. Benson	NP	Purple Prickly-Pear
Lythraceae		Loosestrife Family
Lythrum californicum T. & G.	NP	Hierba del Cancer
Onagraceae		Evening Primrose Family
Calyophus hartwegii (Benth.) Raven	NP	
Gaura boquillensis Raven & Gregory	NP	
Oenothera kunthiana (Spach) Munz	NA	Kunth Sundrops
Oenothera primiveris Gray	NA	Large Yellow Desert Primrose
Ebenaceae		Ebony Family
Diospyros texana Scheele	NP	Mexican Persimmon
Oleaceae		Olive Family
Fraxinus greggii Gray	NP	Little-Leaf Ash, Escobilla
Forestiera angustifolia Torr.	NP	Desert Olive, Panalero
Menodora decemfida (Gill) Gray var. *longifolia* Steyermark	NP	Ten-Finger Menodara
Menodora longiflora Gray	NP	Showy Menodora, Twin-Pod
Menodora scabra Gray var. *ramosissima* Steyermark	NP	Stemmy Menodora
Loganiaceae		Logania Family
Buddleja marrubiifolia Benth.	NP	Wolly Butterflybush
Gentianaceae		Gentian Family
Centaurium calycosum (Buckl.) Fern. var. *calycosum*	NA	Rosita, Centaury
Apocynaceae		Dogbane Family
Macrosiphonia macrosiphon (Torr.) Heller	NP	Flor de San Juan, Plateau Rocktrumpet
Asclepiadaceae		Milkweed Family
Asclepias asperula (Dcne.) Woods.	NP	Spider Antelopehorn
Asclepias oenotheroides Cham. & Schlecht.	NP	Hierba de Zizotes
Cynanchum barbigerum (Scheele) Shinners	NP	Bearded Swallowwort
Matelea producta (Torr.) Woods.	NP	
Sarcostemma cynanchoides Decne. var. *Hartwegii* (Vail) Shinners	NP	
Sarcostemma torreyi (Gray) Woods.	NP	Soft Twinevine
Convovulaceae		Morning Glory Family
Convovulus equitans Benth.	NA	
Evolvulus alsinoides L. var. *hirticaulis* Torr.	NP	Ojo de Vibora
Polemoniaceae		Phlox Family
Gilia stewartii I. M. Johnst.	NA	
Hydrophyllaceae		Waterleaf Family
Nama havardii Gray	NA	Havard Nama
Nama hispidum Gray	NA	Rough Nama
Nama torynophyllum Greenm.	NA	Mat Nama
Phacelia congesta Hook.	NA	Spike Phacelia
Phacelia popei T. & G.	NA	Pope Phacelia

Boraginaceae		Borage Family
Coldenia canescens DC.	NP	Oreja de Perro, Gray Coldenia
Coldenia greggii (T. & G.) Gray	NP	Plume Coldenia
Coldenia hispidissima (T.& G.) Gray	NP	Mexican Cryptantha
Cryptantha mexicana (Brandeg.) I. M. Johnst.	NA	Slimleaf Heliotrope
Heliotropium torreyi I. M. Johnst.	NP	Baccharisleaf Penstemon
Verbenaceae		Vervain Family
Aloysia gratissima (Gill. & Hook.) Troncoso	NP	Common Bee-Brush, Palo Amarillo
Aloysia wrightii (Gray) Heller	NP	Oreganillo
Phyla strigulosa (Mart. & Gal.) Moldenke	NP	Diamond-Leaf Frog Fruit, Turre Hembra
Tetraclea coulteri Gray var. *angustifolia* (Woot. & Standl.) A. Nels. & Machr.	NP	Stink Weed
Verbena bracteata Lag. & Rodr.	NA	Prostrate Vervain
Verbena neomexicana (Gray) Small var. *hirtella* Perry	NP	Hillside Vervain
Verbena wrightii Gray	NA	Desert Verbena, Sweet-William
Labiatae		Mint Family
Hedeoma drummondii Benth. var. *drummondii*	NP	Drummond Hedeoma
Marrubium vulgare L.	NP	Common Horehound, Marrubio
Salvia greggii Gray	NP	Autumn Sage
Salvia lycioides Gray	NP	Canyon Sage
Salvia regla Cav.	NP	Mountain Sage
Solanaceae		Potato Family
Chamaesaracha conoides (Dun.) Britt.	NP	
Chamaesaracha pallida Averett	NP	
Chamaesaracha villosa Rydb.	NP	
Datura wrightii Regel	NA	Indian Apple, Sacred Datura
Lycium berlandieri Dun. var. *parviflorum* (Gray) Terrac.	NP	
Nicotiana trigonophylla Dunal	NA	Desert Tobacco, Tabaquillo
Physalis hederaefolia Gray	NP	Heartleaf Groundcherry
Physalis subulata Rydb. var. *neomexicana* (Rydb.) Waterfall	NA	
Scrophulariaceae		Figwort Family
Castilleja integra Gray	NP	Wholeleaf Paintbrush
Castilleja lanata Gray	NP	Woolly Paintbrush
Castilleja latebracteata Penn.	NP	Bracted Paintbrush
Leucophyllum frutescens (Berl.) I. M. Johnst.	NP	Cenizo, Purple Sage
Leucophyllum minus Gray	NP	Big Bend Silverleaf
Maurandya antirrhinifolia Willd.	NP	Snapdragon Vine
Penstemon baccharifolius Hook.	NP	Baccharisleaf Penstemon
Penstemon dasyphyllus Gray	NP	Thickleaf Penstemon
Verbascum thapsus L.	IA	Flannel Mullein
Bignoniaceae		Catalpa Family
Chilopsis linearis (Cav.) Sweet	NP	Desert Willow, Mimbre
Tecoma stans (L.) Juss. var. *angustata* Rehd.	NP	Trumpet-Flower, Esperanza
Martyniaceae		Unicorn-Plant Family
Proboscidea sp.		Unicorn-Plant
Orobanchaceae		Broomrape Family
Orobanche cooperi (Gray) Heller	NP	Broom-Rape

Acanthaceae		Acanthus Family
Carlowrightia linearifolia (Torr.) Gray	NP	Heath Carlowrightia
Ruellia parryi Gray	NP	Parry Ruellia
Siphonoglossa pilosella (Nees) Torr.	NP	Hairy Tubetongue
Plantaginaceae		Plantain Family
Plantago patagonica Jacq. var. *gnaphaloides* (Nutt.) Gray	NP	Bottlebrush
Rubiaceae		Madder Family
Cephalanthus occidentalis L.	NP	Common Buttonbush, Honey-Balls
Hedyotis acerosa Gray	NP	Needleleaf Bluets
Hedyotis intricata Fosb.	NP	Tangle Bluets
Hedyotis nigricans (Lam.) Fosb. var. *rigidiuscula* (Gray) Shinners	NP	Stiff Bluets
Compositae		Sunflower Family
Artemisia ludoviciana Nutt.	NP	Western Mugwort, White Sage
Baccharis glutinosa (R. & P.) Pers.	NP	Jara, Seepwillow
Bahia absinthifolia Benth.	NP	Hairyseed Bahia
Bahia pedata Gray	NA	Bluntscale Bahia
Baileya multiradiata Harv. & Gray	NA	Desert Baileya
Brickellia coulteri Gray	NP	Coulter Brickelbush
Brickellia laciniata Gray	NP	Splitleaf Brickelbush
Chrysactinia mexicana Gray	NP	Damianita
Cirsium ochrocentrum Gray	NP	Yellow-Spine Thistle
Cirsium texanum Buckl.	NP	Southern Thistle
Conyza canadensis (L.) Cronquist var. *glabratus* (Gray) Cronquist	NA	Horse-Weed
Conyza coulteri Gray	NA	Coulter Conyza
Dyssodia acerosa DC.	NP	Prickleleaf Dogweed
Dyssodia pentachaeta (DC.) Robinson	NP	Parralena, Common Dogweed
Erigeron modestus Gray	NP	Plains Fleabane
Eupatorium greggii Gray	NP	Palmleaf Eupatorium
Evax verna Raf.	NA	
Flourensia cernua DC.	NP	Tarbush, Hojase
Gymnosperma glutinosa (Spreng.) Less.	NP	Tatalencho
Haploesthes greggii Gray var. *texana* (Coult.) I. M. Johnst.	NP	False Broomweed
Helenium quadridentatum Labill.	NA	Rosilla
Heterotheca fulcrata (Greene) Shinners	NP	Rocky Goldaster
Hymenoclea monogyra T. & G.	NP	Burro-Bush
Hymenoxys scaposa (DC.) Parker	NP	
Iva ambrosiaefolia (Gray) Gray	NA	Rage Sumpweed
Leucelene ericoides (Torr.) Greene	NA	White Aster, Rose Heath
Machaeranthera scabrella (Greene) Shinners	NP	
Machaeranthera tanacetifolia (H.B.K.) Nees	NA	Tahoka Daisy
Melampodium leucanthus T. & G. var. *leucanthus*	NP	Plains Blackfoot
Parthenium argentatum Gray	NP	Guayule, Rubber-Plant
Parthenium confertum Gray	NP	Lyreleaf Parthenium
Parthenium incanum H.B.K.	NP	Mariola
Pectis papposa Harv. & Gray	NA	Many-Bristle Pectis
Perezia nana Gray	NP	Desert Holly
Perezia wrightii Gray	NP	Brownfoot

Perityle parryi Gray	NP	Heartleaf Perityle
Perityle vaseyi Coult.	NP	Margined Perityle
Porophyllum scoparium Gray	NP	
Psilostrophe tagetina (Nutt.) Greene	NP	Woolly Paperflower
Ratibida columnaris (Sims) D. Don	NP	Upright Prairie-Coneflower
Senecio douglasii D.C. var. *jamesii* (T. & G.) Ediger	NP	Threadleaf Groundsel
Stephanomeria pauciflora (Torr.) A. Nels.	NP	Desert Skeletonplant
Thelesperma longipes Gray	NP	Longstalk Greenthread
Trixis californica Kell.	NP	American Trixis
Verbesina encelioides (Cav.) Gray	NA	Cowpen Daisy
Viguiera stenoloba Blake	NP	Resin-Bush
Xanthium strumarium L.	NA	Abrojo, American Cocklebur
Zexmenia brevifolia Gray	NP	Shorthorn Zexmenia
Zinnia acerosa (DC.) Gray	NP	Spinyleaf Zinnia

APPENDUM TO THE SOLITARIO VEGETATION SURVEY A SEASONAL COMPARISON

Mary Butterwick and Jim Lamb

Information included in this appendum was based on field studies carried out between September 21 and September 27, 1975. The purpose of the fall survey was to observe and record any seasonal changes as a means of comparison with the data gathered the previous summer. Since most of the annual precipitation in this region occurs in August and September, particular attention was paid to possible effects of rainfall on the different plant associations. This task was accomplished through incidental collecting, with emphasis on species not found during the summer. In addition, each of the established transect sites was revisited and fall data were obtained (see section on Methods). The transect sites were accurately relocated. However, the positioning of the 100-m tape was impossible to duplicate. Because of the inherent variability of this sampling technique, the transect data frequently showed a slightly different composition of the grass, herb, and shrub components from that seen in the summer transect data. Although exact comparisons were not feasible, general trends did present themselves and will be elaborated on in the following discussion. For clarity, the plant associations will be discussed separately.

THE SLOPE ASSOCIATION

Some rather dramatic changes were observed within the Slope Association of the Solitario, apparently as a result of recent substantial rains. In general, the percentage ground cover was noticeably increased. Values for Total Raw Coverage ranged from 60.6% to 82.6%, a significant increase over summer values which ranged from 43.5% to 72.9% (Tables 1, 2, 6, 7, and 8). The total number of individuals encountered on the transects also uniformly rose. The greatest response was seen in the grasses which showed a consistent increase in species diversity. In addition to the continually-dominant grasses, such as *Bouteloua curtipendula, Aristida wrightii,* and *Bothriochloa saccharoides,* several new taxa were encountered, including *Leptochloa dubia, Trichachne californica, Aristida adscensionis, Aristida ternipes,* and *Bouteloua eriopoda. Heteropogon contortus* and *Tridens muticus,* although included in the summer collections, had both increased in frequency and relative dominance.

Several members of the Compositae are primarily fall-flowering taxa. *Gymnosperma glutinosum* and *Xanthocephalum microcephalum* were notable examples that frequented the slopes of the Solitario. Apparently in response to recent rains, *Ariocarpus fissuratus* was found in full flower and in local abundance along the northern and western rim of the Solitario. In the vegetative state this cactus was very inconspicuous and thus only one locality was noted during the previous survey. Aside from the above instances, little significant change was observed in the shrubs and herbs of this association. A majority of the species involved were perennials and thus would not be expected to fluctuate markedly in frequency or relative dominance with the seasons.

The topography characterizing this association may partially account for the responses found due to climatic changes. Here numerous niches and crevices provide for the accumulation of small quantities of water. This supply of moisture during seasonal rains stimulates both germination of annuals and rapid growth from perennial root stocks. Additionally, the relative inaccessibility of the slopes to grazing livestock serves to preserve the potential for a higher diversity of grasses, given the proper moisture conditions.

THE ALLUVIAL-GRAVEL ASSOCIATION

In contrast to the Slope Association, the Alluvial-Gravel Association remains basically unaltered by the transition into fall. This association is characterized by the prominence of shrubs. According to the transect data, shrubs, including *Lycium berlandieri, Aloysia gratissima, Flourensia cernua, Larrea tridentata,* and *Viguiera stenoloba,* are from 29.56% to 43.92% of the total coverage (Tables 3, 4, 5). Although new grass species were encountered on the fall transects, the total grass cover occupies only 1.01% to 9.26% of the total coverage. *Erioneuron pulchellum* remains the dominant grass of the alluvial gravels. *Trichachne californica, Aristida ternipes,* and *Tridens muticus,* along with the annuals *Bouteloua* *barbata* and *Bouteloua aristidoides,* are infrequent. An overall consistency was maintained with the herbaceous species, the majority of which were perennials. However, at one transect site a marked increase in the diversity of herbs is recorded (Table 4). This variability is probably more a result of the sampling method than of any significant seasonal fluctuation.

The Alluvial-Gravel Association has been subject to intense grazing pressure, as evidenced by the predominance of shrubs and corresponding paucity of grasses. These level plains within the Solitario are also dissected by a system of minor drainages which facilitate rapid runoff of any water that has not already percolated through the soil. Maximum exposure to sunlight enhances evaporation of any surface moisture. The result is a limited water supply for plants having relatively shallow root systems, even under conditions of ample rainfall. These physical features combined with the impact of continued grazing diminish this association's potential for rejuvenation in response to seasonal climatic changes.

THE RIPARIAN ASSOCIATION

The characteristic components of the Riparian Association, such as *Chilopsis linearis, Fallugia paradoxa, Hymenoclea monogyra, Acacia greggii,* and *Prosopis glandulosa,* are trees or shrubs and thus do not vary noticeably with the seasons (Table 9). The infrequent herbaceous species scattered along the banks of the drainages reflect those that are found on the slopes and alluvial gravels.

THE CANYON ASSOCIATION

The Lower Shutup, as representative of the Canyon Association, was revisited. That the canyons had been subject to a substantial quantity of water was evidenced by frequent pools and running streams throughout. The current's force had removed numerous herbs such as *Eriogonum abertianum, Boerhaavia coccinea, Eucnide bartonioides, Nama havardii, Hedeoma drummondii,* and *Nicotiana trigonophylla* which previously had frequented the canyon floor. However, the less vulnerable shrubs and trees, including *Salix gooddingii, Ungnadia speciosa, Fendlera rupicola, Quercus pungens,* and *Juglans microcarpa,* that distinquish this association remained unaltered. Many of the grasses encountered in the fall transects were scattered throughout the canyon.

RARE PLANTS

An additional locality for *Cereus greggii* was found within the Solitario. One individual of this rare cactus was growing among *Ziziphus obtusifolia* and *Aloysia gratissima* in the vicinity of Transect 4 (Appendix 1).

On September 25 the *Quercus hinckleyi* site was revisited with the intention of collecting acorns for propagation. From a population of about 45 groups of individuals, only seven mature acorns were retrieved, although numerous acorn cups remained on the plants. Of the seven, four were found to be infested by insect larvae. This type of insect predation is a common problem with many oak species. The remaining acorns readily germinated and have been given to the Rare Plant Study Center at the University of Texas for cultivation. The paucity of acorns may also be due to bird or mammal predation. There was no observable evidence that the leaves had been browsed by animals. However, insect predation was indicated by mottled leaves and webbing on the lower leaf surfaces. About one-third of the population appeared noticeably damaged as a result of the infestation. No indication of such damage was observed the previous summer. Continued observation is needed in order to determine the impact of the insects on the survival of these rare oaks.

Another rare species was located in the Solitario along the northern rim. *Polygala minutifolia* was scattered in the vicinity of Transect 7 (Appendix 1). This milkwort is distinguished by its numerous stems from a low shrubby base, its reduced leaves, and white flowers. Although it is more common in northern Mexico, Presidio County represents the northern extension of its range; it is thus rare in Texas.

FALL TRANSECT DATA

TABLE 1
Quadrat Transect 1

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Bouteloua curtipendula	41	82.0	27.89	41.85	113	21.62	30.73	1081
Heteropogon contortus	2	4.0	1.36	1.85	5	.70	.99	35
Hilaria mutica	1	2.0	.68	3.33	9	.80	1.13	40
Leptochloa dubia	6	12.0	4.08	4.07	11	1.90	2.70	95
Panicum hallii	2	4.0	1.36	2.22	6	.40	.56	20
Setaria leucopila	2	4.0	1.36	2.22	6	.80	1.14	40
Trichachne californica	13	26.0	8.84	9.25	25	2.76	3.92	138
HERBS								
Agave lecheguilla	1	2.0	.68	.37	1	.70	.99	35
Amaranthus arenicola	1	2.0	.68	.37	1	.02	.03	1
Bahia pedata	1	2.0	.68	.74	2	.10	.14	5
Cevallia sinuata	1	2.0	.68	.37	1	.40	.57	20
Convolvulus equitans	2	4.0	1.36	.74	2	.24	.34	12
Croton pottsii	4	8.0	2.72	2.22	6	.84	1.19	42
Euphorbia sp.	1	2.0	.68	.37	1	.02	.03	1
Evolvulus alsinoides	3	6.0	2.04	1.48	4	.22	.21	11
Gaura sp.	2	4.0	1.36	.74	2	.50	.71	25
Iva ambrosiaefolia	3	6.0	2.04	1.48	4	.92	1.30	46
Notholaena sinuata	2	4.0	1.36	.74	2	.36	.51	18
Parthenium confertum	4	8.0	2.72	6.66	18	1.60	2.27	80
Parthenium incanum	1	2.0	.68	.74	2	1.50	2.13	75
Selaginella wrightii	4	8.0	2.72	1.48	4	1.50	2.13	75
Verbena neomexicana	1	2.0	.68	.74	2	.04	.06	2
Verbena wrightii	4	8.0	2.72	2.96	8	.80	1.14	40
SHRUBS								
Aloysia gratissima	19	38.0	12.92	8.88	24	12.16	17.28	608
Aloysia wrightii	3	6.0	2.04	1.11	3	.50	.71	25
Opuntia phaeacantha	7	14.0	4.76	2.59	7	8.16	11.60	408
Prosopis glandulosa	1	2.0	.68	.37	1	1.50	2.13	75
Viguiera stenoloba	15	30.0	10.20	4.44	12	9.30	13.22	465
TOTALS	**147**	**294.0%**	**206.00%**	**104.38%**	**270**	**69.36%**	**99.96%**	**3518%**

FALL TRANSECT DATA

TABLE 2
Quadrat Transect 2

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	9	30.00	7.83	13.30	25	1.70	2.36	51
Aristida ternipes	5	16.67	4.35	2.66	5	2.17	3.01	65
Bouteloua curtipendula	17	56.67	14.78	18.62	35	8.77	12.18	263
Bouteloua eriopoda	2	6.67	1.74	1.06	2	.60	.83	18
Eragrostis neomexicana	1	3.33	.87	.53	1	.06	.09	2
Erionueron grandiflorum	6	20.00	5.22	7.45	14	1.57	2.18	47
Heteropogon contortus	5	16.67	4.35	4.26	8	3.50	4.86	105
Leptochloa dubia	13	43.33	11.30	17.55	33	5.33	7.41	160
Setaria leucopila	3	10.00	2.61	2.66	5	.73	1.02	22
HERBS								
Agave lecheguilla	7	23.33	6.09	3.72	7	5.10	7.08	153
Amaranthus arenicola	1	3.33	.87	.53	1	.03	.05	1
Argythamnia neomexicana	1	3.33	.87	.53	1	.10	.14	3
Boerhavia coccinea	1	3.33	.87	.53	1	.50	.69	15
Brickellia laciniata	3	10.00	2.61	1.60	3	2.33	3.24	70
Cassia lindheimeriana	1	3.33	.87	.53	1	.16	.23	5
Convolvulus equitans	2	6.67	1.74	2.13	4	.83	1.16	25
Cyanchum barbigerum var. *breviforum*	1	3.33	.87	.53	1	.10	.14	3
Echinocereus sp.	2	6.67	1.74	1.06	2	1.33	1.85	40
Iva ambrosiaefolia	3	10.00	2.61	2.13	4	2.00	2.78	60
Lesquerella purpurea	2	6.67	1.74	1.60	3	.33	.46	10
Mammillaria sp.	1	3.33	.87	.53	1	.16	.23	5
Oenothera brachycarpa	1	3.33	.87	1.60	3	.50	.69	15
Portulaca oleracea	1	3.33	.87	.53	1	.16	.23	5
Selaginella wrightii	10	33.33	8.70	5.32	10	13.33	18.52	400
Senecio douglasii var. *jamesii*	1	3.33	.87	.53	1	1.17	1.62	35
Sida filicaulis	1	3.33	.87	.53	1	.50	.69	15
SHRUBS								
Aloysia gratissima	6	20.00	5.22	3.19	6	10.83	15.05	325
Opuntia phaeacantha	7	23.33	6.09	3.72	7	6.23	8.66	187
Viguiera stenoloba	2	6.67	1.74	1.06	2	1.83	2.55	55
TOTALS	**115**	**383.31%**	**100.03%**	**99.99%**	**188**	**71.29%**	**100.00%**	**2160%**

FALL TRANSECT DATA

TABLE 3
Quadrat Transect 3

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida glauca	1	1.67	.70	.45	1	.05	.08	3
Aristida ternipes	1	1.67	.70	.45	1	.17	.26	10
Bouteloua barbata	1	1.67	.70	.45	1	.08	.13	5
Erionueron pulchellum	1	1.67	.70	.45	1	.17	.26	10
Muhlenbergia porteri	5	8.33	3.50	2.27	5	.95	1.46	57
Setaria leucopila	12	20.00	8.39	12.27	27	3.30	5.08	198
Sporobolus cryptandrus	1	1.67	.70	.91	2	.25	.38	15
Trichachne californica	4	6.67	2.80	1.82	4	.67	1.03	40
Tridens muticus	1	1.67	.70	.45	1	.08	.13	5
HERBS								
Argythamnia neomexicana	1	1.67	.70	1.36	3	.17	.26	10
Bahia absinthifolia	11	18.33	7.69	8.64	19	1.45	2.23	87
Baileya multiradiata	3	5.00	2.10	2.27	5	1.25	1.92	75
Boerhavia coccinea	2	3.33	1.40	.91	2	.67	1.03	40
Eriogonum abertianum	2	3.33	1.40	.91	2	.22	.33	13
Euphorbia arizonica	1	1.67	.70	1.36	3	.05	.08	3
Machaeranthera scabrella	13	21.67	9.09	20.00	44	3.73	5.75	224
Menodora scabra	1	1.67	.70	.45	1	.17	.26	10
Mentzelia multiflora	1	1.67	.70	.45	1	.67	1.03	40
Mirabilis diffusa	1	1.67	.70	.45	1	.42	.64	25
Nerisyrenia camporum	2	3.33	1.40	1.36	3	.17	.26	10
Parthenium confertum	2	3.33	1.40	.91	2	.75	1.15	45
Polygala scoparioides	4	6.67	2.80	2.73	6	.50	.77	30
Verbena neomexicana	1	1.67	.70	.45	1	.08	.13	5
Verbena wrightii	3	5.00	2.10	1.36	3	.83	1.28	50
SHRUBS								
Acacia neovernicosa	2	3.33	1.40	.91	2	2.00	3.08	120
Atriplex canescens	3	5.00	2.10	1.36	3	2.50	3.85	150
Flourensia cernua	10	16.67	6.99	4.55	10	7.08	10.90	425
Gymnosperma glutinosum	3	5.00	2.10	2.27	5	.47	.72	28
Koeberlinia spinosa	1	1.67	.70	.45	1	1.67	2.57	100
Larrea tridentata	4	6.67	2.80	2.27	5	2.50	3.85	150
Lycium berlandieri	9	15.00	6.29	4.09	9	10.75	16.55	645
Opuntia leptocaulis	5	8.33	3.50	2.27	5	3.17	4.87	190
Opuntia phaeacantha	1	1.67	.70	.45	1	.42	.64	25
Parthenium incanum	3	5.00	2.10	3.18	7	.67	1.03	40
Prosopis glandulosa	3	5.00	2.10	1.36	3	2.42	3.72	145
Rhus microphylla	2	3.33	1.40	.91	2	1.92	2.95	115
Viguiera stenoloba	4	6.67	2.80	1.82	4	5.33	8.21	320
Xanthocephalum microcephalum	12	20.00	8.39	8.18	18	3.75	5.77	225
Ziziphus obtusifolia	6	10.00	4.20	2.73	6	3.50	5.39	210
TOTALS	143	233.42%	100.04%	99.93%	220	64.97%	100.03%	3898%

TABLE 4
Quadrat Transect 4

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida glauca	2	4	1.30	1.24	3	.40	.61	20
Aristida ternipes	2	4	1.30	.83	2	.20	.31	10
Bouteloua aristidoides	1	2	.65	1.24	3	.30	.46	15
Bouteloua barbata	3	6	1.95	2.07	5	.40	.61	20
Bouteloua curtipendula	2	4	1.30	2.48	6	.90	1.38	45
Erionueron pulchellum	9	18	5.84	5.79	14	.78	1.19	39
Muhlenbergia porteri	5	10	3.25	2.89	7	3.20	4.89	160
Trichachne californica	9	18	5.84	7.02	17	2.94	4.50	147
Tridens muticus	1	2	.65	.83	2	.14	.21	7
HERBS								
Acleisanthes longiflora	2	4	1.30	.83	2	.60	.92	30
Agave lecheguilla	1	2	.65	.41	1	.30	.46	15
Amaranthus arenicola	1	2	.65	.41	1	2.00	3.06	100
Argythamnia neomexicana	2	4	1.30	.83	2	.26	.40	13
Bahia absinthifolia	10	20	6.49	10.33	25	1.32	2.02	66
Bahia pedata	2	4	1.30	1.24	3	.60	.92	30
Baileya multiradiata	7	14	4.55	6.20	15	2.50	3.82	125
Boerhavia coccinea	1	2	.65	.41	1	.50	.76	25
Carlowrightia linearifolia	5	10	3.25	2.07	5	1.80	2.75	90
Cassia bauhinioides	3	6	1.95	1.24	3	.26	.40	13
Croton pottsii	2	4	1.30	.83	2	.26	.40	13
Echinocereus sp.	3	6	1.95	1.24	3	4.00	6.12	200
Eriogonum sp.	1	2	.65	.41	1	.20	.31	10
Euphorbia sp.	3	6	1.95	2.07	5	.36	.55	18
Gaura coccinea	1	2	.65	.83	2	.60	.92	30
Iva ambrosiaeolia	4	8	2.60	2.89	7	1.30	1.99	65
Machaeranthera scabrella	17	34	11.04	16.94	41	3.54	5.41	177
Mentzelia multiflora	1	2	.65	.41	1	.50	.76	25
Parthenium confertum	3	6	1.95	2.48	6	1.30	1.99	65
Senecio douglasii var. *jamesii*	1	2	.65	.41	1	.10	.15	5
Sida tragiaefolia	1	2	.65	.41	1	.20	.31	10
Talinum aurantiocum	1	2	.65	.41	1	.02	.03	1
Tragia ramosa	1	2	.65	.83	2	.10	.15	5
Verbena wrightii	3	6	1.95	1.24	3	.26	.40	13
SHRUBS								
Acacia greggii	2	4	1.30	.83	2	1.40	2.14	70
Aloysia gratissima	14	28	9.09	6.20	15	12.20	18.65	610
Flourensia cernua	1	2	.65	.41	1	1.30	1.99	65
Forestiera angustifolia	1	2	.65	.41	1	1.20	1.83	60
Gymnosperma glutinosum	3	6	1.95	1.65	4	.40	.61	20
Koeberlinia spinosa	1	2	.65	.41	1	.60	.92	30
Krameria grayi	1	2	.65	.41	1	.20	.31	10
Lycium berlandieri	4	8	2.60	1.65	4	5.40	8.26	270
Opuntia leptocaulis	5	10	3.25	2.07	5	1.86	2.84	93
Opuntia phaeacantha	2	4	1.30	.83	2	1.20	1.83	60
Parthenium incanum	1	2	.65	1.65	4	.30	.46	15
Prosopis glandulosa	4	8	2.60	1.65	4	3.60	5.50	180
Rhus microphylla	1	2	.65	.41	1	1.00	1.53	50
Viguiera stenoloba	2	4	1.30	.83	2	.90	1.38	45
Xanthacephalum microcephalum	1	2	.65	.41	1	.30	.46	15
Ziziphus obtusifolia	1	2	.65	.41	1	1.40	2.14	70
TOTALS	**154**	**308%**	**100.05%**	**99.99%**	**242**	**65.40%**	**100.01%**	**3270%**

FALL TRANSECT DATA

TABLE 5
Quadrat Transect 5

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Bouteloua barbata	1	.03	.93	.49	1	.08	.13	3
Erioneuron pulchellum	9	.22	8.33	8.42	17	.93	1.60	37
HERBS								
Bahia absinthifolia	11	.28	10.19	14.36	29	2.13	3.67	85
Baileya multiradiata	30	.75	27.78	46.53	94	18.13	21.39	725
Dalea neomexicana	5	.13	4.63	3.47	7	2.38	4.10	95
Eriogonum abertianum	2	.05	1.85	.99	2	.18	.30	7
Euphorbia cinerascens	1	.03	.93	.50	1	.13	.22	5
Euphorbia serpyllifolia	1	.03	.93	.50	1	.05	.09	2
Polygala macradenia	4	.10	3.70	1.98	4	.70	1.21	28
Polygala scoparioides	5	.13	4.63	3.47	7	.45	.78	18
Sisymbrium linearifolium	1	.03	.93	.50	1	.13	.22	5
Verbena neomexicana	1	.03	.93	.50	1	.13	.22	5
Verbena wrightii	2	.05	1.85	.99	2	.25	.43	10
SHRUBS								
Acacia constricta	3	.08	2.78	1.49	3	4.13	7.12	165
Forestiera angustifolia	1	.03	.93	.50	1	.13	.22	5
Krameria grayi	12	.08	11.11	5.94	12	7.80	13.47	312
Larrea tridentata	16	.40	14.81	7.92	16	19.88	34.31	795
Opuntia phaeacantha	1	.03	.93	.50	1	.13	.22	5
Parthenium incanum	2	.05	1.85	.99	2	.25	.43	10
TOTALS	108	2.53%	100.02%	100.04%	202	55.48%	100.03%	2317%

FALL TRANSECT DATA

TABLE 6
Quadrat Transect 6

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	1	1	.69	.39	1	.20	.29	10
Aristida ternipes	7	14	4.83	4.31	11	2.10	3.03	105
Aristida wrightii	5	10	3.45	3.14	8	1.70	2.46	85
Bothriochloa saccharoides	2	4	1.38	.78	2	1.20	1.73	60
Bouteloua curtipendula	15	30	10.35	10.58	27	4.08	5.89	204
Bouteloua eriopoda	21	42	14.48	20.00	51	13.50	19.49	675
Eroneuron pulchellum	1	2	.69	.78	2	.04	.05	2
Heteropogon contortus	10	20	6.90	10.58	27	4.10	5.92	205
Hilaria mutica	2	4	1.38	1.18	3	1.60	2.31	80
Muhlenbergia porteri	2	4	1.38	1.96	5	.50	.72	25
Setaria leucopila	2	4	1.38	.78	2	.30	.43	15
Trichachne californica	4	8	2.76	3.13	8	1.70	2.45	85
HERBS								
Agave lecheguilla	11	22	7.59	7.45	19	8.40	12.13	420
Bahia absinthifolia	5	10	3.45	1.96	5	.70	1.01	35
Bahia pedata	20	40	13.79	16.86	43	6.30	9.10	315
Croton pottsii	1	2	.69	.78	2	.50	.72	25
Dalea wrightii	2	4	1.38	1.18	3	.50	.72	25
Dyssodia pentachaeta	1	2	.69	.39	1	.20	.29	10
Gaura sp.	1	2	.69	.39	1	.80	1.16	40
Machaeranthera scabrella	3	6	2.07	1.57	4	.12	.17	6
Macrosiphonia macrosiphon	1	2	.69	.78	2	.60	.87	30
Sida tragiaefolia	1	2	.60	.39	1	.20	.29	10
SHRUBS								
Acacia greggii	1	2	.69	.39	1	.30	.43	15
Acacia neovernicosa	6	12	4.14	2.35	6	5.10	7.37	255
Ephedra aspera	1	2	.69	.39	1	.40	.57	20
Forestiera angustifolia	1	2	.60	.39	1	1.00	1.44	50
Fouquieria splendens	1	2	.69	.39	1	.40	.57	20
Mimosa biuncifera	3	6	.69	1.18	3	2.90	4.19	145
Opuntia phaeacantha	3	6	2.07	1.18	3	1.20	1.73	60
Prunus havardii	1	2	.69	.39	1	2.00	2.89	100
Viguiera stenoloba	10	20	6.90	3.92	10	6.60	9.53	330
TOTALS	145	286%	100.02%	99.94%	255	69.24%	99.95%	3462%

FALL TRANSECT DATA

TABLE 7
Quadrat Transect 7

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida wrightii	9	22.5	6.92	6.41	17	4.77	7.86	191
Bouteloua curtipendula	19	47.5	14.61	16.23	43	5.80	9.55	232
Bouteloua ramosa	8	20.0	6.15	6.04	16	5.12	8.44	205
Erioneuron grandiflorum	4	10.0	3.08	13.58	36	1.65	2.72	66
Tridens muticus	2	5.0	1.54	.75	2	.17	.29	7
HERBS								
Acleisanthes longiflora	1	2.5	.77	.38	1	.25	.41	10
Agave lecheguilla	13	32.5	10.00	10.96	29	12.07	19.86	483
Aspicarpa hyssopifolia	2	5.0	1.54	2.26	6	.75	1.23	30
Bahia absinthifolia	2	5.0	1.54	.75	2	.15	.25	6
Boerhaavia coccinea	1	2.5	.77	.38	1	.02	.04	1
Coldenia canescens	2	5.0	1.54	.75	2	1.50	2.47	60
Coldenia hispidissima	1	2.5	.77	.38	1	.35	.41	10
Croton pottsii	6	15.0	4.61	3.02	8	.80	1.32	32
Dasylirion texanum	3	7.5	2.31	1.13	3	6.25	10.29	250
Dyssodia pentachaeta	3	7.5	2.31	1.13	3	.12	.20	5
Euphorbia fendleri	1	2.5	.77	.75	2	.07	.12	3
Gilia rigidula	1	2.5	.77	1.13	3	.25	.41	10
Hedeoma drummondii	1	2.5	.77	.38	1	.02	.04	1
Hedyotis nigricans	3	7.5	2.31	1.51	4	.20	.33	8
Linum rupestre	1	2.5	.77	.38	1	.37	.62	15
Macrosiphonia macrosiphon	2	5.0	1.54	1.89	5	.62	1.03	25
Menodora longiflora	1	2.5	.77	.75	2	.05	.08	2
Menodora scabra	5	12.5	3.87	1.89	5	.55	.90	22
Phyllanthus polygonoides	2	5.0	1.54	1.51	4	.15	.25	6
Polygala longa	5	12.4	3.87	1.89	5	.70	1.15	28
Polygala scoparioides	2	5.0	1.54	1.13	3	.37	.62	15
Ruellia parryi	4	10.0	2.08	1.51	4	.22	.37	9
Thamnosma texana	8	20.0	6.15	8.68	23	.47	.78	19
Zinnia acerosa	1	2.5	.77	3.77	10	.25	.41	10
SHRUBS								
Coldenia greggii	6	15.0	4.61	3.02	8	8.87	14.61	355
Condalia warnockii	1	2.5	.77	.38	1	1.00	1.65	40
Ephedra aspera	1	2.5	.77	.38	1	.37	.12	3
Opuntia phaeacantha	1	2.5	.77	.38	1	.07	.12	3
Viguiera stenoloba	8	20.0	6.15	4.52	12	6.37	10.50	255
TOTALS	**130**	**325.0%**	**100.03%**	**99.98%**	**265**	**60.64%**	**99.94%**	**2429%**

FALL TRANSECT DATA

TABLE 8
Quadrat Transect 8

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	5	10	2.60	5.55	22	.38	.46	19
Aristida wrightii	2	4	1.04	1.01	4	.96	1.16	48
Bothriochloa saccharoides	12	24	6.25	5.30	21	4.60	5.57	230
Bouteloua curtipendula	43	86	22.40	34.09	135	22.26	26.95	1113
Bouteloua hirsuta	1	2	.52	.76	3	.30	.36	15
Hilaria mutica	1	2	.52	1.01	4	1.60	1.94	80
Leptochloa dubia	2	4	1.04	.50	2	.30	.36	15
Panicum hallii	2	4	1.04	.50	2	.08	.10	4
HERBS								
Abutilon parvulum	1	2	.52	.25	1	.20	.24	10
Agave lecheguilla	14	28	7.29	8.08	32	9.60	11.62	480
Argythamnia neomexicana	2	4	1.04	1.01	4	.12	.14	6
Artemisia ludoviciana	9	18	4.69	4.29	17	2.30	2.78	115
Bahia absinthifolia	5	10	2.60	2.78	11	.32	.39	16
Croton sancti-lazari	3	6	1.56	.76	3	1.36	1.65	68
Erigeron modestus	20	40	10.42	7.32	29	2.02	2.44	101
Euphorbia revoluta	1	2	.52	.50	2	.30	.36	15
Hedeoma drummondii	4	8	2.08	1.26	5	.38	.46	19
Hedyotis nigricans	4	8	2.08	2.02	8	.38	.46	19
Lesquerella fendleri	3	6	1.56	2.78	11	.66	.80	33
Leucelene ericoides	2	4	1.04	1.01	4	.30	.36	15
Menodora longiflora	4	8	2.08	1.01	4	.66	.80	33
Parthenium confertum	1	2	.52	.25	1	1.00	1.21	50
Polygala scoparioides	1	2	.52	.25	1	.02	.02	1
Selaginella wrightii	5	10	2.60	1.26	5	1.60	1.94	80
Tragia ramosa	2	4	1.04	2.02	8	.20	.24	10
Verbena wrightii	4	8	2.08	1.01	4	.22	.27	11
SHRUBS								
Acacia noevernicosa	1	2	.52	.25	1	1.00	1.21	50
Dasylirion texanum	4	8	2.08	1.01	4	4.60	5.57	230
Forestiera angustifolia	1	2	.52	.25	1	2.00	2.42	100
Gymnosperma glutinosum	14	28	7.29	6.31	25	1.68	2.02	84
Juniperus pinchotii	5	10	2.60	1.26	5	3.70	4.48	185
Mimosa biuncifera	1	2	.52	.50	2	.80	.97	40
Nolina erumpens	4	8	2.08	1.01	4	7.60	9.20	380
Opuntia phaeacantha	3	6	1.56	.76	3	3.70	4.48	185
Viguiera stenoloba	3	6	1.56	1.01	4	2.40	2.90	120
Xanthocephalum microcephalum	2	4	1.04	.50	2	1.00	1.21	50
Yucca thompsoniana	1	2	.52	.50	2	2.00	2.42	100
TOTALS	**192**	**384%**	**99.94%**	**99.94%**	**396**	**82.60%**	**99.96%**	**4130%**

FALL TRANSECT DATA

TABLE 9
Line Transect 1

SPECIES	RDi	TI	RDii	TA
Acacia greggii	15.24	16	19.62	38.50
Aloysia grattissima	5.71	6	5.61	11.00
Aloysia wrightii	.95	1	.76	1.50
Atriplex canescens	7.63	8	4.33	8.50
Chilopsis linearis	7.62	8	13.38	26.25
Clematis alpina	12.38	12	9.81	19.25
Fallugia paradoxa	26.67	28	23.82	46.75
Forestiera angustifolia	1.90	2	2.17	4.25
Gymnosperma glutinosum	1.90	2	.51	1.00
Larrea tridentata	.95	1	.25	.50
Prosopis glandulosa	2.86	3	3.82	7.50
Rhus microphylla	11.43	12	14.01	27.50
Viguiera stenoloba	4.76	5	1.91	3.75
TOTALS	99.99%	105	100.00%	196.25%

APPENDUM TO SOLITARIO SPECIES LIST

A — Annual
P — Perennial
I — Introduced
N — Native
* — Endemic or Rare

POLYPODIACEAE		TRUE FERN FAMILY
Cheilanthes eatonii Hook. & Baker f. *eatonii*	NP	Lip Fern
GRAMINAE		GRASS FAMILY
Aristida adscensionis L.	NA	Six Week Three Awn
Aristida glauca (Nees) Walp.	NP	
Aristida ternipes Cav.	NP	Spider Grass
Bouteloua aristidoides (H.B.K.) Griseb.	NA	Needle Grama
Bouteloua barbata Lag.	NA	Six Weeks Grama
Bouteloua eriopoda (Torr.) Torr.	NP	Black Grama, Wooly Foot Grama
Bouteloua hirsuta Lag.	NP	Hairy Grama
Chloris virgata Sw.	NA	Feather Finger Grass
Eragrostis cilianensis (All.) E. Mosher	NA	Stink Grass
Erionueron grandiflorum (Vasey) Tateoka	NP	
Leptochloa dubia (H.B.K.) Nees	NP	Green Sprangletop
Panicum hallii Vaey	NP	Halls Panicum
Schizachyrium scoparium (Michx.) Nash var. *neomexicanum* (Nash) Gould	NP	New Mexico Bluestem
Sporobolus cryptandrus (Torr.) Gray	NP	Sand Drop Seed
POLYGONACEAE		KNOT WEED FAMILY
Eriogonum wrightii Torr.	NP	Wild Buckwheat

AMARANTHACEAE		AMARANTH FAMILY
Amaranthus arenicola I. M. Johnst.	NA	Sand Hills Amaranth
NYCTAGINACEAE		FOUR O'CLOCK FAMILY
Boerhaavia coccinea Mill.	NP	Scarlet Spiderling
Mirabilis diffusa (Heller) Reed	NP	
PORTULACACEAE		PURSLANE FAMILY
Portulaca oleracea L.	NA	Purslane, Verdolaga
Talinum aurantiacum Englem.	NP	Flame Flower
CRASSULACEAE		ORPINE FAMILY
Echeveria strictiflora Gray	NP	Longpetal Echeveria
LEGUMINOSAE		LEGUME FAMILY
Acacia angustissima (Mill) O. Ktze. var. *chisosiana* Isely	NP	
Calliandra conferta Gray	NP	
Dalea lachnostachys Gray	NP	Glandleaf Dalea
Dalea pogonathera Gray	NP	Hierba Del Corazon, Bearded Dalea
Desmanthus cooleyi (Eat.) Trel	NP	James Bundleflower
Hoffmanseggia glauca (Ort.) Eifert	NP	Rushpea
MALPIGHIACEAE		MALPIGHIA FAMILY
Aspicarpa hyssopifolia Gray	NP	Asp-Head
POLYGALACEAE		MILKWORT FAMILY
Polygala minutifolia Rose	NP	
EUPHORBIACEAE		SPURGE FAMILY
Euphorbia cinerascens Engelm.	NP	
Euphorbia dentata Michx.	NA	
Euphorbia revoluta Engelm.	NA	
Euphorbia serpyllifolia Pers.	NA	
Phyllanthus polygonoides Spreng.	NP	Knotweed Leafflower
MALVACEAE		MALLOW FAMILY
Sida tragiaefolia Gray	NP	
Sphaeralcea digitata (Greene) Rydb.	NP	Juniper Globe-Mallow
ONAGRACEAE		EVENING PRIMROSE FAMILY
Gaura sp.		
Gaura coccinea Pursh.	NP	Scarlet Gaura
Oanothera brachycarpa Gray	NP	Evening Primrose
CONVOLVULACEAE		MORNING GLORY FAMILY
Ipomoea cristulata Hallier f.	NA	Ivy Morning Glory
POLEMONIACEAE		
Gilia rigidula Benth. subsp. *rigidula*	NP	Brickleaf Gilia
LABIATAE		MINT FAMILY
Hedeoma molle Torr.	NP	Mock Pennyroyal
CUCURBITACEAE		GOURD FAMILY
Ibervillea tenuisecta (Gray) Small	NP	Slimlobe Globeberry
COMPOSITAE		SUNFLOWER FAMILY
Brickellia cylindracea Gray & Engelm.	NP	
Eupatorium wrightii Gray	NP	Wright Boneset, Thoroughwort
Gnaphalium wrightii Gray	NA	Cudweed, Everlasting
Viguiera dentata (Cav.) Spreng.	NP	Golden Eye
Xanthocephalum microcephalum (D.C.) Shinners	NP	Broomweed

RANGES AND RANGE MANAGEMENT IN THE SOLITARIO

C. Wayne Hanselka

The Chihuahuan desert of Northern Mexico and the Southwestern United States has traditionally been used primarily for the grazing of domestic livestock. Presently, added pressures for alternate uses and increased demands for fiber and red meat have resulted in a reassessment of the traditional uses of this land.

Southwest Texas, with Big Bend National Park, is confronted with a demand for recreational facilities for annually increasing numbers of tourists. Concurrently, increasing numbers of sportsmen are willing to pay for hunting rights on private lands to pursue the desert mule deer, scaled quail, and two species of doves in the region. At the same time, the world food crisis calls for increased production from grazing lands.

Together, these factors make necessary a sound management program for these semiarid lands. Range management is defined as the art and science of planning and directing range use to obtain sustained, maximum animal production, consistent with perpetuation of the range resource. This concept combines animal production and other uses of the range.

DESCRIPTION OF THE AREA

The Solitario is a geologically unique area located between 103° 45' and 103° 51'30" west longitude and 29° 24' and 29° 30' north latitude in Southwest Texas. The terrain consists of rough mountains and hills interspersed with valleys and cut by deep canyons. Soils are principally of the Lozier association (Soil Conservation Service, General Soil Map, Brewster County, Texas, 1973). These are very shallow, hilly and steep, calcareous soils that have developed over limestone. Limited areas of Brewster association soils occur on igneous hills. The valleys between hills contain soils of the Nickel-Canutio association.

Climatologically, the area is in a semiarid to arid zone. It is characterized by dry, mild winters and hot summers. Mean daily maximum temperatures for the summer months are well over 40°C. Minimum winter temperatures may drop below freezing. Precipitation is infrequent and erratic. Most is received during the late summer and early autumn. Summer rains usually are in the form of convective thunderstorms. Annual totals are usually less than 254 cm.

The vegetative covering is primarily dominated by various species of desert shrubs (see botanical report in this volume). Several plant associations can be delineated, depending upon local conditions and moisture relationships.

RESULTS AND DISCUSSION

The area is located to the northwest of the Terlingua mining district. In spite of this proximity, little or no mining has occurred in the Solitario proper. As mentioned earlier, the traditional use of the land has been, and still is, the grazing of domestic animals. Livestock was brought into the region in the last two decades of the nineteenth century, although extensive ranching did not occur until the beginning of the twentieth century. At various times cattle, sheep, and goats were grazed on the area. Heavy grazing pressure, coupled with periodic droughts, has resulted in a marked deterioration of the range grasses. The area changed ownership in the early 1960s and has been lightly grazed by cattle to the present time. No stock has been in the Solitario for the past two growing seasons.

One of the basic concepts in the management of grazing lands is that of the range site. A range site is an area of land having a combination of ecological factors that is significantly different from adjacent areas. The differing combinations of factors result in differences in the potential to produce forage and, thus, in the management of each area.

Five basic sites are recognized in the Solitario (Range Site map accompanies this report):

1) The limestone hill and mountain site is the most extensive site on the area. It occupies approximately 75% of the terrain. This site occurs as hills and mountains of limestone origin. Rocky outcrops, cliffs, and escarpments are often associates. Slopes are generally from 8% to 30%, and soils are shallow and stony. The climax plant community is a grassland, but, with retrogression, several species of brush species will increase and dominate.

2) Gravelly sites are next in importance and extend over 15% of the area. This site occupies gently rolling terrain to hills and ridges of 3% to 8%. It is

formed by soil materials that have washed from surrounding hills and mountains at higher elevations. Soils are generally calcareous, gravelly loams and are shallow with rocks up to 3 inches in size. Climax vegetation is grasses with an abundance of shrubs. Shrubs increase and dominate as retrogression occurs.

3) The chert hill site is localized in the northern half of the Solitario. It occurs as gently sloping to steep broken hills. Slopes from 8% to 30% occur. The soils are stony loams with frequent outcrops of metamorphic stone and chert. They are usually very shallow. Short and midgrasses are the dominant plants in the climax community on this site. Retrogression results in a decrease in vegetative cover and an increase in shrubby vegetation.

4) The eroded nature of the terrain has resulted in numerous narrow draws between the hills and mountains. The draw sites receive runoff and overflow from surrounding areas. Slope varies from flat to nearly level. Soils are usually deep and alluvial in origin. They are rich with a good soil-air-moisture-plant relationship. However, the site is subject to severe flash flooding and overgrazing. Consequently, the productive short and midgrasses of the climax community are often replaced by a dense growth of shrubs.

5) The igneous hill occurs as rough broken igneous areas on moderately steep to steep slopes. Soils are shallow with fragments of igneous rocks and boulders. Short and midgrasses associated with shrubs dominate the climax community. Retrogression results in an increase or invasion of the shrubs.

Condition of the range is usually based on the percent of climax species in the plant composition present as compared to that at climax. Retrogression results in a decrease in the amount of palatable, highly nutritious, and productive vegetation. Concurrently, there is an increase in less desirable plant species. The "increasers" provide good forage for livestock, and often the aim of management should be to manage for these species. Continued deterioration results in a marked increase in "invader" shrubby and annual plant species. The decreaser, increaser, and invader species may vary from range site to range site.

Condition classes are:

Excellent: 76%-100% climax species in the composition

Good: 51%-75% climax species in the composition

Fair: 26%-50% climax species in the composition

Poor: 0-25% climax species in the composition

Species composition on each range site was determined by line intercept methods and compared to climax vegetation descriptions provided by the Soil Conservation Service. Stocking rates are estimated from tables prepared by the SCS.

The limestone hill and mountain site occupies approximately 12,096 hectares in the Solitario. This site was determined to be in good condition in the northern half of the area and excellent in the southern half. In the north, desirable climax grasses compose 32.4% of the vegetative cover. Climax woody plants provide an additional 12.6% and allowable forbs contribute 10.2%. A vegetative cover of 80% climax plants occupies large portions of this site in the south of the Solitario.

Carrying capacity for this site in good condition is approximately 48 hectares per animal unit under year-long grazing. An animal unit (A.U.) is a mature cow or her equivalent (six goats, five mule deer, etc.). The limestone sites in excellent condition can support one A.U. on every 20 hectares.

The gravel site is the second largest site in the Solitario (2,419 hectares). This site was judged to be in fair condition with 44.5% of the vegetative cover being desirable climax species. This site has been severely overgrazed in the past and presently supports many shrubby plants. Evidence of many annual and perennial forbs are present. In its present condition the gravel site has a carrying capacity of 44 hectares/A.U./year-long grazing. More stock could possibly use this site for seasonal grazing due to the abundance of ephemeral forbs.

The low chert hills located in the northern half of the Solitario are also in fair condition. Desirable grasses compose 30.3% of the vegetative cover. Desirable, allowable woody plants contribute an additional 12.8%. The remainder are low quality invader plants. No climax herbaceous forbs were recorded on the site. The carrying capacity for this site is approximately 24 hectares/A.U./year-long grazing. Again, heavier stocking rates may be possible due to an abundance of ephemeral forbs. This site occupies approximately 484 hectares.

The draw sites in the Solitario are very overgrazed. Only 28.7% of the vegetation is of desirable plant species. Woody plants contribute 15% of this total. This 484-hectare area would support an A.U. on every 42 hectares when grazed year-long.

The igneous hill and mountain site covers an area of 645 hectares. It is in good condition with 57% of the plant cover being desirable. Good quality grass species compose 27.7% of the total. Consequently, this site could carry an A.U./35 hectares under year-long grazing.

Overall, the ranges in the Solitario are in fair condition and, theoretically, could support 460 A.U. Unfortunately, this carrying capacity estimate is based upon amount of desirable forage produced and does not consider several limiting factors. Various areas of the Solitario, particularly in the southern third and around the rim, are topographically extremely rough. The steep, sloping sides of narrow canyons, such as the shutups, are in excellent condition but are inaccessible to cattle. Goats would have a rough time negotiating many of the slopes. These topographic features have resulted in overgrazing the lower and flat areas of the Solitario in the past.

Another factor limiting grazing would be that of water. The only well in the Solitario is located at Tres Papalotes (Fig. 1). Presently, this water is piped several miles to the northwest to provide water in the northern half of the area. There are two dirt water tanks in this area, also. These depend on precipitation as a water supply and cannot be depended upon over an annual cycle.

The entire southern half has no permanent water. Tinajas may fill during rain but soon dry out. Historically, this area was watered from springs and by pipelines. The few perennial springs are now dry, and the pipelines have fallen into disrepair.

When these limiting factors are considered, the carrying capacity of the Solitario Range is lowered considerably. A conservative estimate of the possible carrying capacity in its present condition would be 153 A.U. on the entire 16,128-hectare area.

Range Improvements

Due to the location of the Solitario in a semidesert mountain environment, any improvement from deteriorated conditions is necessarily a long-term process, but the application of various range management techniques could aid in this process.

Improved water distribution and permanency would be the primary consideration. Cattle and wildlife species should not have to move over 2 km to water in level to gently rolling range. This distance decreases to .5-1 km in rough, steep country.

The present water system on the Solitario is woefully inadequate. If water can be reestablished in the southern half of the area, then grazing distribution and numbers of domestic livestock would be enhanced greatly. Populations of desert mule deer and other wildlife species also would benefit.

Fencing is another major tool of range management, particularly as regards livestock production. The fencing situation in the Solitario is badly deteriorated. Existing fences are down, incomplete, or damaged in some way. The entire Solitario is essentially one large pasture. Repair of these fences, taking advantage of natural barriers, would also enhance management of the land.

SUMMARY AND CONCLUSION

The Solitario is a 16,128-hectare area of Chihuahuan Desert. In spite of misuse in the past, it is slowly improving. The vegetation is largely woody species adapted to semiarid conditions with a good mixture of annual and perennial grasses and forbs. Five major range sites are delineated on the area. These are: (1) limestone hills and mountains, (2) gravelly, (3) chert hills, (4) draw, and (5) igneous hills and mountains. These sites were determined to be in fair to good range condition, capable of carrying 460 A.U.'s in the Solitario.

Lack of water and topography drastically limit this carrying capacity. Lack of fencing also limits any intensive domestic livestock use and, thus, range management on the area. Any such improvement would have a beneficial effect on all vertebrate populations in the area.

VERTEBRATE FAUNA OF THE SOLITARIO

James F. Scudday

The Solitario lies in the north-central part of the Chihuahuan Biotic Province as defined by Blair (1950). Its central location within the Chihuahuan Biotic Province accounts for the fact that the biota is typically Chihuahuan with very little influence from neighboring biotas. However, the Chihuahuan Province is quite large, and within the extremes of its boundaries are found the most diverse vertebrate fauna of any North American biotic province.

Geologists have long been attracted to the Solitario because of the uniqueness of its rock formations and geological origins, but biologists generally have not explored the great diversity of habitats formed there by geological cataclysms of the past. The complex intermixture of igneous and sedimentary rocks and the abrupt extrusion of rocky precipices from sandy or gravelly desert floors would be expected to provide for a wide variety of animal forms over a very short linear distance. This is, in fact, what one encounters with the vertebrate fauna of the Solitario—a virtual microcosm of much of the Chihuahuan Desert. Some of the rarest Chihuahuan vertebrates are found there, such as the Leaf-chinned Bat, Elf Owl, and Big Bend Gecko, as are some of the most ubiquitous Chihuahuan species such as Merriam's Kangaroo Rat and the Greater Earless Lizard.

The Solitario is one of the few areas where the parthenogenetic (all-female) Checkered Whiptail Lizard is found coexisting with its putative bisexual progenitors, the Western Whiptail and the Rusty-rumped Whiptail. Although ecologically separated most of the time, the two bisexual species do periodically overlap the habitat of the other as sudden climatological changes (almost a trademark of the Chihuahuan Desert) occur.

Most previous biological studies conducted in the Solitario were done by botanists, whose results have been published in the form of descriptions of new species of plants from the area [see botanical report]. I know of no published data about the fauna of the Solitario, although some zoologists, including myself, have visited the area before. At least two studies have been published on the nearby La Mota Mountain area. Milstead (1953) reported on the herpetofauna of the area while Tamsitt (1954) compared the mammalian fauna of the La Mota Ranch with that of the Black Gap area.

This preliminary report is based almost solely upon one week of field work in the Solitario, from June 2 through June 7, 1975. A very small amount of information has been derived from prior data in the vertebrate collection at Sul Ross State University. Thus, the bias of seasonality is obvious.

The most important limiting factor for animal life within the Solitario is the availability of free water. The lack of free water has also been a major problem to man's attempts to utilize the Solitario for his own purposes. Springs are nonexistent within the Solitario, and underground water is deep and difficult to locate. Everywhere one sees evidence of man's attempts to provide water to the area for livestock use—remnants of wells, broken dams across arroyos, broken pipes sticking awry from the ground, cracked and now dry concrete troughs and tanks. Oddly enough, water is often responsible for wrecking man's attempts to establish water sources in the Solitario, for when it does rain, it may come too much, too fast. Then, water rushing for the few outlets from the Solitario (called shutups) washes out dams and interdicts pipelines, leaving troughs and tanks without a source of water.

A well at Tres Papalotes now supplies the few remaining operational tanks and troughs with water. Relatively new surface tanks (called McGuirks Tanks) contained a small amount of water in June, but the water was unapproachable by large animals because of the deep, soft mud surrounding it. Probably the most reliable source of natural water exists in a few natural water tanks called tinajas. However, the tinajas can also become deathtraps when the water level recedes enough to leave steep slick-sided walls that cannot be scaled by animals that fall into the water while attempting to drink. Tinajas of varying size and depth exist in all of the shutups but are best developed at the lower shutup.

The vertebrate fauna of the Solitario is divided into those kinds of animals that have acquired the ability either to produce metabolic water or to secure sufficient water from their food items and those kinds that occur there only seasonally when free water is available. Reptiles, rodents, and rabbits belong to the first category, while much of the avifauna, bats, and larger mammals belong to the second.

The well at Tres Papalotes, although primarily maintained for livestock use, is an important factor in maintaining a diverse and static wildlife community. Birds and large mammals, such as the grey fox, coyote, and mule deer, must inevitably visit watering places. Bats are seen dipping for drinks all night long. Such artificial watering places become true oases.

HERPETOFAUNA OF THE SOLITARIO (AMPHIBIANS AND REPTILES)

CLASS AMPHIBIA

Order Anura	
Family Bufonidae	*Bufo punctatus*—Red-spotted Toad
	Bufo speciosus—Texas Toad

CLASS REPTILIA

Order Squamata	
Family Geckonidae	*Coleonyx brevis*—Texas Banded Gecko
	C. reticulatus—Big Bend Gecko
Family Iguanidae	*Cophosaurus texana*—Greater Earless Lizard
	Crotaphytus collaris—Collared Lizard
	Sceloporus merriami—Canyon Lizard
	S. poinsetti—Crevice Spiny Lizard
	Urosaurus ornatus—Tree Lizard
	Phrynosoma modestum—Round-tailed Horned Lizard
Family Teiidae	*Cnemidophorus septemvittatus*—Rusty-rumped Whiptail
	C. tesselatus—Checkered Whiptail
	C. inornatus—Little Striped Whiptail
	C. tigris—Western Whiptail
Family Colubridae	*Diadophis punctatus*—Ringnecked Snake
	Ficimia cana—Western Hook-nosed Snake
	Masticophis flagellum—Coachwhip
Family Viperidae	*Crotalus atrox*—Western Diamondback Rattlesnake
	C. lepidus—Rock Rattlesnake

SPECIES ACCOUNTS

Amphibia

The amphibian fauna of the Solitario is the most dapauperate of any vertebrate group, but this situation is to be expected within such an arid setting. Only two species of amphibians were encountered there in June, and this was during a period of moderate rainfall in the area. The Red Spotted Toad (*Bufo punctatus*) was common everywhere within the Solitario rim. A single Texas Toad (*Bufo compactilis*) was found near McGuirks Tanks. I would expect *Scaphiopus couchi* to be common, but none were found at this time.

Reptilia

Reptiles are almost synomynous with deserts. The reptilian fauna of the Solitario is one of the most visible vertebrate components of the area, with lizards of the genus *Cnemidophorus* predominating. By far the most commonly seen animal was the unisexual Checkered Whiptail (*C. tesselatus*). The Rusty-rumped Whiptail (*C. septemvittatus*) is not abundant, but can be found in rough-land situations throughout the Solitario. Although the Western Whiptail was not seen within the Solitario Basin, it is the most commonly encountered lizard outside of the basin in the creosote flats to the north and east. Western Whiptails may occur in small numbers within the basin itself. The occurrence of the Western Whiptail, Checkered Whiptail, and Rusty-rumped Whiptail in the same geographical area is of special interest to herpetologists.

The Checkered Whiptail is an all-female species, reproducing by parthenogenesis, and is believed to have arisen through hybridization of the Rusty-rumped and Western Whiptail. Both Western and Checkered

Whiptails occur sympatrically throughout much of the northern Chihuahuan Desert, but finding all three species together is rare.

The Rusty-rumped Whiptail is mostly a Mexican species and just reaches its northernmost distribution in Presidio and Brewster Counties, Texas. This would have to be considered an uncommon species for Texas.

Merriam's Canyon Lizard is another uncommon lizard for Texas, although it is the most commonly found lizard among the rocks and bluffs of southern Presidio County. Olson (1973) recently completed a study of this species in Texas and designated a population in southern Presidio County as a distinct subspecies, *Sceloporus merriami longipunctatus.* His series of specimens contained distinct *longipunctatus* forms from La Mota Mountain and distinct *annulatus* forms from near Terlingua in southern Brewster County. He hypothesized that the two forms probably intergraded along the Brewster-Presidio County line, which passes through the Solitario. Our series of specimens from the Solitario bears out his supposition in that most specimens, although predominantly *longipunctatus,* show some *annulatus* influence.

Probably the rarest and most unique vertebrate animal for the Solitario area is the Big Bend Gecko. Although I did not see one within the Solitario, I did see a specimen collected by Randy Reynolds on the Tanque Caballo Road through the Blue Ridge, an area just one-half mile beyond the Lefthand Shutup, on Terlingua Ranch property. It is on this basis the species is included among the Solitario herpetofauna.

Snakes were not numerous nor obvious during my early summer survey. Undoubtedly a much greater diversity of snakes occurs within the Solitario than was found in June. It was strange that such oddities as the Ring-necked Snake (*Diadophis punctatus*) and the Western Hook-nosed Snake (*Ficimia cana*) were found, but I did not record such common Chihuahuan species as the Bullsnake (*Pituophis melanoleucus*), the Big Bend Patch-nosed Snake (*Salvadora hexilepis*), the night snake (*Hypsiglena torquata*), nor the small, secretive but common Ground Snake (*Sonora semiannulata*) and Black-headed Snake (*Tantilla atriceps*). All the latter species must be there; they just did not occur in the early June census.

SUMMER BIRDS OF THE SOLITARIO

CLASS AVES

Order Charadriiformes
- Family Charadriidae .... *Charadrius vociferus*—Killdeer

Order Falconiformes
- Family Cathartidae .... *Cathartes aura*—Turkey Vulture
- Family Accipiteridae .... *Buteo jamaicensis*—Red-tailed Hawk
  B. swainsoni—Swainson's Hawk

Order Galliformes
- Family Phasianidae .... *Calipepla squamata*—Scaled Quail

Order Columbiformes
- Family Columbidae .... *Zenaida macroura*—Mourning Dove
  Z. asiatica—Whitewing Dove

Order Cuculiformes
- Family Cuculidae .... *Geococcyx californicus*—Roadrunner

Order Strigiformes
- Family Strigidae .... *Micrathene whitneyi*—Elf Owl
  Bubo virginianus—Great Horned Owl

Order Caprimulgiformes
- Family Caprimulgidae .... *Phalaenoptilus nutallii*—Poorwill
  Chordeiles minor—Common Nighthawk
  C. acutipennis—Lesser Nighthawk

Order Apodiformes
- Family Apodidae .... *Aeronautes saxatalis*—White-throated Swift
- Family Trochilidae .... *Archilochus alexanderi*—Black-chinned Hummingbird

Order Piciformes
- Family Picidae .... *Dendrocopos scalaris*—Ladder-backed Woodpecker

Order Passiformes
- Family Tyrannidae .... *Saya saya*—Say's Phoebe
  Myirarchus cinerascens—Ash-throated Flycatcher

Family Hirundinidae	*Petrochelidon pyrrhonotus*—Cliff Swallow
Family Paridae	*Auriparus flaviceps*—Verdin
Family Troglodytes	*Campylorhynchus brunneicapillus*—Cactus Wren
	Catherepes mexicanus—Canyon Wren
Family Mimidae	*Mimus polyglottos*—Mockingbird
	Toxostoma dorsale—Crissal Thrasher
Family Sylvidae	*Polioptila melanura*—Black-tailed Gnatcatcher
Family Laniidae	*Lanius ludovicianus*—Loggerhead Shrike
Family Vireonidae	*Vireo belli*—Bell's Vireo
Family Ploceridae	*Passer domesticus*—House Sparrow
Family Icteridae	*Icterus parisorum*—Scott's Oriole
	Molothrus ater—Brown-headed Cowbird
Family Thraupidae	*Piranga rubra*—Summer Tanager
Family Fringillidae	*Pyrrhuloxia sinuata*—Pyrrhuloxia
	Carpodacus mexicanus—House Finch
	Aimospiza bilineata—Black-throated Sparrow

SUMMER AVIFAUNA OF THE SOLITARIO AREA

Diversity of bird habitat within the Solitario is not as great as it is for other kinds of vertebrates. The habitat strata most obviously missing is that associated with free running water and/or springs. Species of woody shrubs form dense thickets along the dry arroyos. These areas constitute a favored bird habitat, but such habitat is not truly riparian. The lack of free water coupled with the seasonality of bird distribution produced a paucity of avian records for one week in June. The distance to free-running water and more diverse habitats in Fresno Canyon does not preclude occasional visits into the Solitario by some avian species. Such a distance barrier is much more effective for nonflying vertebrates. The number of avian species recorded for the Solitario should increase proportionately as more observation days are made throughout the year.

The greatest value of an early June observation period is that most species present at that time can be assumed to be birds that nest in the area and thus perhaps are more important "users" of the available habitat.

I was somewhat surprised that so few members of the large family Fringillidae were represented in my observations. The most significant avian record was a pair of nesting Elf Owls in a utility pole at Tres Papalotes. The status of the Elf Owl in Texas was summarized by Barlow and Johnson (1967).

Dense brush along the margins of dry arroyos and in the lowlands around McGuirks Tanks were preferred avian habitat during early June in terms of bird density. However, a few species (such as the Canyon Wren, Scott's Oriole, Great Horned Owl, Cliff Swallows, and White-throated Swifts) preferred the open hill and cliff sites. Mockingbirds were the most common bird present and were observed in every habitat, while the White-throated Swift was the most restricted, being observed only at Los Portales Shutup.

MAMMALS OF THE SOLITARIO

CLASS MAMMALIA

Order Chiroptera

Family Mormoopidae	*Mormoops megalophylla*—Leaf-chinned Bat
Family Vespertilionidae	*Antrozous pallidus*—Pallid Cave Bat
	Pipestrellus hesperus—Canyon Bat

Order Lagomorpha

Family leporidae	*Lepus californicus*—Black-tailed Jackrabbit
	Sylivilagus auduboni—Desert Cottontail

Order Rodentia

Family Sciuruidae	*Spermophilus spilosoma*—Spotted Ground Squirrel
	S. variegatus—Rock Squirrel
	Ammospermophilus interpres—Texas Antelope Ground Squirrel

Family Heteromyidae	*Perognathus penicillatus*—Desert Pocket Mouse
	P. merriami—Merriam's Pocket Mouse
	Dipodomys merriami—Merriam's Kangaroo Rat
Family Cricetidae	*Peromyscus pectoralis*—White-ankeled Mouse
	P. eremicus—Cactus Mouse
	P. leucopus—White-footed Mouse
	Neotoma albigula—White-throated Woodrat
Order Carnivora	
Family Procyonidae	*Procyon lotor*—Raccoon
Family Mustelidae	*Mephitis mephitis*—Striped Skunk
Family Canidae	*Canis latrans*—Coyote
Family Felidae	*Felis concolor*—Cougar
Order Artiodactyla	
Family Tayassuidae	*Tayassu tajacu*—Javelina
Family Cervidae	*Odocoileus hemionus*—Mule Deer

SPECIES ACCOUNTS

The mammalian fauna of the Solitario is typically Chihuahuan. As with other kinds of vertebrates, the documented list of mammals that occur there probably could be enlarged over long observation periods because of the occasional wanderings into the area of species known to occur nearby. But the uncertainty of available water is surely a limiting factor operating more effectively upon mammals than on any other group of vertebrates.

The paucity of chiropteran (bat) records within the Solitario is difficult to explain except to say there is a bias in the technique of sampling for bats. No specimens of the cosmopolitan genus *Myotis* nor of the typical Chihuahuan family Molossidae were taken within the Solitario, although representatives of these groups were common components of the bat fauna in nearby Fresno Canyon. Roosting sites appeared to be plentiful in the Solitario, and I would think sufficient free-standing water is available to accommodate bats. It could be that many bat species are reluctant to water at small, circular, man-made tanks and troughs. On the other hand, bats could very likely fly out of the Solitario to nearby streams and springs in Fresno Canyon and its associated drainages for feeding and watering, thereby not being available for the sampling nets over watering places within the Solitario.

The most significant mammalian record from the Solitario is that of a Leaf-chinned Bat (*Mormoops megalophylla*) netted over the tank at Tres Papalotes on the night of June 3, 1975. Only two species of bats, the Pallid Cave Bat (*Antrozous pallidus*) and the small Canyon Bat (*Pipistrellus herperus*), were commonly seen and netted over artificial watering places.

Lagomorphs (rabbits) were common within the Solitario Basin. Jackrabbits and cottontails were readily seen in brushy situations around McGuirks Tanks and at Tres Papalotes. Rabbits were not often seen at the higher elevations. Coyotes were heard almost every night and all coyote scat examined contained some rabbit hair. The jackrabbit and cottontail populations appeared to be well balanced with the resident predator populations.

Two of the three species of ground squirrels recorded for the Solitario are ecologically separated on basis of habitat preference. The small Spotted Ground Squirrel (*Spermophius spilosoma*) occupies the flat area and gravelly slopes while the Rock Squirrel (*S. variegatus*) is found only along extensive rock outcroppings. The ranges of Spotted Ground Squirrels and Antelope Ground Squirrels (*Ammospermophilus interpres*) somewhat overlap, but Antelope Ground Squirrels are more likely to be found along rocky arroyo banks and hill slopes.

Heteromyid rodents are the most typical dwellers of desert areas. Kangaroo rats are especially adapted to desert survival with their capability of utilizing metabolic water, thus freeing them from dependence upon availability of free water. Merriam's Kangaroo Rat (*Dipodmys merriami*) appears to be widely distributed within the Solitario and is likely to be the most well-adapted mammalian species for survival there. Only two species of pocket-mice (*Perognathus*) were recorded from the Solitario in June, although it is suspected that at least two other species also occur there. The tiny Merriam's Pocket Mouse (*P. merriami*) was not taken in traps, but was often seen on the roads at night. The Desert Pocket Mouse (*P. penicillatus*) was trapped as well as observed numerous times at night.

Three species of the cricetid genus *Peromyscus* were recorded for the Solitario. The White-ankled Mouse (*P. pectoralis*) is the most abundant and widely distributed species, with specimens being taken from the lowest to the highest elevations. Only two specimens of the Cactus Mouse (*P. eremicus*) were taken, both from the lefthand shutup. A single specimen of the White-footed Mouse (*P. leucopus*) was captured in the high tobosa grass and dense brush around McGuirks Tanks. Habitat for *P. leucopus* is certainly marginal in the Solitario, but *P. eremicus* could be more abundant than our brief sampling period revealed.

White-throated Woodrats appeared to be fairly common throughout the basin area. These large rodents play an important role in predator-prey interactions. Presence of wood-rat fur was also common in coyote scat.

Porcupines are not common to the Solitario, but they do occur there. The spread of porcupines in the arid Trans-Pecos region since the 1940s has been phenomenal. Porcupines are encountered now in every mountain range, flat, and valley west of the Pecos River. Little damage to vegetation is noticed, because there is so little woody vegetation of any size for the porcupines to damage. Ranchers generally despise the porcupine because their dogs, calves, and colts may get a face full of quills while investigating a porcupine out of curiosity.

The kinds of carnivores are not as diverse within the Solitario as occurs in the surrounding area, but the carnivores that do occur there are the big, efficient ones. Despite man's attempts with gun, trap, and poison, cougars and coyotes still dominate the Solitario. It is the pressure applied by these two large carnivores that has shaped and fashioned the mammalian faunal assemblage of the area almost as much as has the availability of water. For any lesser species to survive the rigors of the Solitario, it must also survive the predation of such efficient predators. Smaller predators, so common where cougars and coyotes have been eliminated, must be either absent or very scarce within the Solitario. Tracks of raccoons and foxes were almost nil. A single dead raccoon was found drowned in one of the tanks in the saddle of the hill just north of Tres Papalotes. Even skunks were not numerous, only one striped skunk being found during a week of field work.

Coyotes were heard every night, and even once during midday. Coyote scat was evident in nearly all the arroyos and along the roads.

Cougars are known to inhabit the Solitario, and ranchers keep blind sets (unbaited traps in arroyo bottoms and crossings) out all the time, hoping to catch them. A young cougar was caught in such a set while we were in the Solitario in June, and the skin and skull were given to Sul Ross State University (SRSU 1603), along with the skull of an older cougar that was trapped there in April (SRSU 1604).

Cougars seldom bother cattle but will kill young horses and mules. They can do a great deal of damage to sheep or goat herds. Presently, as over the past 20 years, only cattle are pastured in the Solitario. Yet trapping pressure on cougars has not abated. Most ranchers agree that they lose no cattle to cougars but resent the cats killing colts and mule deer which to the ranchers represents a cash crop from deer hunting. Much of the antagonism to cougars by ranchers is simply an old traditional holdover of past experiences with goats or sheep plus a basic dislike for any predatory animal. Also, the loss of several valuable horses to cougar predation can readily justify some form of control for the big cats, at least in pastures where horses are bred and raised. In areas closed to deer hunting, the cougar would be an extremely important factor in maintaining a balanced healthy deer herd.

The future of the cougar in Texas is tied completely to the preservation of some large tract of wilderness land with suitable cougar habitat and a source of natural prey. As human population pressures increase in Texas, suitable wilderness habitats required by cougars will diminish. Much of Trans-Pecos Texas now meets the wilderness and solitude requirements of cougars, but the future of some of these lands is questionable. The Solitario and surrounding environs are ideal cougar habitat as evidenced by the big cats' continued use of the area in spite of eradication efforts and a large land development program nearby.

The cougar should be designated a game animal in Texas in order for the state to maintain adequate control over populations of the big cat. Certainly, in some management situations, cougars might have to be controlled, and the state should not let this option slip away.

The very name, the Solitario, well describes the wilderness character of this study area, and the potential role it could play in the preservation of Texas' largest and most efficient predator, the cougar.

LITERATURE CITED

Barlow, Jon C. and Roy Johnson. 1967. Current status of the elf owl in the southwestern United States. *Southwest Nat.* 12:331-332.

Blair, W. F. 1950. The biotic provinces of Texas. *Tex. Jour. Sci.* 2:93-117.

Milstead, W. W. 1953. Ecological distribution of the lizards of the La Mota Mountain region of Trans-Pecos Texas. *Texas Jour. Sci.* 5:403-415.

Olson, R. Earl. 1973. Variation in the canyon lizard, *Sceloporus merriami* Stejnegar. *Herpetologica* 29:116-127.

Tamsitt, J. R. 1954. The mammals of two areas in the Big Bend region of Trans-Pecos Texas. *Tex. Jour. Sci.* 6:33-61.

Thomas, Robert A. 1974. A checklist of Texas Amphibians and Reptiles. Texas Parks and Wildlife Dept., *Tech. Series No. 17.* 15 pp.

AVIFAUNA OF THE SOLITARIO WITH ADDITIONAL NOTES ON THE MAMMALIAN AND HERPETOFAUNA, BREWSTER AND PRESIDIO COUNTIES, TEXAS

Rick L. LoBello

Vertebrates inhabiting the Solitario region west of Big Bend National Park have been previously studied by Scudday (1976a). The present report deals primarily with migratory avifauna as determined from 10 days of field work conducted 26-30 September and 15-20 December, 1975. Additional notes on the mammalian and herpetofauna are also included.

The Solitario region lies within the Chihuahuan biotic province (Blair 1940; Dice 1943) and is located on the southwestern edge of Brewster County and the southeastern edge of Presidio County, Texas. Vertebrate fauna recorded during this study period were all typically Chihuahuan.

Scudday's (1976a) work in the Solitario was conducted during early June and represents only that season's avifauna. The additional bird species reported here portray a more complete picture of the area's breeding and migratory avifauna. Bird species observed by Scudday in June and also during the study period can be construed as breeding. To further substantiate any conclusions of this type, comparisons with Wauer's (1973) work in nearby Big Bend National Park were made. Investigations by Scudday (1976b) in Fresno Canyon and by LoBello (1976) in the Bofecillos Mountains are also referenced. Since these two regions lie side by side to the immediate and nearby west of the Solitario and are vegetatively similar, it can be assumed that faunal relationships would also be similar.

AVIFAUNA OF THE SOLITARIO

The following revised list of 113 species of birds represents data obtained from the Solitario region during the September and December months of 1975 and includes 43 suspected species, preceded with an asterisk (*), as noted from observations made in Fresno Canyon (Scudday 1976b) and in the Bofecillos Mountains (LoBello 1976). Nine bird species reported by Scudday (1976a) during June in the Solitario but not during the September and December study period are preceded by a cross (†).

Observations in the Solitario were concentrated in the following areas: Tres Papalotes, McGuirks Tanks, Righthand and Lefthand Shutups. These areas fall within Blair's and Miller's (1949) description of the Roughland Life Belt.

The last two days of the December observation period were cloudy and cold, while all other days were clear and warm, allowing for good birding conditions.

I am indebted to Stephen Wagner for his field assistance and to Jack Burns and Robert Walters for helping to collect some specimens. For critically reading the manuscript and providing many helpful suggestions, I wish to thank Dr. James F. Scudday of Sul Ross State University.

CLASS ANSERIFORMES

Order Aneriformes

Family Anatidae, Subfamily Anatinae .... **Anas diazi*—Mexican Duck
Anas carolinensis—Green-winged Teal
**Anas cyanoptera*—Cinnamon Teal
Spatula clypeata—Shoveler

Order Falconiformes

Family Cathartidae .... *Cathartes aura*—Turkey Vulture

Family Accipitridae .... **Accipiter striatus*—Sharp-shinned Hawk
Accipiter cooperii—Cooper's Hawk
Buteo jamaicensis—Red-tailed Hawk
†Buteo swainsoni—Swainson's Hawk
**Buteo albonotatus*—Zone-tailed Hawk

Buteo regalis—Ferruginous Hawk
Aquila chrysaetos—Golden Eagle
Circus cyaneus—Marsh Hawk

Family Falconidae .... *Falco sparverius*—Sparrow Hawk

Order Galliformes
Family Phasianidae .... *Callipepla squamata*—Scaled Quail

Order Charadriidae
Family Charadriidae, Subfamily Charadriinae .... *Charadrius vociferus*—Killdeer
Family Scolopacidae .... **Capella gallinago*—Common Snipe
**Actitis macularia*—Spotted Sandpiper

Order Columbiformes
Family Columbidae .... *Zenaida asiatica*—White-winged Dove
Zenaida macroura—Mourning Dove
**Columbigallina passerina*—Ground Dove

Order Cuculiformes
Family Cuculidae .... **Coccyzus americanus*—Yellow-billed Cuckoo
Geococcyx californicus—Roadrunner

Order Strigiformes
Family Tytonidae .... **Tyto alba*—Barn Owl
Family Strigidae .... **Otus asio*—Screech Owl
Bubo virginianus—Great Horned Owl
†*Micrathene whitneyi*—Elf Owl

Order Caprimulgiformes
Family Caprimulgidae .... *Phalaenoptilus nuttalii*—Poor-will
Chordeiles acutipennis—Lesser Nighthawk
†*Chordeiles minor*—Common Nighthawk

Order Apodiformes
Family Apodidae .... †*Aeronautes saxatalis*—White-throated Swift
Family Trochilidae .... **Selasphorus platycercus*—Broad-tailed Hummingbird
†*Archilochus alexanderi*—Black-chinned Hummingbird
**Selasphorus rufus*—Rufous Hummingbird
**Calothorax lucifer*—Lucifer Hummingbird

Order Piciformes
Family Picidae .... *Colaptes cafer*—Red-shafted Flicker
**Centurus aurifrons*—Golden-fronted Woodpecker
Dendrocopos scalaris—Ladder-backed Woodpecker
Sphyrapicus varius—Yellow-bellied Sapsucker

Order Passeriformes
Family Tyrannidae .... **Pyrocephalus rubinus*—Vermillion Flycatcher
**Tyrannus verticalis*—Western Kingbird
†*Myiarchus tyrannulus*—Ash-throated Flycatcher
Sayornis phoebe—Eastern Phoebe
Sayornis nigricans—Black Phoebe
Sayornis saya—Say's Phoebe
**Empidonax* sp.
Contopus sordidulus—Western Wood Pewee

Family Hirundinidae	**Hirundo rustica*—Barn Swallow
	†*Petrochelidon pyrrhonotus*—Cliff Swallow
	**Stelgidopteryx ruficollis*—Rough-wing Swallow
Family Corvidae	*Aphelocoma coerulescens*—Scrub Jay
	Corvus cryptoleucus—White-necked Raven
	Corvus corax—Common Raven
Family Paridae	**Parus atricristatus*—Black-crested Titmouse
	Auriparus flaviceps—Verdin
Family Troglodytidae	**Troglodytes aedon*—House Wren
	**Troglodytes bewickii*—Bewicks Wren
	Campylorhynchus brunneicapillus—Cactus Wren
	Salpinctes obsoletus—Rock Wren
	Catherpes mexicanus—Canyon Wren
Family Mimidae	*Mimus polyglottos*—Mockingbird
	Toxostoma curvirostre—Curve-billed Thrasher
	Toxostoma dorsale—Crissal Thrasher
Family Turdidae	**Turdus migratorius*—Robin
	Hylocichla guttata—Hermit Thrush
Family Sylviidae	**Polioptila caerulea*—Blue-gray Gnatcatcher
	Polioptila melanura—Black-tailed Gnatcatcher
	Regulus calendula—Ruby-crowned Kinglet
Family Motacillidae	**Anthus spinoletta*—Water Pipit
Family Bombycillidae	**Bombycilla cedrorum*—Cedar Waxwing
Family Lannidae	*Lanius ludovicianus*—Loggerhead Shrike
Family Ptilogonatidae	**Phainopepla nitens*—Phainopepla
Family Vireonidae	**Vireo vincinior*—Gray Vireo
	**Vireo solitarius*—Solitary Vireo
	†*Vireo belli*—Bell's Vireo
Family Parulidae	**Vermivora celata*—Orange-crowned Warbler
	**Dendroica cornata*—Myrtle Warbler
	Dendroica auduboni—Audubon's Warbler
	Dendroica townsendi—Townsend's Warbler
	**Icteria virens*—Yellow-breasted Chat
	Oporonis tolmiei—Macgillivray's Warbler
	Wilsonia pusilla—Wilson's Warbler
Family Ploceidae	**Passer domesticus*—House Sparrow
Family Icteridae	*Sturnella* sp.—Meadowlark
	Euphagus cyanocephalus—Brewer's Blackbird
	**Icterus spurius*—Orchard Oriole
	Icterus parisorum—Scott's Oriole
	**Icterus bullockii*—Bullock's Oriole
Family Thraupidae	*Piranga ludoviciana*—Western Tanager
	†*Piranga rubra*—Summer Tanager
Family Fringillidae	**Richmondena cardinalis*—Cardinal
	Pyrrhuloxia sinuata—Pyrruloxia
	**Guiraca cairules*—Blue Grosbeak
	**Passerina versicolor*—Varied Bunting
	**Passerina ciris*—Painted Bunting
	Carpodacus mexicanus—House Finch
	Spinus pinus—Pine Siskin
	Spinus psaltria—Lesser Goldfinch
	Chlorura chlorura—Green-tailed Towhee
	Pipilo erythrophthalmus—Rufous-sided Towhee
	Pipilo fuscus—Brown Towhee
	Calamospiza melanocorys—Lark Bunting

**Pooecetes gramineus*—Vesper Sparrow
**Chondestes grammacus*—Lark Sparrow
Amphispiza bilineata—Black-throated Sparrow
Junco oreganus—Oregon Junco
**Junco caniceps*—Gray-headed Junco
Aimophila ruficeps—Rufous-crowned Sparrow
Aimophila cassinii—Cassin's Sparrow
Spizella passerina—Chipping Sparrow
Zonotrichia leucophrys—White-crowned Sparrow
**Melospiza lincolnii*—Lincoln's Sparrow
Spizella pallida—Clay-colored Sparrow

CLASS MAMMALIA

Order Chiroptera
- Family Mormoopidae .... *Mormoops megalophylla*—Leaf-chinned Bat
- Family Vespertilionidae .... *Antrozous pallidus*—Pallid Cave Bat
  - *Pipistrellus hesperus*—Canyon Bat

Order Lagomorpha
- Family Leporidae .... *Lepus californicus*—Black-tailed Jackrabbit
  - *Sylvilagus auduboni*—Desert Cottontail

Order Rodentia
- Family Sciuridae .... *Spermophilus spilosoma*—Spotted Ground Squirrel
  - *Spermophilus variegatus*—Rock Squirrel
  - *Ammospermophilus interpres*—Texas Antelope Ground Squirrel
- Family Heteromyidae .... *Perognathus penicillatus*—Desert Pocket Mouse
  - *Perognathus merriami*—Merriam's Pocket Mouse
  - *Dipodomys merriami*—Merriam's Kangaroo Rat
- Family Cricetidae .... *Peromyscus pectoralis*—White ankled Mouse
  - *Peromyscus eremicus*—Cactus Mouse
  - *Peromyscus leucopus*—White-footed Mouse
  - *Neotoma albigula*—White-throated Woodrat

Order Carnivora
- Family Canidae .... *Canis latrans*—Coyote
  - **Urocyon cinereoargenteus*—Gray Fox
  - **Vulpes macrotis*—Kit Fox
- Family Procyonidae .... *Procyon lotor*—Raccoon
  - **Bassariscus astutus*—Ringtail Cat
- Family Felidae .... *Felis concolor*—Mountain Lion
  - *Lynx rufus*—Bobcat
- Family Mustelidae .... *Mephitis mephitis*—Striped Skunk
  - **Spilogale gracilis*—Western Spotted Skunk
  - *Conepatus mesoleucus*—Hog-nosed Skunk
  - *Taxidea taxus*—Badger

Order Artiodactyla
- Family Tayassuidae .... *Tayassu tajacu*—Javelina
- Family Cervidae .... *Odocoileus hemionus*—Mule Deer

The following 22 species of birds, recorded by Scudday (1976a) as summer birds, also were sighted during the fall and winter study periods of that same year, 1975: Killdeer, Turkey Vulture, Red-tailed Hawk, Scaled Quail, Mourning Dove, Roadrunner, Great Horned Owl, Poorwill, Lesser Nighthawk, Ladder-back Woodpecker, Say's Phoebe, Verdin, Cactus Wren, Canyon Wren, Mockingbird, Crissal Thrasher, Black-tailed Gnatcatcher, Loggerhead Shrike, Scott's Oriole, Pyrrhuloxia, House Finch, and Black-throated Sparrow. All can be assumed to be breeding species. Wauer (1973) has breeding records for all 22 of these species in nearby Big Bend National Park.

Nine species sighted during June by Scudday (1976a) but not during the September and December study periods include: Swainson's Hawk, Elf Owl, Common Nighthawk, White-throated Swift, Black-chinned Hummingbird, Ash-throated Flycatcher, Cliff Swallow, Bell's Vireo, and Summer Tanager. Two of these, the Elf Owl and Black-chinned Hummingbird, were recorded as breeding. Species seen during the September and December study periods but not during June include: Green-winged Teal, Shoveler, Cooper's Hawk, Ferruginous Hawk, Golden Eagle, Marsh Hawk, Sparrow Hawk, Red-shafted Flicker, Yellow-bellied Sapsucker, Eastern Phoebe, Black Phoebe, Western Wood Pewee, Scrub Jay, White-necked Ravn, Common Raven, Rock Wren, Curve-billed Thrasher, Hermit Thrush, Ruby-crowned Kinglet, Audubon's Warbler, Townsend's Warbler, Macgillivray's Warbler, Wilson's Warbler, Meadowlark, Brewer's Blackbird, Western Tanager, Pine Siskin, Lesser Goldfinch, Green-tailed Towhee, Rufous-sided Towhee, Brown Towhee, Lark Bunting, Oregon Junco, Rufous-crowned Sparrow, Cassin's Sparrow, Chipping Sparrow, Clay-colored Sparrow, and White-crowned Sparrow.

Examination of the above lists, when compared with references to records obtained by Wauer (1973) in Big Bend National Park, indicates that as many as 11 additional breeding species might be expected in the Solitario. The 11 additional suspected breeding species are: White-throated Swift, Ash-throated Flycatcher, Common Raven, Rock Wren, Curve-billed Thrasher, Bell's Vireo, Summer Tanager, Lesser Goldfinch, Brown Towhee, Rufous-crowned Sparrow, and Cassin's Sparrow. The final count of suspected breeding birds would then number 33 species or 47% of the total number of 70 recorded for the Solitario thus far.

Undoubtedly an important factor limiting migratory birds inhabiting the Solitario is water. During the dry months of September and December, standing water was found only at a few scattered earthen and stationary tanks and in a small depression on the west end of the Righthand Shutup. Three species of birds—the Green-winged Teal, Shoveler, and Killdeer—were found directly associated with standing water at tanks. Other birds found associated with standing water to some degree included: the Black Phoebe, Yellow-bellied Sapsucker, Hermit Thrush, Pine Siskin, Lesser Goldfinch, and Oregon Junco.

The most significant migratory avifauna record for the Solitario was the sighting of a Ferruginous Hawk on 26 September just south of McGuirks Tanks. Wauer (1973) reports this hawk as an uncommon migrant of, and in the vicinity of, Big Bend National Park and that the earliest record for the area is 28 October. The sighting of this individual represents a new early seasonal record for the species.

The Marsh Hawk is for the most part a raptor of the Plains Life Belt and was not sighted within the marginal rim of the Solitario. It can be expected to pass through the Solitario as it migrates. On 15 December five individuals were sighted on the high plains just north of the Solitario.

The sighting of a pair of MacGillivray's Warblers at McGuirks Tanks on 26 September should also be noted because of its rarity as a fall migrant in the Big Bend area (Wauer 1973). The previously recorded late fall record was 14 September (Wauer 1973).

Identification of the Western Wood Pewee was based upon the fact that the eastern variety has never been positively recorded from the Big Bend country.

HERPETOFAUNA OF THE SOLITARIO

Scudday (1976a) listed two species of amphibia and 17 species of reptilia for the Solitario. With every subsequent visit to this region, new species undoubtedly will be added to the list. September observation produced only four herpetofaunal species. Two of these, *Salvadora g. grahamiae* and *Crotalus m. molossus* were additions to Scudday's list. The other two, *Bufo punctatus* and *Sceloporus poinsetti*, have been previously reported.

MAMMALS OF THE SOLITARIO

Fourteen of the 21 mammalian species listed by Scudday (1976a) were recorded during the fall and winter studies. Three additional species not previously recorded—the badger (*Taxidea taxus*), hog-nose skunk (*Conepatus mesoleucus*), and bobcat (*Lynx rufus*)—were added to the list bringing the total for this period of study to 17 and the total for the area to 24 species. Those not recorded during this trip into the Solitario included: *Mormoops megalophylla, Antrozous pallidus, Perognathus merriami,* *Peromyscus eremicus, Spermophilus spilosoma,* and *Procyon lotor.* Those species suspected to occur, marked with an asterisk (*) and included in the following revised list, are as follows: *Urocyon cinereoargenteus, Vulpes macrotis, Bassariscus astutus,* and *Spilogale gracilis.*

Bats were seen flying over a tank at Tres Papalotes in September, but none were captured. A lone bat was seen flying over this same tank in December but was not captured. No bats were seen flying the evening of 18 December, when temperatures at McGuirks Tanks reached near 38.9°C during the day.

The preceding revised list of 28 mammalian species could have been enlarged if suspected bats from nearby Fresno Canyon (Scudday 1976b) had been included. Since there still remains much to be known concerning the ranging habits of many of these species, they are not included here.

The most significant mammal records obtained from the Solitario during the fall and winter study periods were those of the striped (*Mephitis mephitis*) and hognose (*Conepatus mesoleucus*) skunks. Patton (1974) studied the ecological relationships between the four species of skunks inhabiting the Trans-Pecos and found that *Mephitis mephitis* is absent from the more rugged areas that are inhabited by *Spilogale gracilis* and *Conepatus.* This ecological relationship deserves further investigation, since both *Mephitis mephitis* and *Conepatus* were collected from within the rugged habitat of the Solitario at Tres Papalotes. Another interesting observation arises from the location of the *Conepatus* capture site, about 100 m from the Tres Papalotes hunters camp. Patton states that during his study *Conepatus* was never trapped around dwellings used by man. In the Solitario the Tres Papalotes hunter's camp has been used three full days prior to the *Conepatus* capture and was used quite extensively by deer hunters the month before.

The badger (*Taxidea taxus*) was never seen within the boundaries of the Solitario rim, but signs of its diggings were commonly seen along the ranch roads and on the desert flats around McGuirk's Tanks. The only individual seen was found just north of the Solitario, 0.8 km south of Wire Gap. The adult animal was eating on an old deer carcass along the road and was observed entering a burrow along the roads edge.

Because of the secretive habits of the bobcat and because of the difficulty in tracking it, records in this part of the country are difficult to obtain. No sign of it was found within the Solitario rim, but a series of tracks was found in December along a soft, dirt ranch road, just outside the north entrance to the Lefthand Shutup.

CONCLUSION

The composition of the vertebrate fauna of the Solitario becomes better known with each subsequent visit. Of the three major groups discussed, the mammals are best known. Undoubtedly a greater number of additional herp and bird records will be found on follow-up visits during different times of the year.

BIBLIOGRAPHY

Blair, W. Frank. 1950. The biotic provinces of Texas. *Tx. J Sci* 2(1):93-117.

Blair, W. F. and C. E. Miller Jr. 1949. The mammals of the Sierra Vieja region, southwestern Texas, with remarks on the biogeographic position of the region. *Tx J Sci* 1(1):67-92.

Dice, L. R. 1943. *Biotic provinces of North America.* University of Michigan Press, Ann Arbor, Michigan:3-66.

LoBello, R. L. 1976. *The vertebrate fauna of the Bofecillos Mountains,* Univ. of Texas, Austin, Center for Natural Resource and Environment, Natural Areas Survey.

Patton, R. F. 1974. *Ecological and behavioral relationships of the skunks of the Trans-Pecos Texas.* Phd Dissertation, Texas A&M Univ. 199 pp.

Scudday, James F. 1976a. *The vertebrate fauna of the Solitario area, Brewster-Presidio counties, Texas.* Univ. of Texas, Austin, Center for Natural Resources and Environment, Natural Areas Survey.

Scudday, James F. 1976b. *The vertebrate fauna of the Fresno-Chorro Canyon area, Presidio county, Texas.* Univ. of Texas, Austin, Center for Natural Resources and Environment, Natural Areas Survey.

GRASSHOPPER AFFINITIES AND HABITAT RELATIONS IN THE SOLITARIO

Anthony Joern

Invertebrate herbivores consume the energy base (vegetation) of a habitat and are a major prey item for a significant part of the vertebrate community. The study of such herbivores, affecting both the plant and animal components, therefore provides important insights into the dynamic relationships of the environment. Tinkham (1948) has noted the strong affinities of grasshopper species with specific habitats. Characteristics such as large size, a manageable number of species, relatively large population sizes, a relatively sedentary existence, and variable space-time distribution patterns make this group valuable in describing habitats and faunal zones (Tinkham 1948). To this end, the grasshopper fauna (*Orthoptera: Acrididae*) of the Solitario region near Tres Papalotes Camp was sampled and compared to neighboring regions.

Grasshopper diversity in an area is strongly correlated with plant species diversity (Otte and Joern n.d.). Present practice is to evaluate the structure of the habitat (vegetation and substrate) as potentially more important than only the number of plant species in an area. Since most of the species studied are extremely cryptic, background coloration is probably extremely important in influencing the grasshopper-habitat faunal relationship. It therefore seems probable that vegetational structure and substrate diversity mediate the species composition in an area.

Collections were made in late June, 1975. Six sites were chosen to reflect the diversity of grasshopper fauna in this region. Although the sites were selected to reflect the apparent plant associations, I had no knowledge of the acridid species present at any one site, thus minimizing bias. That all species present in this area were not located is a definite possibility because of my short stay in the area. I believe, however, the present description accurately reflects the nature of the Solitario fauna, allowing comparison with other Big Bend areas. A list of the species collected is given in Table 1.

Grasshopper Fauna in the Solitario

Grasshopper species showed varying affinities for certain plant associations and plant species. Shrub inhabiting species include *Bootettix argentatus* and *Clematodes larreae* exclusively on the creosote bush (*Larrea divaricata*), and *Goniatron planum* only on the southern blackbrush (*Fluorensia cernua*). These species are very cryptic with *B. argentatus* residing on the foliage of creosote and *C. larreae* and *G. planum* having colors and behaviors making it difficult to locate either on the stems of their respective host plants. *Clematodes larreae* is uncommon, and the discovery of this species was exciting though not completely unexpected.

Common species associated with substrates on creosote flats include the ubiquitous *Trimerotropis pallidipennis* and *Psoloessa texana*. *Cibolacris parviceps* is also common on the ground, with some populations being very dense. *Cibolacris parviceps* is found only on the desert pavement with a varied background (i.e., rocky) and very seldom is found on the hillsides. The creosote/blackbrush flat exhibiting the greatest grasshopper diversity was associated with *Leucophyllum minus* and *Coldenia greggii*. The stone

TABLE 1

Species collected in the Solitario near Tres Papalotes camp June 7-8, 1975

Subfamily Acridinae
Bootettis argentatus Bruner
Cibolacris parviceps (F. Walker)
Goniatron planum Bruner
Mermiria texana Bruner
Psoloessa texana pusilla (Scudder)

Subfamily Oedipodinae
Arphia aberrans Bruner
Platylactista azteca (Saussure)
Trimerotropis pallidipennis pallidipennis (Burmeister)

Subfamily Catantopinae
Clematodes larreae Scudder
Schistocerca vaga vaga Scudder

Subfamily Pamphiginae
Phrynotettis robustus (Bruner)

mimicking toadhopper or toad lubber *Phrynotettix robustus* was present in this association. This species is also very uncommon.

Arphia aberrans, Platylactista azteca, and *Mermiria texana* were found only on slopes without creosote. *Arphia aberrans* and *P. lactista* are ground inhabitors, and *M. texana* is found in grass bunches. *Trimerotropis pallidipennis* and *P. texana* were also abundant on the slopes. On some of the drier east-facing slopes, only *P. texana* was abundant, although some *T. pallidipennis* were found occasionally.

Very steep slopes may present a special habitat in analyzing the grasshopper community. The diversity of species and population sizes along the very steep, rocky slopes of the lower shutup was very low, despite the presence of a dense cover of chino grama (*Bouteloua breviseta*). A single *Schistocerca vaga* was encountered on a yucca stalk. In addition, I heard *B. argentatus* on creosote and collected a single *P. texana* nymph. The habitat relationships of these species are emphasized in Table 2.

Discussion and Comparison with Neighboring Fauna

The Big Bend region of Texas, including the grasslands of the Davis Mountains, has an extremely rich grasshopper fauna. In his 1948 monograph, Tinkham lists records of approximately 90-100 species taken from this region. Thirty-nine of these species (ca. 40%) may be considered members of the Chihuahuan Desert fauna. Table 3 presents the desert species listed by Tinkham (1948) according to their geographic affinity. Twelve of the 39 species are found early in the season. Many other species have life histories marginally extending into the period I was collecting in this area. Thus, I collected 7 of 12 species expected to be present and 10 of 22 if the marginal species are included.

The faunal affinities of these species have been arranged by Tinkham (1948) into the following groups:

Lower Sonoran Fauna – The range of creosote bush is the primary factor characterizing the range of species in this faunal group. This description primarily characterizes the desert regions of the Southwest.

Mexican Lower Sonoran Fauna – This includes fauna found primarily in northern Mexico whose northern distributions are found in the southern portion of the Big Bend region.

Chihuahuan Lower Sonoran Fauna – This group includes fauna indigenous to the Chihuahuan Desert. This fauna is found east of the continental divide.

TABLE 2

Faunal habitat relationships in the Solitario

		HABITAT	
		Desert Flat	Hillside*
MICROHABITAT	Creosote (*Larrea*)	*Bootettix argentatus* *(Clematodes larrae ?)*	*Bootettix argentatus* *Clematodes larreae*
	Blackbrush (*Flourensia*)	*Goniatron Planum*	*(Goniatron planum ?)*
	Grass	*Psoloessa texana*	*Mermiria texana* *Psoloessa texana*
	Open Substrate	*Psolessa texana* *Cibolacris parviceps* *Trimerotropis pallidipennis* *Phrynotettix robustus*	*Arphia aberrans* *Platylactista azteca* *Psoloessa texana* *Trimerotropis pallidepennis*

**Schistocera vaga* was first seen on a yucca stalk on a steep hillside. Although they were not collected, some grasshopper species may be present in a different habitat. In these cases the host plant extended from the desert flat and up the hillside. This is indicated by a question mark.

TABLE 3

Desert grasshoppers of the Big Bend Region and their faunal affinities (from Tinkham 1948)

A single asterisk indicates the life history overlaps with the period during which the present collection was made. A double asterisk indicates marginal overlap of life history period. See the text for an explanation of the faunal assemblages.

Lower Sonoran Fauna	Mexican Lower Sonoran	Chihuahuan Lower Sonora
***Mermiria neomexicana*	*Acantherus piperatus*	**Bootettix argentatus*
Mermiria texana	*Zapata brevipennis*	***Pedioscrirtetes maculipennis*
**Orphullela pelidna*	**Clematodes larreae*	***Goniatron planum*
**Psoloessa texana*		**Derotmema haydeni*
**Arphia aberrans*		***Trimerotropis texana*
**Encoptolophus subgracilis*		***Anconia hebardi*
**Spharagemon cristatum*		**Phrynotettix robustus*
**Platylactista azteca*		**Phrynotettix tschivavensis*
Mestobregma terricolor		*Schistocerca chinatiensis*
**Trimerotropis pallidipennis*		*Netrosoma nigropleura*
***Trimerotropis strenua*		*Phaedrotenttix dumicola*
**Cibolacris parviceps*		*Phaulotettix eurycercus*
Taeniopoda eques		***Agroecotettix modestus*
***Schistocerca vaga*		***Camplycantha olivacea*
**Melanoplus aridis*		**Aeoloplus elegans*
Melanoplus desultorius		*Melanoplus eumera*
***Melanoplus herbaceus ?*		
Melanoplus differentialis		
***Melanoplus bowditchi*		

The grasshopper fauna in the Solitario is a typical representation of the desert region within which it lies. This conclusion is based on my collecting in the region, compared to the summary provided by Tinkham. The ratios of species collected to the potential number available are similar for species from each of the faunal affinity groups (Lower Sonoran, .5-.6; Mexican Lower Sonora, .33-.5; and Chihuahuan Lower Sonoran, .38). The higher value for species from the Lower Sonoran group probably reflects large population sizes and attendant sampling problems over a short-time course. Further collecting and study in the area would probably more fully substantiate the similarity between regions.

The precise role microhabitat selection differences within a habitat and cryptic coloration play in structuring the Solitario grasshopper community cannot be determined from the above data. Precise population statistics for each species are needed. In addition, the role each of the vertebrate predators plays in influencing these parameters needs to be determined. This has not been done in this study. However, if my earlier predictions hold, much of the vertebrate community may be explained by carefully monitering invertebrate populations.

LITERATURE CITED

Otte, Daniel and Anthony Joern. n.d. Feeding patterns among desert grasshoppers and the evolution of specialization. *Proceedings of the Academy of Natural Sciences,* In press, MS. 1977. Philadelphia.

Tinkham, Ernest R. 1948. Faunistic and ecological studies of the orthoptera of the Big Bend Region of the Trans-Pecos Texas, with special reference to the Orthopteran zones and faunae of midwestern North America. *Amer. Midl. Nat.* 40:521-663.

BUTTERFLIES OF THE SOLITARIO – FRESNO CREEK – BOFECILLOS MOUNTAINS REGION WESTERN BIG BEND (PRESIDIO AND BREWSTER COUNTIES) TEXAS

Christopher J. Durden

Forty-seven species of butterflies in the western Big Bend region were recorded during collecting visits in May 1973, October 1974, and June 1975. Although this list is perhaps less than one-half of the potential, it is possible to draw some conclusions regarding the faunal affinities of the area.

There are a few taxa of restricted range. Two are restricted to the immediate Big Bend Region of West Texas (including the Davis Mountains): *Megisto rubricata smithorum* and *Thessalia chinatiensis*. Two are restricted to a narrow band, and extension of the Sierra Madre Oriental of Mexico: *Strymon* new species and *Celotes limpia*. One occurs throughout the Rio Grande basin below Albuquerque and westward through the Lordsburg gap over surfaces drained by the ancestral Rio Mimbres (R. C. Belcher 1975:44) in mid-Tertiary time: *Dymasia dymas*. One is a western disjunct of a Tamaulipan shrubland species: *Thessalia theona bollii*. Four are Sonoran desert species either disjunct or at the eastern edge of their ranges (which pass through the Lordsburg gap): *Chlosyne lacinia crocale, Asterocampa leila, Asterocampa subpallida,* and *Systasea zampa*.

Four species are widely distributed in both Sonoran and Chihuahuan deserts: *Papilio rudkini clarki, Calephelis nemesis, Cogia hippalus,* and *Atrytonopsis ovinia edwardsi*. Two have a Kansan Province (short grass prairie) distribution and are at the southern end of their range: *Phyciodes picta* and *Amblyscirtes oslari*. One eastern deciduous forest species is disjunct here and in Durango: *Polygonia interrogationis*. One is eastern Neotropical, extending into the eastern Great Plains: *Agraulis vanillae incarnata*.

Ten species have broad ranges on either side of the continental divide but do not extend south of Northern Mexico: *Papilio polyxenes curvifascia, Eurema mexicana, Thessalia fulvia, Limenitis bredowii eulalia, Phyciodes vesta, Leptotes marina, Strymon melinus franki, Atlides halesus corcorani, Icaricia acmon texanus, Hesperia pahaska williamsi*. Five species have broad ranges on both sides of the continental divide, mostly in Mexico: *Phoebis sennae marcellina, Kricogonia lyside, Danaus gilippus strigosus, Libytheana carinenta mexicana,* and *Copaeodes aurantiaca*.

Six species have very broad temperate ranges: *Pieris protodice, Colias eurytheme, Danaus plexippus, Euptoieta claudia, Hemiargus isola alce,* and *Pyrgus communis*. Six species have very broad subtropical ranges: *Battus philenor, Nathalis iole, Eurema nicippe, Zerene cesonia, Brephidium exilis,* and *Erynnis funeralis*. Two species range throughout North America: *Vanessa virginiensis* and *Vanessa cardui*.

The chief surprises are the lack of uniquely Chihuahuan Desert species. Species endemic to the Big Bend will probably be found south of the Rio Grande in the isolated ranges of western Coahuila and eastern Chihuahua. Endemic species of the northern Sierra Madre Oriental occur in arid habitats and should be assigned to the Chihuahuan Desert fauna (they are not likely however to be found in Chihuahua). Disjuncts from both Tamaulipan and Sonoran provinces suggest that the Rio Grande has been an important route of dispersal. The several species that leak through the Lordsburg Gap from the Sonoran desert indicate that this mid-Tertiary segment of the Rio Grande drainage, the ancestral Mimbres-upper Gila River of mid-Miocene to mid-Pliocene time (Belcher 1975:38), has been and continues to be an important passage for extension of ranges of both eastern and western desert species.

Locality Register

All voucher specimens are numbered as follows: First two digits are last two of the year, next three digits are day of the year, followed by a punctuating letter designating site collected during the day, terminated by unique specimen number. Number is prefixed by collector's name in citation.

Solitario Localities

Brewster County

Lefthand Shutup (103.75-6°W, 29.47°N): 73141J, 75162B.

Tres Papalotes (103.77°W, 29.45°N): 73141H, 75159A (part).

Summit and ridge south of Tres Papalotes (103.77°W, 29.44°N): 75159A (part).

SUMMARY OF OCCURRENCE OF BUTTERFLIES IN THE SOLITARIO (S), FRESNO CREEK (F), AND BOFECILLOS MOUNTAINS (B) OF WESTERN BIG BEND, TEXAS

		S	F	B
1	*Battus philenor*	S	F	
2	*Papilio polyxenes curvifascia*	S	F	
3	*Papilio rudkini clarki*	S	F	
4	*Pieris protodice*	S		
5	*Nathalis iole*		F	
6	*Colias eurytheme*	S		
7	*Zerene cesonia*		F	
8	*Eurema mexicana*	S		
9	*Eurema nicippe*	S	F	B
10	*Phoebis sennae marcellina*		F	
11	*Kricogonia lyside*		F	
12	*Danaus gilippus strigosa*	S	F	B
13	*Danaus plexippus*		F	
14	*Megisto rubricata smithorum*	S	F	
15	*Agraulis vanillae incarnata*		F	
16	*Euptoieta claudia*		F	
17	*Polygonia interrogationis*		F	
18	*Vanessa virginiensis*	S		
19	*Vanessa cardui*	S		
20	*Chlosyne lacinia crocale*	S		
21	*Thessalia chinatiensis*	S		
22	*Thessalia theona bollii*	S		
23	*Thessalia fulvia*	S		
24	*Dymasia dymas*		F	
25	*Phyciodes vesta*	S	F	
26	*Phyciodes picta*		F	
27	*Limenitis bredowii eulalia*		F	
28	*Asterocampa leila*	S	F	B
29	*Asterocampa subpallida*			B
30	*Libytheana carinenta mexicana*		F	
31	*Calephelis nemesis*		F	B
32	*Atlides halesus corcorani*		F	
33	*Strymon melinus franki*	S	F	
34	*Strymon* new species	S	F	
35	*Brephidium exilis*	S		
36	*Hemiargus isola alce*	S	F	B
37	*Leptotes marina*	S	F	B
38	*Icaricia acmon texanus*	S		B
39	*Cogia hippalus*			B
40	*Systasea zampa*			B
41	*Erynnis funeralis*	S	F	
42	*Celotes limpia*	S		B
43	*Pyrgus communis*	S		B
44	*Copaeodes aurantiaca*	S	F	
45	*Herperia pahaska williamsi*		F	
46	*Amblyscirtes oslari*	S		
47	*Atrytonopsis ovinia edwardsi*	S	F	

Presidio County

Fresno Peak (103.83°W, 29.42°N): 75162A (part).

Chert ridge and gulch south of Middle Tank (103.81°W, 29.44°N): 75162A (part).

Middle Tank (103.81°W, 29.44°N): 75161C (part).

Grays Ridge Gulch (103.81°W, 29.44°N): 75161C (part), 73140E.

Grays Ridge (103.80°W, 29.43°N): 73140D.

Lower Shutup (103.80°W, 29.41°N): 73140A.

Righthand Shutup to Solitario Peak (103.84-5°W, 29.45-6°N):73136C.

Rim of Solitario and limestone summit west of Solitario Peak (103.84°W, 29.46°N): 73136A.

Southwest chimney of Solitario Peak (103.84°W, 29.46°N): 73136B.

Gulch and limestone summit north of Solitario Peak (103.84°W, 29.46°N): 75160A.

East slope of Solitario Peak (103.83°W, 29.46°N): 73140C, 75160A (part).

South slope of Solitario Peak (103.83°W, 29.46°N): 75161A.

Localities in the Western Drainage of Fresno Creek

Presidio County

Log Spring Draw (103.87°W, 29.45°N): 73137B.

Slopes above Log Spring Draw (103.87°W, 29.45°N): 73137A.

Seep Springs Draw (103.86°W, 29.44°N): 73137C.

Upper and Lower Seep Springs (103.87°W, 29.44°N): 73138A.

Summit and slopes west of Seep Springs (103.88°W, 29.45°N): 73137B.

Smith Ranch (103.86°W, 29.39°N): 73135A (part).

Smith Spring Draw (103.87°W, 29.39°N): 73135A (part).

Rancho Madrid (103.87°W, 29.37°N): 73138D, 74293B.

Chorro Canyon below Madrid Falls (103.88°W, 29.37°N): 73138C, 74291A, 74293A.

Chorro Canyon above Madrid Falls (103.88°W, 29.38°N): 73138F, 74292B.

Localities in the Bofecillos Mountains

Presidio County

Bofecillos Canyon, springs below pictographs (104.10°W, 29.49°N): 73142A.

Lower Tapado Canyon, springs above main fork (104.08°W, 29.38°N): 73143A.

All voucher specimens are curated in the Ecological and Systematic Survey of Texas Arthropods (ESSTA)

Collection of Texas Memorial Museum, 2400 Trinity Street, Austin, Texas 78705, and are available for study by qualified investigators.

Family PAPILIONIDAE

Battus philenor Linnaeus, 1771. 73138D1 Rancho Madrid, 75162A1 Fresno Peak.

This black and blue, glossy, orange-spotted swallowtail is conspicuous throughout the area and may be seen on warm days almost all year. It was present in hilltopping assemblages at Seep Springs summit and on Fresno Peak, and was seen flying along washes west of Fresno Creek and in the Shutups of the Solitario. Adults frequently feed at the blooms of desert willow *Chilopsis linearis,* and the larvae feed exclusively on species of *Aristolochia.*

Papilio polyxenes curvifascia Skinner, 1902. 73137B sight Seep Springs summit, 75159A5-9 Tres Papalotes summit, 75160A9 summit N of Solitario Peak.

This yellow-spotted, black swallowtail was a frequent component of hilltopping assemblages on the summit north of Chorro Canyon, summit west of Seep Springs, rim summits west of Solitario Peak, Solitario Peak, and Gray's Ridge. It is distinguished from its sibling *P. rudkini* by the odor (resembling cheap perfume) of the androconial scales of the male forewing, the irregularly aligned and rough-edged spots of the post-median yellow band, the coarse or fluffy appearance of the wing scales, and the black cast of the ventral proximal dark area of the wings. Where *P. polyxenes* occurs in arid regions, in potential sympatry with *P. rudkini,* it is represented by the subspecies *curvifascia* and individuals resembling the eastern subspecies, *asterius* Stoll, are uncommon. Larvae of *P. polyxenes* feed on Umbelliferae and the occasional reports of Rutaceae may refer to individuals of the following species.

Papilio rudkini clarki Chermock & Chermock, 1937. 73140D2 Gray's Ridge, 73137B1 Seep Springs summit, 75162A2 Fresno Peak.

This very close sibling species is distinguished from *P. polyxenes* by the odor (citrus) of the androconia or scent scales of the male forewing, the straighter alignment of the more evenly bordered post-median spotband, the smoother appearance of the scales, and the gray cast of the ventral proximal dark area of the wings. *P. r. clarki* is the dark form of the species found in areas where *P. rudkini* and *P. polyxenes* are sympatric, from eastern California through eastern Arizona to southern Colorado, eastern New Mexico, and the Edwards Plateau (Travis County) of Texas. Its range southward in the Chihuahuan Desert region has not been documented. It is found in arid habitats; rock summits in the west; gravel-covered river terraces and talus in the east. *P. rudkini* larvae feed on Rutaceae, particularly species of *Thamnosma. P. r. clarki* appears to grade into the Central American *P. americus stabilis* Rothschild and Jordan in South Texas (Hays and Bexar Counties). When details of its biology are worked out *clarki* (and other races of *rudkini* and *coloro* Wright) will probably be recognized as subspecies of *P. americus* Kollar as was predicted by Edwards in 1877.

Family PIERIDAE

Pieris protodice Boisduval & Leconte, 1829. 73136A1-2 summit west of Solitario Peak, 75159A11 summit south of Tres Papalotes, 75161C21-23 Middle Tank

This common white desert butterfly is a frequent component of hilltopping assemblages. It is also encountered flying along washes where its larval foodplants, various cruciferous weeds, occur. It was commonly seen visiting the sunflowers on the graded area of Middle Tank.

Nathalis iole Boisduval 1836. 73138D sight Rancho Madrid.

This widespread species of desert and plains occurs in weedy areas along washes as well as on heavily grazed pasture where the foodplants are found. These include species of *Dysodia, Helenium, Stellaria, Bidens, Thelosperma,* and *Palafoxia.*

Colias eurytheme Boisduval, 1852. 75161C24 Middle Tank.

This temperate meadow species also occurs abundantly in desert areas along gulches where herbaceous legumes, the larval foodplants, grow. Adults habitually fly along gravel stream beds and are less frequently observed crossing open country. They are preadapted to fly along road shoulders, an artificial habitat also occupied by the larval foodplants. Hence the species has extended its range eastward in historic times. The species breeds year round at this latitude and numbers are highest in spring and fall.

Zerene cesonia Stoll, 1790. 73138D sight Rancho Madrid.

This species is an occasional hilltopper and is seen frequently flying across desert scrub in the Solitario. Adults are avid flower visitors, feeding at desert willow *Chilopsis linearis* and wild china *Sapindus saponaria.* The larvae feed on various herbaceous legumes.

Eurema mexicana Boisduval, 1836. 75161C25-26 Middle Tank.

This species ranges from tropical forest habitats in Central America to montane woodland sites in the Rocky Mountains. In the latter area the larval foodplant is *Robinia neomexicana.* In this area it may use *Cassia lindheimeriana* or one of the *Acacia* species.

Eurema nicippe Cramer, 1780. 73138D3 Rancho Madrid, 73141H1 Tres Papalotes, 73143A1 lower Tapado Canyon, 74291A7 lower Chorro Canyon, 75161C20 Middle Tank.

At times this is one of the commonest butterflies of the area. A small orange butterfly, it is seen frequently along washes and the lower valley flats where the principal foodplant senna, *Cassia linhdeimeriana,* grows. Adults may be found in warm weather at any time of year.

Phoebis sennae marcellina Cramer, 1777. 73138D2 Rancho Madrid, 74292B3 upper Chorro Canyon, 74293B3-4 Rancho Madrid.

This large, yellow-sulfur butterfly (which has both orange and white forms of the female) is seen infrequently along dry washes in all areas. Old adults have a strong odor of rancid butter. The larvae feed on various species of senna, *Cassia* spp. in a tent formed from a folded leaf, tied with silk.

Kricogonia lyside vàr. *terissa* Lucas, 1852. 73138D4 Rancho Madrid.

This species of the Chihuahuan Desert and Tamaulipan shrubland feeds, as larva, on guyacan, *Porlieria angustifolia.* A female was observed to oviposit on this shrub at upper Seep Spring. The species occurs as several genetically determined varieties and phenotypic forms of quite different appearance, the ecological significance of which is not yet understood. Under epidemic conditions, all named forms and varieties have been taken together. Following certain climatic events this species migrates in flocks of millions of individuals, often in the company of the snout butterfly, *Libytheana bachmanii.* Adults of *K. lyside,* when not in migration, tend to be crepuscular, or most active at dusk, when they gather in bushes about seeps and springs. Occasionally they congregate at the flowers of wild china, *Sapindus saponaria.*

Family NYMPHALIDAE

Danaus gilippus strigosa Bates, 1864. 73138D sight Rancho Madrid, 73135A sight Smith Ranch, 73137B sight Log Spring Draw, 73136C sight Righthand Shutup, 73140A sight Lower Shutup, 73141J sight Lefthand Shutup, 73142A3 Bofecillos Canyon, 74293B2 Rancho Madrid, 75161C5 Middle Tank.

This small, dull brown to tan monarch is frequent along washes where the foodplants (*Asclepias* spp.) of the larvae grow.

Danaus plexippus Linnaeus, 1758. 73138D9 Rancho Madrid, 74291A1 upper Chorro Canyon, 74293B1 Rancho Madrid.

A larger number of monarchs were seen in the area than was expected. In both May and October, most were in sustained flight along dry washes, but some were engaged in roosting activity in trees around Smith Spring and Seep Spring. No monarchs were seen in June, and it is unlikely that they breed in the area.

Megisto rubricata smithorum Wind, 1946. 73140C1 east slope Solitario Peak, 73138C1 lower Chorro Canyon, 73137B2-3 slopes of Seep Springs summit, 73136C1 dry wash west of Solitario Peak, 73136B1-6 SW chimney of Solitario Peak, 73135A1-4 Smith Spring draw, 74292B4 upper Chorro Canyon, 75159A2 ridge south of Tres Papalotes, 75160A1,7 east slope Solitario Peak, 75161C1 Gray's Ridge Gulch, 75162A3 chert ridge south of Middle Tank.

The subspecies *smithorum* is found in oak and juniper woodland habitats in the Davis and Chisos Mountains. Subspecies *rubricata* is found in oak and juniper woodland habitats of the Guadalupe Mountains, Wichita Mountains (Oklahoma), and Edwards Plateau. Subspecies *cheneyorum* occurs in oak and juniper woodland of eastern Arizona and southern New Mexico. An underscribed subspecies occurs in live oak woodland at the eastern edge of the Edwards Plateau and in the Serranias del Burro (Coahuila). The Solitario populations differ from but are closest to *smithorum.* They are the only nonwoodland race yet known of *M. rubricata.* Adults may be flushed from the tall tufted grasses, the probable larval foodplant, that grow on the steep upper talus slopes below chert or volcanic cliffs. It is in such situations that other woodland relicts are found, including scattered oaks. *M. rubricata* is found far beyond these oaks, however. The distribution of this species is probably relict from a time when much of the Solitario and Fresno Canyon were clothed in oak woodland.

Agraulis vanillae incarnata Riley, 1926. 73138D sight Rancho Madrid.

The gulf fritillary is usually found along well-vegetated washes where its larval foodplants, the vine *Passiflora* spp. grow.

Euptoieta claudia Cramer, 1776. 73137B sight Seep Springs summit.

This fritillary of the Great Plains and Mexican Plateau is abundant where heavy grazing has disturbed the grassland to the point that weedy plants such as *Portulaca* spp., *Sedum* spp., *Meibomia* spp., and *Plantago* spp. can act as larval foodplant. Larvae have also been found to eat many other plants, including species of *Viola, Passiflora, Menispermum,* and *Podophyllum* in other areas.

Polygonia interrogationis Fabricius, 1798. 74292B2 upper Chorro Canyon.

This widespread species of eastern North America is (except for a population in Durango), unusual west or south of the prairies and Edwards Plateau. As food, the larvae prefer species of *Celtis*, but will also eat species of *Ulmus, Humulus, Urtica*, and *Tilia*.

Vanessa virginiensis Drury, 1773. 73140A sight Lower Shutup, 75161C14 Middle Tank.

This is a common species of shrublands, where the larval foodplants are species of *Senecio, Artemisia, Anaphalis, Antennaria, Gnaphalium, Myosotis, Antirrhinum* and *Malva*. Adults may be found on warm days in winter.

Vanessa cardui Linnaeus, 1758. 73140C sight east slope Solitario Peak. 73141J sight Lefthand Shutup.

This is a common species of arid shrublands, where it utilizes as larval food species of *Malva, Althea, Borago, Cirsium, Carduus, Centaurea, Arctium, Anaphalis, Artemisia*, and *Gnaphalium*. The species is found on all continents except Australia. It breeds year round in the Sonoran, Chihuahuan, Saharan, Arabian, and Gobi deserts and emigrates annually to higher latitudes, having been taken at the northernmost point of Greenland.

Chlosyne lacinia crocale Edwards, 1874. 75159A10 summit south of Tres Papalotes, 75161C19 (near *adjutrix*) Middle Tank, 75162A5 (*crocale*), 6 (near *adjutrix*) Fresno Peak.

This butterfly is found in disturbed sites in arid regions on both sides of the continental divide. It is at the eastern edge of its range here and shows evidence of intergradation with the Tamaulipan *C. l. adjutrix*. The latter ranges northwest to the Texas Panhandle (Blackwater Draw) and eastern New Mexico. Typical *C. l. crocale* was unexpected in the Solitario. The larval foodplants include a number of species of sunflowers of several genera.

Thessalia chinatiensis Tinkham, 1944. 75161A2-3 south slope Solitario Peak, 75162A7-9 Fresno Peak.

This West Texas endemic occurs in the Chinati Mountains, at Toyahvale, and near Terlingua. In Big Bend National Park it is found at lower elevations than the related *T. thekla* Edwards, which feeds as larva on *Castilleja lanata* and *Verbena* in the Sonoran desert. *T. thekla* has not yet been found in the Solitario area, where *T. chinatiensis* is found at moderate and high elevations, and is always associated with *Castilleja* spp. On Fresno Peak *T. chinatiensis* flies with *T. fulvia*.

Thessalia theona bollii Edwards, 1877. 75159A4 summit south of Tres Papalotes.

This species of the Tamaulipan shrubland is at the western and northern extremity of its range here. In South Texas its larvae are known to eat *Leucophyllum texanum*. It was found here with *T. fulvia* on a shrubby summit.

Thessalia fulvia Edwards, 1879. 73137B4-5 Seep Springs summit, 75159A3 summit south of Tres Papalotes, 75160A3-6 summit north of Solitario Peak, 75161C17-18 slopes above Gray's Ridge Gulch, 75162A10-13 Fresno Peak.

This species is found on dry, rocky summits where the larval foodplant *Castilleja* spp. grows. The thermoregulatory and territorial habits of this species are similar to the more northern genus *Euphydryas*, to which *T. fulvia* bears a superficial resemblance.

Dymasia dymas Edwards, 1877. 74292B5-6 upper Chorro Canyon.

This species of the Chihuahuan Desert and Tamaulipan shrubland is known to feed as larva on *Siphonoglossa pilosella*. Specimens taken in upper Chorro Canyon were all of the large light form *larunda* Strecker. Individuals of the typical form were seen in lower Chorro Canyon.

Phyciodes vesta Edwards, 1869. 73138D5 Rancho Madrid, 75162A4 chert gulch south of Middle Tank.

This species of dry washes in arid country and the subtropics utilizes *Siphonoglossa pilosella* as larval foodplant.

Phyciodes picta Edwards, 1865. 73138D6 Rancho Madrid, 74293B12-15 Rancho Madrid.

This species of the southern Great Plains (there is another race in the Sonoran Desert) occurs in grassy areas around seeps and along washes where *Aster* spp., the larval foodplants, grow.

Limenitis bredowii eulalia Doubleday, 1848. 73138F sight upper Chorro Madrid.

This large, spectacular, white-banded, black butterfly with orange-spotted wing apex occurs typically in oak woodland habitats of northern Mexico, mountains of the continental divide to Colorado, and the Edwards Plateau and Trans-Pecos ranges of Texas. Elsewhere, the larvae are known to eat various species of each of the three temperate American oak subgenera. In Chorro Canyon it may utilize *Quercus oblongifolia*. In the Davis Mountains *Q. hypoleucoides* is the presumed larval foodplant.

Asterocampa leila Edwards, 1874. 73138D7-8 Rancho Madrid, 73143A2 lower Tapado Canyon, 74291A1-6 lower Chorro Canyon, 74292B1 upper Chorro Canyon, 74293B7-10 & 11 (var.) Rancho Madrid, 75162B1 Lefthand Shutup.

This species is closely associated with the low shrubby growth of *Celtis pallida*, the larval foodplant. All specimens from this area are of the typical subspecies (described from the Sonoran Desert) rather than the south and central Texas subspecies *cocles* Lintner.

Asterocampa subpallida Barnes & McDunnough, 1913. 73142A1-2 Bofecillos Canyon.

This species previously was known only from the Sonoran Desert in the Santa Rita, Baboquivari, Huachuca, and Chiricahua Mountains of Arizona. Here it is associated with an old grove of *Celtis reticulata,* the presumed larval foodplant.

Family LIBYTHEIDAE

Libytheana carinenta mexicana Michener, 1943. 73138D10 Rancho Madrid, 73137A sight Log Spring Draw, 74293A2-3 lower Chorro Canyon, 74293B5-6 Rancho Madrid.

The larvae of this species feed on various species of *Celtis* and the adults are frequently seen roosting in thorn thickets along draws. Adults are often active at temperatures well over 38°C (100°F), when other butterflies have sought shaded refuge. After certain climatic events this species undergoes epidemic reproduction and adults migrate in great clouds both north and south out of the Chihuahuan Desert. All specimens taken appear to be this species rather than the very similar *L. bachmanii larvata* Strecker, which may also occur in the area.

Family LYCAENIDAE

Calephelis nemesis Edwards, 1871. 73143A sight lower Tapado Canyon, 74293B16-17 Rancho Madrid.

This metalmark is found at seeps along washes where its foodplants, *Baccharis* spp. and *Clematis* spp., grow.

Atlides halesus corcorani Gunder, 1934. 73137B6-7 Seep Springs summit.

Three individuals were defending territories on and around a large *Yucca thompsoniana* at the top of Seep Springs summit. Larval foodplants, the mistletoe *Phoradendron* spp., are uncommon in the area.

Strymon melinus franki Field, 1938. 73141H2-3 Tres Papalotes, 74292B10 upper Chorro Canyon, 75160A8 south slope Solitario Peak, 75161C5-9 Middle Tank.

This species is found around seeps; a couple were flushed from a fig bush at Tres Papalotes. The larval foodplants are diverse, mostly *Leguminosae, Malvaceae,* and *Rosaceae,* including 46 genera and 21 families.

Strymon new species. 73140D3-4 Gray's Ridge, 75159A13-17 ridge south of Tres Papalotes, 73137B sight Log Spring Draw.

This species was found hilltopping at two locations, visiting flowers of *Acacia greggii* and defending bush-top territories. It looks superficially like *Tmolus azia* Hewitson, but it is a *Strymon* spp. related to *S. melinus* and *S. rufofusca* Hewitson. Elsewhere it is known from southern Tamaulipas (Durden 70360A), probably from Big Bend National Park (specimens not seen), and possibly from Colorado (Boulder, Chataqua Mesa). In the Solitario it is associated with *Prunus havardii* thickets.

Brephidium exilis Boisduval, 1852. 75159A12 Tres Papalotes, 75160A11 gulch north of Solitario Peak, 75161C3 Middle Tank.

This species ranges throughout the Great Basin, Mexican Plateau, and arid regions of Texas, to the mouth of the Rio Grande. Larval foodplants include many common weeds such as *Atriplex bracteosa, Chenopodium album, Salicornia ambigua,* and *Petunia parviflora.*

Hemiargus isola alce Edwards, 1871. 73136C1-3 Righthand Shutup, 73137C1 Seep Springs, 73138A1-2 Smith Spring, 73138D11 Rancho Madrid, 73141H4 Tres Papalotes, 73142A8-9 Bofecillos Canyon, 73143A4 lower Tapado Canyon, 74292B7-9 upper Chorro Canyon, 74293A5 lower Chorro Canyon.

This species is frequent throughout the area and is often abundant at seeps, where it drinks interstitial water from wet silt. Foodplants of the mesquite blue include species of *Prosopis, Acacia, Albizzia, Indigofera, Melilotis, Desmanthus,* and *Dalea.*

Leptotes marina Reakirt, 1868. 73138D12 Rancho Madrid, 73141H5-7 Tres Papalotes, 73142A4-7 Bofecillos Canyon, 73143A5-6 lower Tapado Canyon, 75159A1 Tres Papalotes, 75162B2 Lefthand Shutup.

The marine blue congregates at seeps to drink on moist earth. The larval foodplants include species of *Astragalus, Plumbago, Dolichos, Galactia, Medicago, Phaseolus,* and *Lysiloma.*

Icaricia acomon texanus Goodpasture, 1973. 73143A3 lower Tapado Canyon, 75160A2 south slope Solitario Peak, 75161C4,10 Middle Tank.

Colonies of this species are very local and scattered in arid country and are associated with the larval foodplant *Eriogonum albertianum.*

Family HESPERIIDAE

Cogia hippalus Edwards, 1882. 73142A10-11 Bofecillos Canyon.

This species of Chihuahuan and Sonoran desert distribution, was found drinking at moist earth in the shade of cottonwood trees. The larval foodplant is unknown but related species utilize *Acacia* spp. and *Mimosa* spp.

Systasea zampa Edwards, 1876. 73143A7 lower Tapado Canyon.

This species of the Sonoran and Chihuahuan deserts flies along dry washes, where some of its larval foodplants grow. These are various species of Malvaceae.

Erynnis funeralis Scudder & Burgess, 1870. 73136A3 Solitario rim west of Solitario Peak, 74293A1 lower Chorro Canyon.

This widespread species of dry, disturbed open areas is quite variable in size. The unusually large October specimen from Chorro Canyon was found, upon dissection, to be this species. Known larval foodplants are species of *Lotus, Olneya, Robinia, Vicia, Indigofera, Geoffroca, Medicago,* and *Nemophila.*

Celotes limpia Burns, 1974. 75162A14 Fresno Peak.

This streaky skipper is endemic in West Texas and Coahuila. It is sympatric with the broader ranged *C. nessus* (Sonora to Oklahoma, Arizona to lower Rio Grande Valley). Both fly together at several localities and as larvae feed on various Malvaceae. *C. limpia* has been recorded as utilizing *Abutilon malacum, A. incanum, Sphaeralcea angustifolia* var. *lobata,* and *Wissadula holosericea.* In the Davis Mountains larvae of both species have been found on the same foodplant. *C. limpia* appears to occur at higher elevations and *C. nessus* at lower elevations beyond their zone of sympatry. Other records from this area are Kendall 29-31 August 1966, 1, 4-11, 17, 29 September 1966 on Ranch Road 170 15 mi SE of Redford (gulch west of Panther Canyon), and Lennox 26 March 1966, same locality.

Pyrgus communis Grote, 1872. 73143A sight lower Tapado Canyon, 75161C13 Middle Tank.

This species is widespread in disturbed areas where the larval foodplants grow. These are species of *Abutilon, Althea, Anoda, Callirhoe, Hibiscus, Malva, Sida, Sidalcea,* and *Sphaeralcea.* The single specimen is of the typical form but in the hot season the polymorphic var. *albescens* Plotz, differing in genitalic structure, is to be expected.

Copaeodes aurantiaca Hewitson, 1868. 73137C2-3 Seep Springs Draw, 73138C2 lower Chorro Canyon, 73140E1 Gray's Ridge gulch, 74292B11-12 upper Chorro Canyon, 74293A4 lower Chorro Canyon, 75160A10 gulch north of Solitario Peak, 75161C16 Middle Tank, 75161A1 south slope Solitario Peak.

This common orange skipperling is known to feed as larva on *Cynodon dactylon* elsewhere. Here it is associated with tall grasses in the heads of gulches and around springs.

Hesperia pahaska williamsi Lindsey, 1940. 73137B8 Seep Springs summit.

This skipper is found on high grasslands of Sonora, southern Arizona, Chihuahua, and western Texas. The foodplants are grasses.

Amblyscirtes oslari Skinner, 1899. 75161C2, 11, 12 Gray's Ridge gulch.

This is a species of bluff shrubland sites in prairie regions and ranges from Arizona to Saskatchewan, North Dakota, to North Central Texas (Baylor County). It is at the limits of its known distribution here. The single colony found in the Solitario is associated with the only pocket of *Quercus mohriana* (also a species of the southern plains) relict here. The life history is unknown, but the larval foodplants of its closest relatives are grasses.

Atrytonopsis ovinia edwardsi Barnes & McDunnough, 1916. 73138D13 Rancho Madrid.

This species was seen occasionally in the more rugged gulches of the Solitario. It ranges from Arizona to Coahuila (Serranias del Burro), and in Texas is known from the Guadalupe, Davis, and Chisos mountains, ranging south into Mexico.

REFERENCE CITED

Belcher, R. C. 1975. The geomorphic evolution of the Rio Grande. *Baylor Geological Studies* 29:1-64.

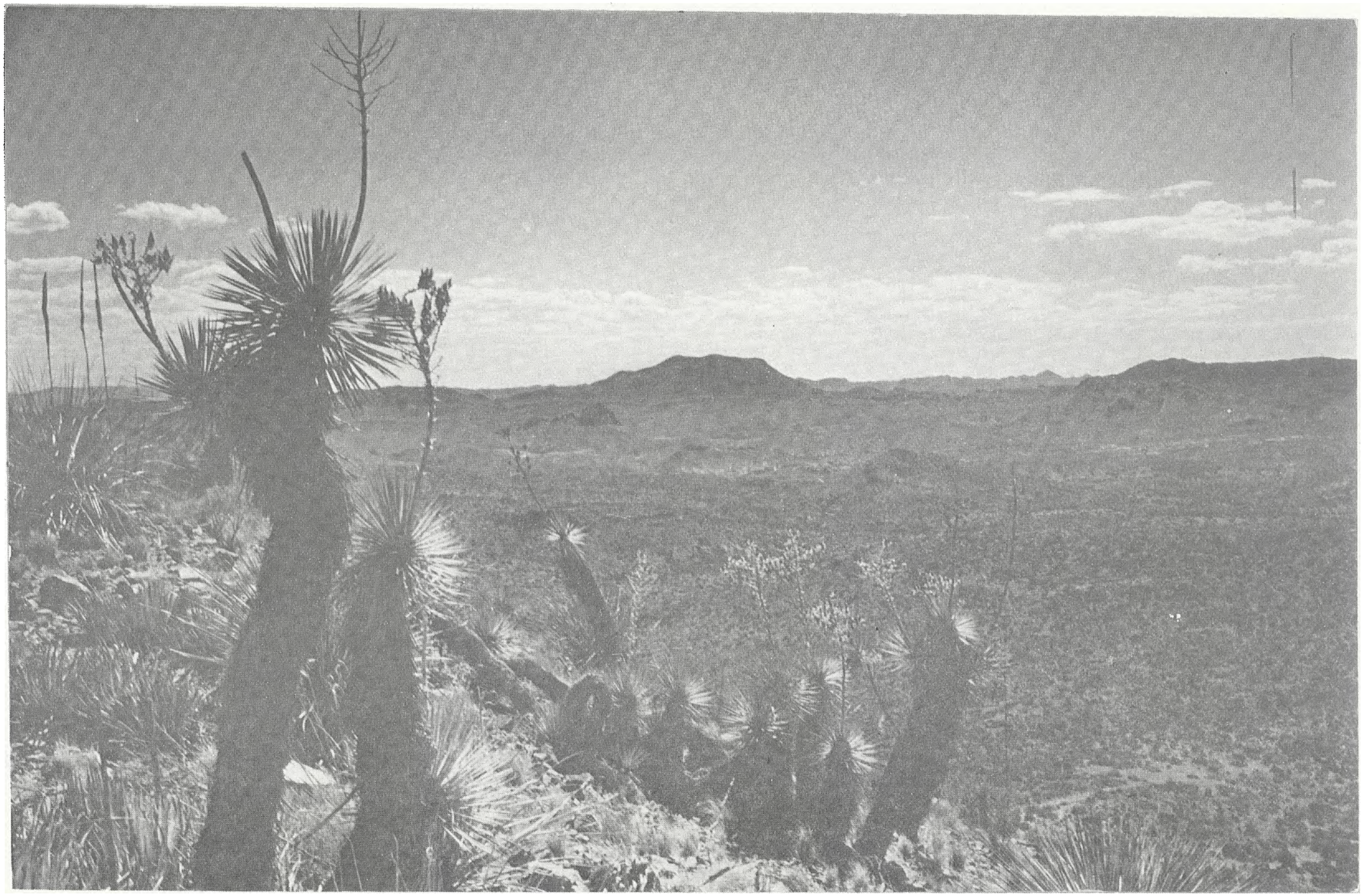


FIGURE 1
View of the interior of the Solitario looking southwest from the northern rim.
Solitario Peak is the dark igneous plug in center interior with Fresno Peak behind on the horizon.

A PRELIMINARY ARCHEOLOGICAL RECONNAISSANCE OF THE SOLITARIO

William R. Hudson, Jr.

INTRODUCTION

Environment

Lying within the Chihuahuan Desert biotic province (Blair 1950), the Solitario and upper Fresno Canyon area is one of the most diverse and, at the same time, undisturbed archeological, biological, and geological areas of Trans-Pecos Texas (Fig. 1). The study area is characterized by an arid climate, lowland and upland environments, broad dry stream beds, boulder choked arroyos, and numerous steep-sided canyons. A low annual rainfall (30 cm) occurs mainly during the late summer months and brings with it severe flash flooding (Carr 1967:16). Natural surface water is scarce in the upper Fresno Canyon area and almost nonexistent in the Solitario, occurring only in tinajas, large bedrock depressions that catch and hold rainwater.

Generally speaking, the flora and fauna consist of arid to semiarid adaptive forms, with unusual exceptions occuring in the moist shaded canyons along the Fresno Creek drainage and its tributaries. Especially interesting are the relic plant communities that have survived in these isolated pockets, perhaps from the Pleistocene to the present, and which suggest more abundant moisture in the past. There appear to have been progressive drying and erosion at least in the last 200 years, and several local inhabitants can remember considerably more water available as little as 50 years ago. As a result of less available surface water, vegetation in the Solitario is not quite as diverse as in Fresno Canyon.

The geologic complexity of the Solitario-Fresno Canyon area provokes more than routine geologic interest. Of particular interest is the Solitario, a nearly circular domal uplift whose eroded core exposes a complexly distorted series of ancient sedimentary rocks. West of Fresno Canyon, volcanic activity and erosional forces have formed a series of lava and ash deposits, some of which contain volcanic glass that was a lithic resource for native, stone-tool using inhabitants. Rapid and recent erosion by tributaries of the Rio Grande has created a rugged and harsh environment that is formidable even to the most hardy individuals.

Erosion in these areas has created numerous rockshelters and overhangs, both at various altitudes and in numerous environmental locations. Of archeological interest, these shelters provide an excellent opportunity for animals and man to escape the harsh daytime summer temperatures and sometimes intense rainfall and provide some of the few spots of all-day shade to be found in the area. Not surprisingly, evidence of human occupation has been found at many of these shelters.

In addition, a wide variety of lithic materials suitable for tool production is found in the study area. These occur both as outcrops and as water-deposited cobbles. Geologic formations within the Solitario are primarily sandstones, shales, and chert in the northern part of the basin, and volcanic ash dominates in the southern basin. Fresno Creek is characterized by essentially volcanic formations to the west and cretaceous limestone to the east in the rim of the Solitario. This geologic diversity of Fresno Canyon, although much less than in the Solitario, presents few differences in formations suitable for rockshelters and increases the variation of lithic materials available for chipping, especially on the western side of Fresno Creek.

The Solitario and upper Fresno Canyon areas are currently used almost exclusively for ranching activities. Historically, cattle ranching has been predominant, but large numbers of sheep and goats have been grazed in the area with little attention given to range management. This activity during the last 70 years has had adverse effects on the area with overgrazing increasing the rate of erosional processes on open archeological sites. Numerous rockshelters have been used as makeshift pens, disturbing the fill and talus slopes, and ranch hands and visitors to the area continually pick up artifacts of archeological interest and carry them from the sites (Ralph Hager June 1975: personal communication).

Previous Archeological Investigations

For the purpose of this report it will not be necessary to give a detailed account of all the previous archeological investigations that have been conducted in Trans-Pecos Texas as this information is available in several current manuscripts (Story and Bryant 1966; Campbell 1970; Marmaduke 1975). A brief summary of the more significant data will suffice.

Perhaps the earliest intensive work was performed by the West Texas Historical and Scientific Society of Alpine in the 1920s when over 200 sites were recorded, all within a 100-mile radius of Alpine (Fletcher 1931; Smith 1931). Victor Smith of Alpine was instrumental in this effort and contributed several publications on work he carried out in the area (Smith 1927, 1931).

Later work by Frank M. Setzler (1935) of the Smithsonian Institution also contributed to the general knowledge of the area. His investigations were conducted at a time when the Pecos Classification System for the southwestern United States was in its developing stages. The system was based primarily on information from the Four Corners area and the upper Rio Grande, and Setzler and others noticed obvious similarities between Basket Maker remains from dry rockshelters in the southwestern United States and materials found in the dry shelters in Trans-Pecos Texas. They naturally attempted to equate the two areas.

Realizing the complexity of the southwestern area, E. B. Sayles (1935) defined new terms for Trans-Pecos Texas, and, using information gathered primarily from excavated rockshelters, constructed the first chronological framework for the area.

Sayles' sequences were later modified by J. Charles Kelley who, with the help of geologists Claude Albritton and Kirk Bryan, recognized stratigraphic geological evidence for new cultural units based on a series of sites buried in the alluvial valley fill of the Alpine area (Albritton and Bryan 1939). Kelley, T. N. Campbell, and Donald J. Lehmer (1940) elaborated on this system as a result of extensive field work done in the late 1930s.

Probably the most important and useful work conducted during the early stages of Trans-Pecos archeology was the recording of numerous pictograph and petroglyph sites by A. T. Jackson (1938) and Forrest Kirkland (1967). Since these archeological resources are in an extremely fragile state and are in constant danger of being destroyed, it is fortunate that these two men provided such detailed descriptions of their findings.

Current investigations in Trans-Pecos Texas have added greatly to the body of knowledge of the area, especially the southeastern portion. Here, as a result of the construction of Amistad Reservoir on the Rio Grande in the vicinity of the Pecos River, much research has been accomplished, mainly in the early 1960s. Excavations in both open terrace sites and rockshelters have produced stratigraphic sequences of lithic tools that, together with radiocarbon dates, provide general time markers, primarily represented by projectile point types. This tool type is extremely durable and occurs on most sites in addition to exhibiting considerable morphological change through time (Story and Bryant 1966:9).

In 1967 and 1968, T. N. Campbell conducted an archeological survey of Big Bend National Park (Campbell 1970). Numerous sites were recorded, but no excavations were performed, and Campbell felt no reason to revise the classification system that he formulated with Kelley and Lehmer in 1940.

Although work has been done in many areas of Trans-Pecos Texas, numerous large areas are still unexplored from an archeological standpoint. Much of the early archeological work has been poorly documented by current research standards, and almost all of the data comes from shelter sites. Dry rockshelter situations do provide an invaluable amount of information because of excellent preservation of perishable materials, but there has been a definite lack of work conducted on other important types of sites (for example, the numerous large, open terrace sites) to determine their place in the cultural framework of the area.

Little archeological information exists on the area of the Solitario and upper Fresno Canyon, and, although the prehistory there is probably related to a trend that appears to be common throughout Trans-Pecos Texas, local variations do exist. The only information available prior to this present survey was 15 archeological sites located by the General Land Office in May 1973, five of which are in the Solitario and 10 in upper Fresno Canyon. The sites represent utilization of several different habitation areas including prehistoric rockshelters, open terrace sites, and historic ranch sites. Other than this cursory survey, there has been no other work in the area.

To date, the most useful chronological study has resulted from work in the Amistad Reservoir area (Story and Bryant 1966). Although tentative, it is of tremendous value in the archeological interpretations of Trans-Pecos Texas. A simplified table of the time periods and dates, in which projectile points have been used to characterize eight time/culture periods, is shown in Table 1.

Field Procedures

Of primary concern in any archeological field research is the location of prehistoric and historic sites with emphasis on describing the characteristics of the sites and their environmental surroundings. A site here can be defined as any location occupied, utilized, or exploited by a prehistoric group. Several examples of the types of sites that might be found

TABLE I

Tentative Chronology in Amistad Reservoir from Story (1966)

Period	Estimated Date	Characteristic Projectile Point Designs
VIII	A.D.1600-?	metal arrow points
VII	A.D.1000-A.D.1600	cliffton, toyah, perdiz
VI	200B.C.-A.D.1000	ensor, frio, paisano, and figueroa
V	1000B.C.-200B.C.	montell, castroville shumla, marshall, and marcos
IV	2500B.C.-1000B.C.	langtry, val verde, and almagre
III	4000B.C.-2500B.C.	nolan and pandale
II	7000B.C.-4000B.C.	gower-like, early barbed bifurcated stem, and uvalde
I	?-7000B.C.	plainview, plainview golondrina, lerma, folsom and angostura

during a survey include: village sites, campsites, quarry sites and flaking stations where raw materials are gathered for tool production, butchering and kill sites, and plant processing sites. Usually not all types of sites are represented in any one survey, so it is important to become familiarized with any previous research conducted in the study area. The archival research should include a preliminary environmental study of the area as well as inspection of detailed topographic maps to help determine the archeological potential of any landforms.

Ideally, study areas should be surveyed according to systematic sampling procedures. However, in this case it was not feasible, a difficulty characteristic of most archeological surveys. Again, detailed topographic maps can help determine what areas should be covered, given the time limitations under which work has to be accomplished, and were invaluable aids in planning this project.

On this particular survey, two physiographic areas were being studied, the Solitario with its moderately steep-sided mountains, basin floor and choked drainages, and upper Fresno Canyon, a major stream drainage with broad alluvial and colluvial terraces, steep-walled tributaries, and numerous spring locations. Our approach has been to examine intensively all major drainage and spring areas with spot-checking on other topographic locations such as mountain tops, canyon rims, flat uplands, and ridges. It is obvious from previous archeological endeavors that most prehistoric archeological sites have a close proximity to a water source, so our efforts were concentrated in these areas. Unfortunately, time precluded the coverage of much of the upland areas, but we were able to visit briefly most of the topographical and environmental settings in both areas.

The best method for locating sites proved to be traversing the land on foot. The terrain was such that vehicular travel was limited to several jeep trails through the areas. Once a site was discovered, its exact location was established on U.S.G.S. 7.5-minute topographic maps and site survey forms were completed. These include such data as site description, nearest water location, pertinent geological information, etc. In addition, detailed sketch maps were completed, along with descriptive notes, and photographs were taken of each site and of any special features or artifacts observed. All sites were given temporary identification numbers in the field, and were later assigned permanent numbers using the trinomial system employed by The University of Texas at Austin. Thus, 41PS35 indicates that the site is in Texas (41), in Presidio County (PS), and is the 35th site recorded in that county. Site survey forms and photographs are filed permanently in the Office of the State Archeologist, Texas Historical Commission, and at the Texas Archeological Research Laboratory, Balcones Research Center, both in Austin, Texas.

Since the primary concern of this initial reconnaissance was site locations, no surface collections were made and no subsurface testing was performed. Although many of the sites located during the survey showed evidence of pothunting, there were areas on these sites that remain undisturbed, and many sites have not been discovered by local relic-hunters. Any collecting essentially destroys a part of the site, so, in order not to further disturb these sites, all cultural debris has been left intact. Photographs and descriptions are provided for those artifacts that show a reasonably clear indication of function, age, or possible cultural affiliations. Much can be learned from controlled surface collections and it is suggested that statistically viable controlled collecting and subsurface testing be the next step in determining the importance of the prehistoric archeological resources of these areas. Both the Solitario and Fresno Canyon are relatively isolated areas and are protected from many of the destructive forces that occur to archeological sites. However, in light of active pothunting in the area, all sites are in immediate danger of being destroyed.

In an effort to determine the availability, use, and source of lithic materials for tool production, comparative samples were taken from various sites, stream beds, and outcrops. The collections will help define the use of natural resources in the area and possibly determine any contact or foraging into other areas for desirable raw materials. Data derived from this analysis is presented in the section on site descriptions.

SITE LOCATIONS

Perhaps for as many as 10,000-12,000 years, the Solitario and upper Fresno Canyon areas have been inhabited by prehistoric peoples, and evidence of their presence is exhibited in the numerous sites located in the study area. Of the 46 sites recorded during the survey, 19 are located in the Solitario, 22 in the upper Fresno Canyon area, and five in the shutups (the constricted arroyos) that drain the interior of the Solitario. For discussion and comparative purposes, sites have been placed into these three physiographical categories, each of which exhibits sites with noticeable differences in location, size, vertical depth, and in some instances, artifactual materials.

Sites in each of the three areas have been further categorized according to their topographic location. Those in the Solitario include gravel terrace sites and unusual location sites. Sites in upper Fresno Canyon consist of silt terrace sites, gravel terrace sites, canyon rim sites, ridge sites, and rockshelter sites. Only rockshelter sites were observed in the shutups.

Additional site information is available in the companion volume on Fresno Canyon (Hudson 1976) and in Appendix 1, a chart made for the purpose of conducting preliminary comparisons between sites. This chart is based entirely on surface observations.

The Solitario

Of the 19 prehistoric sites recorded in the Solitario, 13 are open sites and six are rockshelter sites. The open sites occur primarily on the colluvial gravel terraces that fill much of the basin floor of the Solitario (Fig. 2). Fine-grained fluvial deposition commonly associated with perennial drainages and rivers is not present in the Solitario. Erosion occurring along the inside rim of the Solitario has contributed great quantities of angular colluvial fragments to the basin deposits, and fluvial deposits are very coarse gravel with a limited quantity of sand and silt-sized material in the matrix. The formation of silt terraces is rare, and those that are present occur at low elevations above the stream bed and are not conducive to habitation because of flood danger.

Although natural surface water occurs in the Solitario only for short periods after rains, at the time of the survey all open sites appeared to be situated in close proximity to either dry arroyo systems or intermittent spring areas. These dry water systems have been designated hypothetical aboriginal water sources on the grounds that they may have been more permanent at the time of occupation. The springs in the area are active after heavy rain periods and are recognized by deposits of travertine and heavy vegetative growth in the immediate area.

Of the 13 open sites recorded in the Solitario, 10 are located on gravel terraces. Except for Site 41PS144, all of these sites appear to be surface manifestations and are characterized by a scatter of lithic tools and debitage and occasionally fire-cracked rocks scattered about, both on the surface and in the midden. Bisecting the eastern portion of the site is a jeep trail which, due to bulldozer activity, provides a good view of the soil profile. Artifacts observed on the surface and eroding out of the road cut include several whole and fragmentary projectile points, marginally trimmed and bifacially trimmed chert tools, and two fragments of large basin-shaped metates. One small fragment of shell was located on the surface, although its association with the site is questionable. There is a burned historic structure approximately 100 m to the south which could be the source of the shell. Unlike the other gravel terrace sites which have been deflated by erosion, Site 41PS144 is situated at the base of several high limestone knolls, and soils and gravels eroding from these hills have covered and stabilized areas of the site.

Among the other gravel terrace sites, 41PS151 deserves special attention, primarily due to its large size and dense lithic scatter. Covering approximately 30,000 square meters, it is the largest site recorded in the Solitario, and, although all artifacts are exposed, it could provide invaluable information if a systematic and controlled surface collection were performed. Being exposed and in close proximity to a jeep trail, the site has been subjected to surface collection by local relic-hunters; however, much of the debris appears to be intact. Artifacts observed include numerous chipped stone implements, projectile point fragments, concentrations of debitage, mano and metate fragments, and scattered concentrations of fire-cracked rock. See Appendix 1 for further information on this and other sites in the Solitario.

Because of their topographically unique locales, three sites, 41PS149, 41PS152, and 41BS476, are designated as "unusual location sites" (Appendix 1). This term was coined primarily to avoid the use of confusing categories for defining site locations by landform.

Site 41PS149 is situated on a prominent sandstone knoll in the western interior basin of the Solitario and is characterized by a thin lithic scatter spread over approximately 100 square meters. Most of the lithic debris appears to be debitage resulting from knapping activities, and few implements were observed that exhibited marginal trimming or use-wear patterns. A jeep trail bisects the site but causes little damage to the artifact distribution. The site is entirely on the surface, and artifacts and debitage are eroding down the sandstone slope into a dry arroyo. It is difficult to

FIGURE 2

Northwest interior of the Solitario looking at northern rim. Notice large dry drainage and surrounding gravel terraces. Vegetation is primarily creosotebush. This drainage is flowing into the Lefthand Shutup, the head of which is just out of the photo to right.

determine the function of the site, but it may have been a resource area where sandstone was gathered for grinding purposes. Sandstone can be seen eroding from the outcrop in tabular form, some of which appears suitable for use as metates. The geological formation is known as Dagger Flats Sandstone.

Also situated on a sandstone outcrop is Site 41PS476. Limestone knolls of cretaceous age surround the site and give its locale the shape of a small basin with several small arroyos draining the area to the north. The rocks exposed at the site are in the Tesnus Formation, and the dark brown sandstone visually contrasts with the surrounding buff-colored limestone knolls. Chipped stone materials, primarily of light gray chert and white novaculite, are easily visible on the surface of the site. There appear to be two concentrations of these artifacts, most of which show signs of intentional modification to their edges. Also observed among the artifact inventory was an unusually high frequency of thick, triangular to subtriangular, gougelike tools, vaguely similar to a tool type known as "Clear Fork Gouges" described by Epstein (1969:39-42).

It is interesting to note that few unutilized flakes and chips were observed and that most artifacts exhibited edges trimmed and shaped by pressure-flaking instead of use retouched. This unusual tool inventory, coupled with the fact that all the lithic materials were transported to the site, suggests exploitation of a particular natural resource, possibly in association with the sandstone outcrop. What it may have been is unclear at this time. The sandstone is eroding out in small fragments which seem unsuitable for grinding purposes, and no changes in vegetation between the sandstone area and the surrounding limestone hills were noticed.

The third unusual location site, 41PS152, is situated on a low saddle between two cretaceous limestone hills. There is a thin scatter of chipping debris mixed with the limestone fragments eroding from the surface, and most of this debitage appears to have been associated primarily with chipping activities at the site. Few flakes and chips show signs of post-detachment modification, and, other than the chipping debris, no cultural or diagnostic materials were observed. South of the site approximately 200 meters is a large dry streambed draining a large portion of the eastern interior of the Solitario. From the site excellent views are afforded to both east and west along this streambed.

Of the 19 sites recorded in the Solitario, six are located in rockshelters. The term rockshelter is used here as an inclusive term meaning any sheltered site (cave, rock overhang, etc.). Before describing particular sites, it is necessary to discuss some general observations made on shelter-containing geologic formations.

1) Limestone: Although generally poor conditions exist, such as severe spalling and flakiness, the local limestone does contain shelters formed both by ground water solution and wind-driven rain. Occurring at varying altitudes within the Solitario, such shelters are generally small, but may contain evidence of human occupation, such as fire-blackened ceilings and lithic debris scattered about the talus slope. The inside walls of limestone shelters are prone to spalling, greatly reducing chances for locating pictograph sites if they exist.

2) Tuff: Caves in consolidated tuffaceous bluff-forming sediments occur. These shelters are found in tuffs that are both homogeneous and occasionally in tuff conglomerates. Tuff conglomerates consist of hard fragments of predominantly igneous rock in an easily weathered matrix of tuff, which leaves fragments of shale, chert, and various kinds of igneous rocks in relief. Weathering of both types of tuff tends to destroy pictographs quickly, and, like the local limestone, the unwelded tuff tends to spall and flake easily. Tuffaceous outcrops are not widespread but occur primarily in the central and southern portions of the Solitario.

3) Conglomerates: A massive conglomerate (the Shutup Conglomerate) occurs at the base of the Lower Cretaceous section in the Solitario and is prominent in the northeast, north, and west part of the Solitario basin. Shelters also occur in this formation. The conglomerate is composed of small to medium rounded pebbles cemented together in a matrix that does not spall and fracture to the degree of the local limestone and tuff formations. Pictographs, should they occur in the Solitario, are more likely to be preserved in the Shutup Conglomerate.

Because of dry, stabilized conditions in rockshelters, much of the perishable cultural materials (textiles, pictographs, bone, shell, coprolites, etc.) are preserved for long periods of time. Excavations at these unique sites have provided invaluable information that is unobtainable from open sites, so their archeological importance is obvious. Three of the six sheltered sites in the Solitario contain middens with considerable depth inside the sheltered area. One of these, Site 41BS477, has been severely vandalized; however, several small areas of the midden remain intact. This site, located beneath a limestone overhang, is characterized by dark gray, ashy soil with numerous fire-cracked rocks littered about the talus slope. There is an abundance of chipped stone artifacts and debitage in addition to numerous bone fragments, some of which show signs of utilization. Unfortunately, pothunters have destroyed a major portion of the midden by uncontrolled digging.

The midden in Site 41PS145, although not very deep, is fortunately intact. This small shelter, situated in a limestone outcrop on the side of a large igneous hill in the central basin of the Solitario, may have been used for purposes other than habitation. It is a considerable distance from any major drainage system and no evidence of springs past or present was observed in the area. Access to the shelter is difficult and is gained by climbing a steep slope over loose angular rocks. The shelter is quite small, and cultural debris in the midden and on the talus slope does not appear to be very extensive. The ceiling is heavily smoke-blackened and no recent spalling has occurred. This site offers good views of the eastern and southern interior basin.

The largest and best-preserved site to be found in the Solitario is Site 41PS150. Located in an unwelded tuffaceous conglomerate outcrop in the central basin (Fig. 3), this site is actually a series of shelters, two of which show extensive signs of habitation. The surface around the shelters is littered with chipping debitage, fire-cracked rock, and ground-stone implements, probably used for grinding seeds and plants, are numerous (Fig. 4). These include manos, large basin-shaped metate fragments, and six bedrock mortars located in the tuff outcrop. Two small "pot-holes" are present in the largest of the shelters, and the site probably has been surface collected by local relic-hunters. Approximately 90% of the site remains intact. Twenty m to the west is a major streambed which, though presently dry, may have carried water at the time of occupation. The site affords excellent views of the southern interior basin of the Solitario (Fig 5).

The three remaining sheltered sites in the Solitario will be mentioned briefly. Site 41BS479 is a conglomerate site near the head of the Lefthand Shutup. Large quantities of chipped stone, burned rock, and ground stone fragments on the talus slope below the site indicate that the site has received considerable use. No cultural debris was found inside the shelter as the floor is exposed bedrock. Smoke-black covers the entire ceiling.

Another small shelter, Site 41PS148, is located in a limestone bluff in the western interior of the Solitario. This site contains little in the way of cultural debris; a smoke-blackened ceiling and several chert flakes are the only indications of human habitation.

Interesting to note is the formation in which Site 41PS148 is located. This limestone is one of the few within the Solitario with chert nodules eroding out of it (Fig. 6 and 7). These can be seen throughout the limestone, and those within easy reach of the shelter entrance have been chipped away, more than likely by occupants of the shelter. This is the only quarry site observed within the Solitario that yielded quality flint nodules. Limestones are rare within the Solitario but most on the rim contain abundant chert.

Site 41BS478 is a small shelter situated on a small hill in the eastern portion of the Solitario rim. The only evidence of human occupation observed was smoke-black on portions of the ceiling.

It should be noted here that large areas of the Solitario have yet to be surveyed, and it is likely that many more shelter sites as well as open sites exist within this area. It is to be hoped that more intensive investigations will be conducted in the near future.

The Shutups

There are four major drainages from the interior of the Solitario. These are characterized by steep-sided, constricted passages cut by stream action into the rim of the Solitario (Fig. 8), and, during periods of wetness, large quantities of water flow through them. The Lefthand Shutup, cut through the northeastern rim drains the northcentral and eastern part of the interior; the Righthand Shutup, through the western rim, drains the northwestern part of the interior, and the Lower Shutup drains the central and southern half of the interior through the southern rim. Los Portales Shutup drains the western interior slopes through the western rim.

As mentioned, great quantities of water periodically rush through the shutups as the result of heavy rains and extremely rapid run-off. This usually occurs during late July and August. All of the shutups were traversed on foot by the survey party, and all were found to be passable with little difficulty, the Lefthand Shutup being the easiest since there is a less dramatic change of elevation per mile. It is interesting to note that the shutups present the easiest and most direct routes of Solitario entrance and egress, much easier than the steep-sided rim that, except for some of the northern parts, completely surrounds the Solitario.

Because of the topography of the shutups, the only locales suitable for occupation within them are rock-shelters that occasionally occur in the walls overlooking the streambed. Typically, most of these shelters are small with little room for a person to move about other than in crouching position.

Five archeological sites were located in the shutups: Sites 41PS49 and 41PS153 in the Lower Shutup; Sites 41PS154 and 41PS155 in the Righthand Shutup; and Site 41PS480 at the mouth of the Lefthand Shutup. This last site is not typical of the other shutup sites for several reasons. It is situated at the base of a high limestone bluff and is an extremely large

FIGURE 3

View of Unit A, Site 41PS150, looking northwest.
Large shelter is situated under large boulder to right.
Rock is tuffaceous conglomerate.

FIGURE 4

Largest shelter in Site 41PS150.
Note smoke black on ceiling and burned rock and dark stained soil.
Pot hunter's rake is at left.

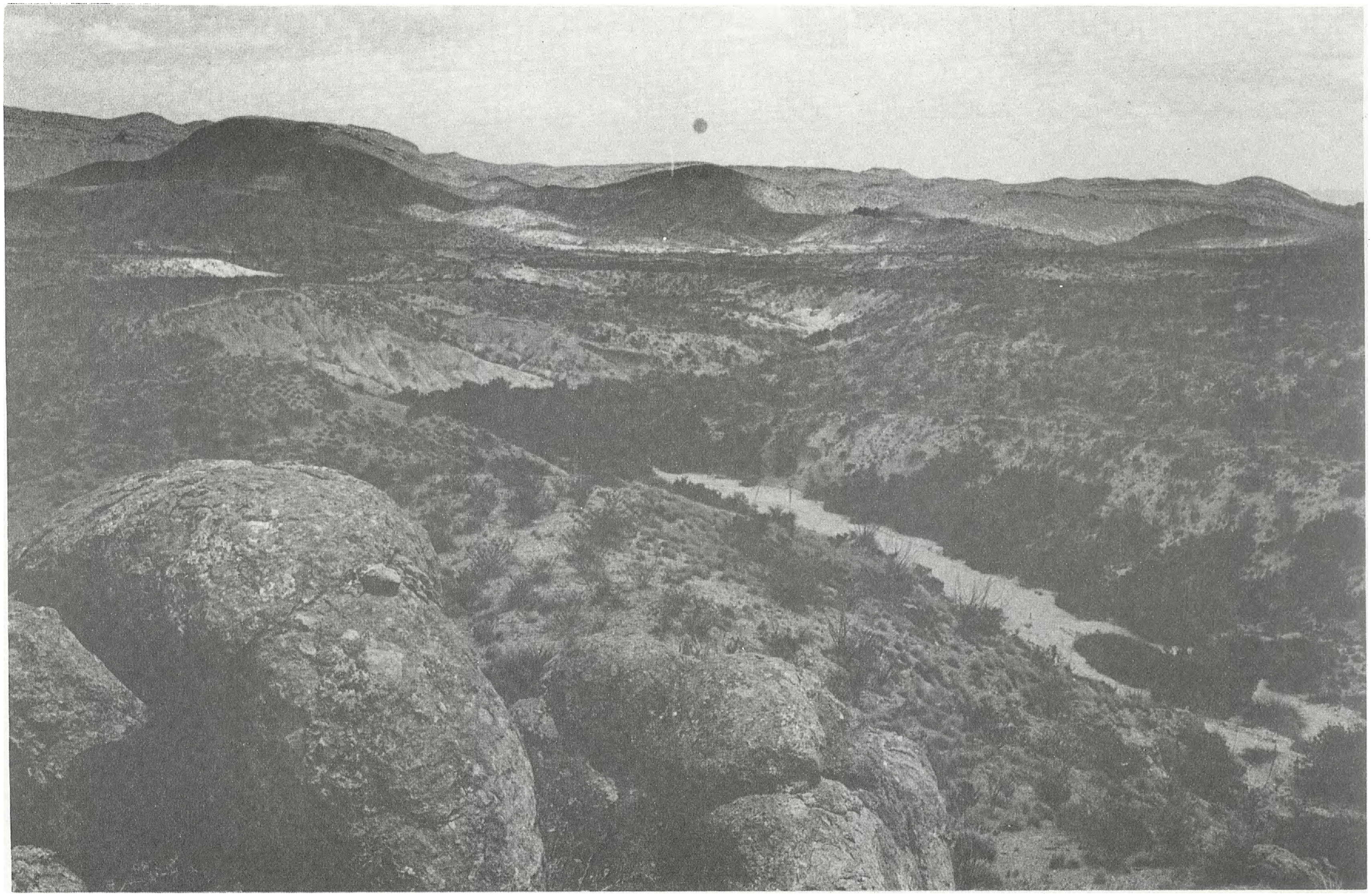


FIGURE 5

View of interior of the Solitario looking south from Site 41PS150.
Dry streambed and intermittent spring area in streambed at center.

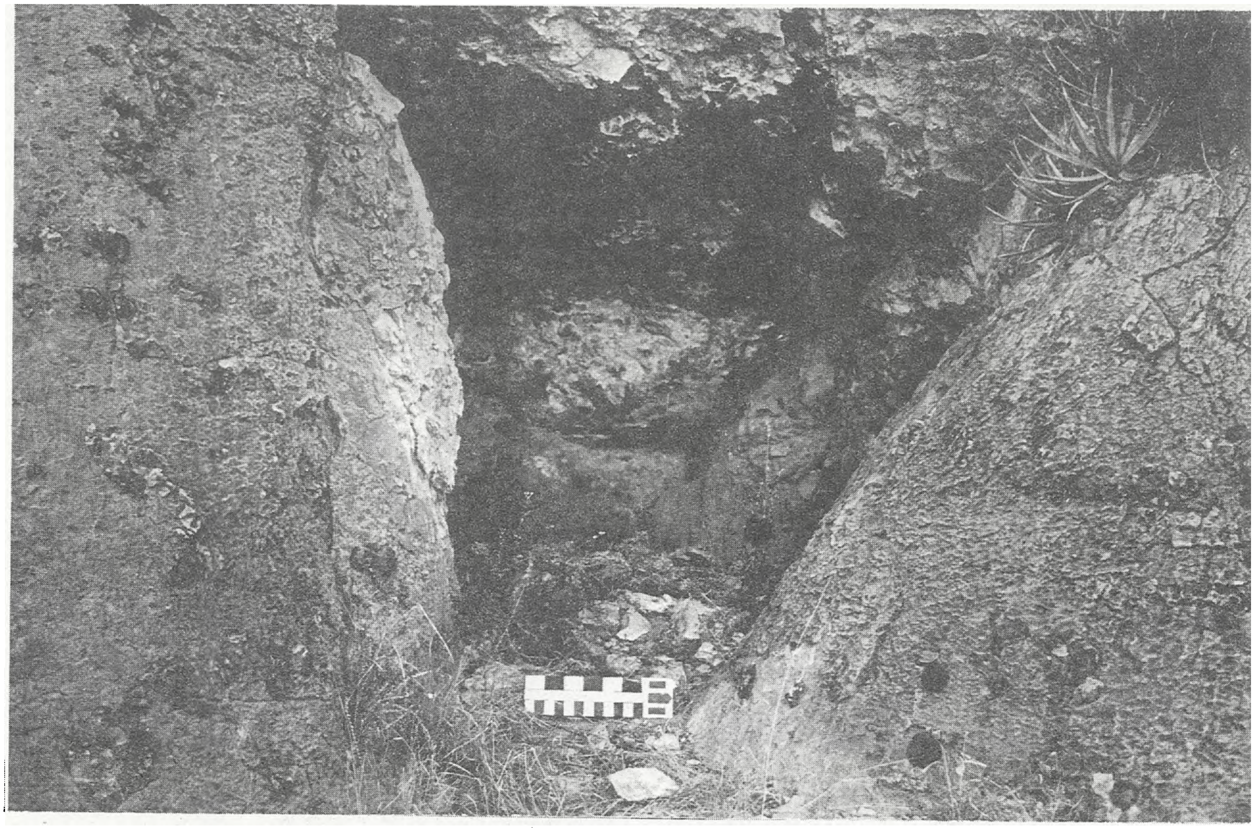


FIGURE 6

Site 41PS148 looking east.
Note chert nodules in limestone and smoke black on ceiling.

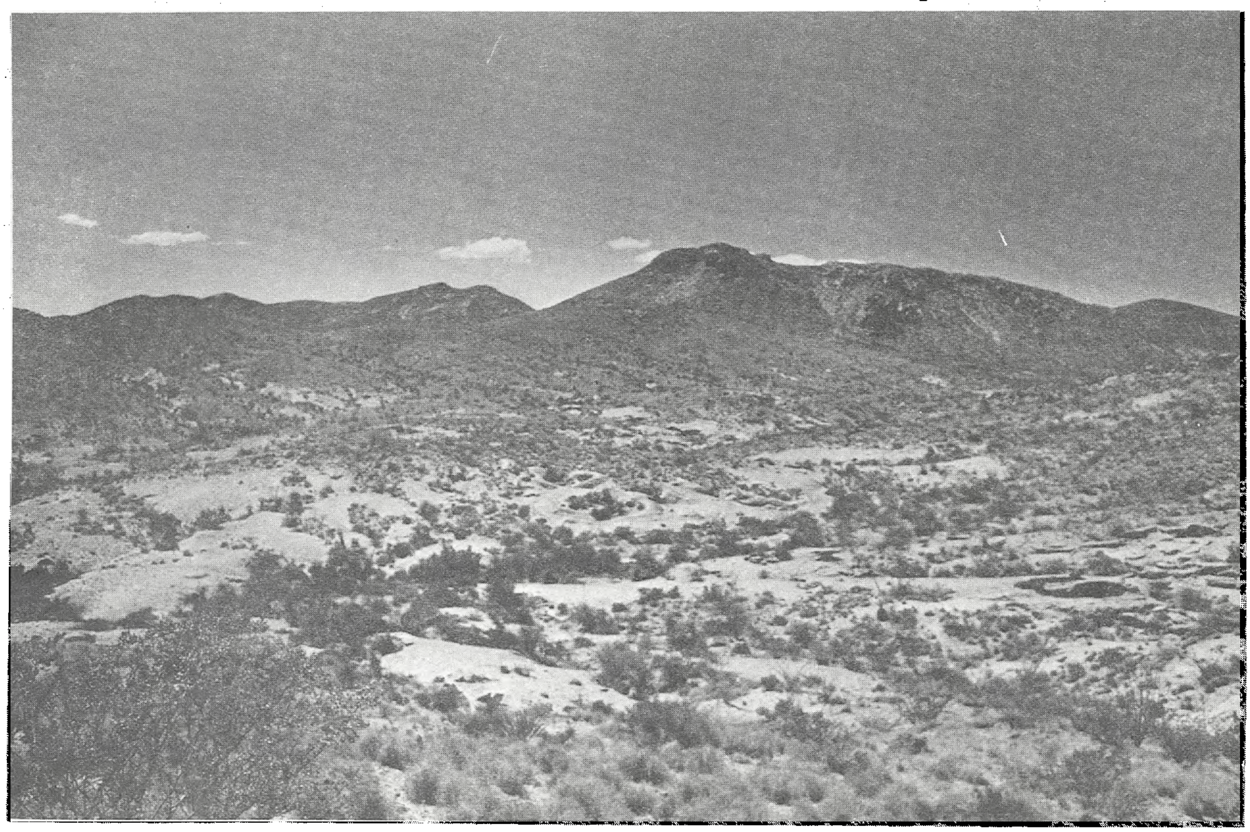


FIGURE 7

View to south from Site 41PS148.
Note tuffaceous outcrop.

FIGURE 8

Looking east into Lefthand Shutup.
Note steep walls of the eastern rim and scoured streambed.

FIGURE 9

Site 41PS480 looking east from mouth of Lefthand Shutup.
Back wall of this shelter covered with obscure pictographs.

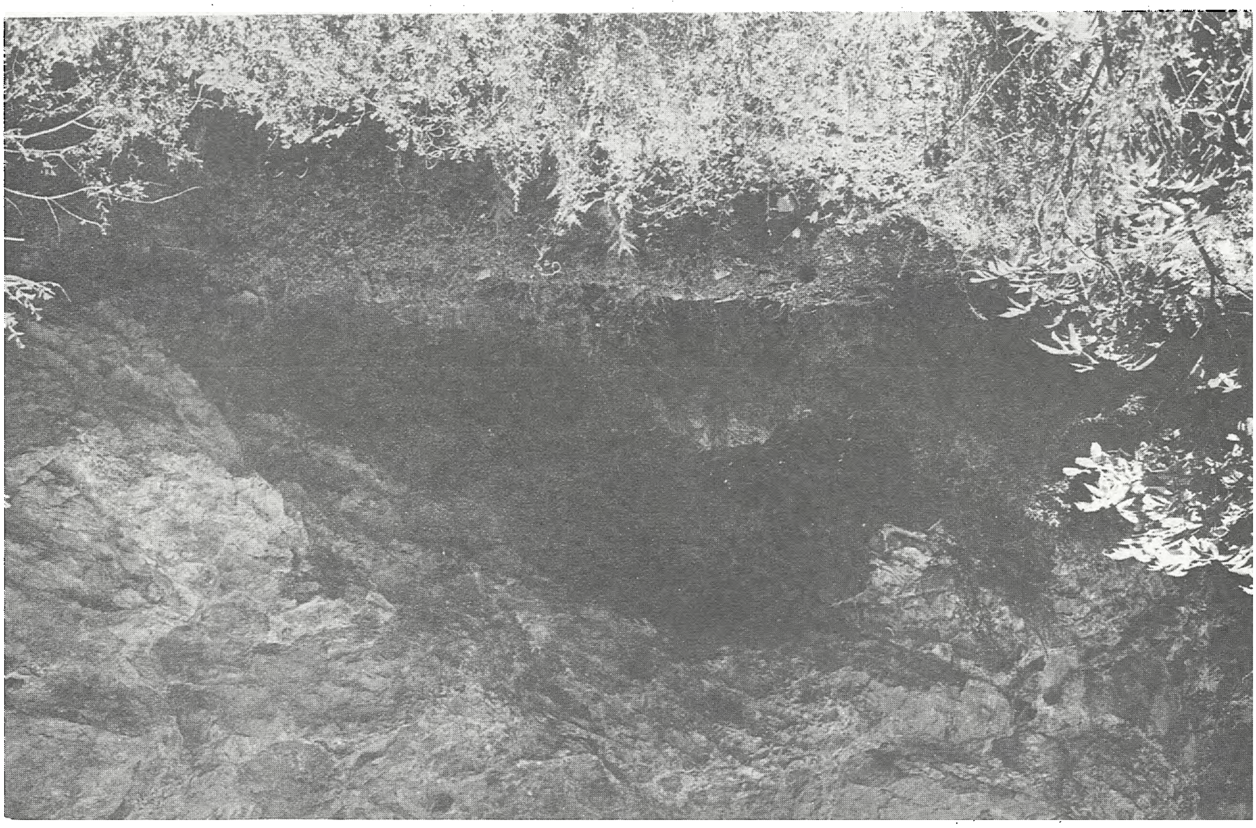


FIGURE 10

Site 41PS49 in Lower Shutup.
Located in Limestone Cliff. Notice dense smoke on ceiling.

shelter, the dimensions being approximately 40 m long by 7 m high by 10 m deep (Fig. 9). Observed in this shelters is a heavily smoke-blackened ceiling, flaking debitage, burned stone, and perishables (sotol, lechugilla, quids, and cane). The entire back wall is covered with obscure pictographs in both red and black pigments. The site is presently being vandalized with numerous potholes observed, but portions of the site are partially protected by severe spalling from the ceiling which has left large limestone blocks on the floor of the cave, preventing vandals from digging.

Sites 41PS49 and 41PS153 located in the Lower Shutup are typical of the shelters found on these drainages. They are characterized by heavy smoke black on the ceiling, little evidence of cultural debris (one chert flake was observed at Site 41PS49), and no talus slope. Site 41PS49 (Fig. 10) is located approximately seven meters above the streambed; however, the walls of the shutup are so narrow that it is probable that the site gets washed out occasionally. Site 41PS153 is situated high on the western side approximately 70 meters above the streambed and is almost inaccessible. Smoke black and one small bedrock mortar are the only evidence of occupation.

Similar to the sites in the Lower Shutup are two others located in the Righthand Shutup. The only evidence suggesting Sites 41PS154 and 41PS155 were occupied is smoke black on the ceiling. Both shelters are small and present little in the way of protection from the elements. Both sites are located approximately five meters above the dry streambed, and the floors in each are covered with silt suggesting periodic inundation. No sites were located in the unnamed drainage south of the Righthand Shutup.

The Lower Shutup, Los Portales Shutup, and the Righthand Shutup drain into Fresno Creek, and the Lefthand Shutup eventually drains into Terlingua Creek, both of which in turn drain into the Rio Grande approximately 16 kilometers to the south.

LITHIC MATERIAL SAMPLE ANALYSIS

Studying the availability and desirability of lithic materials used for tool production is a problem that until recently has not been included in many archeological reports. Much can be learned from such a study, for an understanding of the relationship between prehistoric groups and their environment is of primary concern to all archeologists. Lithic materials are natural resources, and prehistoric people had to know something about those natural resources to extract them and use them. Whether materials are locally available or are obtained elsewhere either directly or by trade may tell something about the social and/or political considerations of a group, such as group movement or trade relations. Identifying the sources of lithic materials and examining the patterns of exploitation may yield information, such as site function, and explain certain site locations, thus making possible more accurate descriptions and reconstruction of prehistoric societies.

The majority of the lithic material used in the Solitario and Fresno Canyon areas can be classified under the general heading of chert. Several variations can be identified and placed into certain parent geologic formations; however, outcrops of these formations are available in numerous places, so it is difficult to determine actual quarry areas. It is possible to make only general statements concerning site location and settlement patterns from this information. Unfortunately, there is no evidence that any of the materials collected in the Solitario and Fresno Creek are from exotic resource areas. All probably can be found in the immediate area. This statement, however, must be considered tentative until a more intensive study can be performed.

Several criteria are involved in the analysis of lithic sample, characteristics, and many of them can be accomplished in the field. Collections of materials are made from sites and also from possible resource or quarry areas in the hope of finding the parent sources of the materials used on the sites. With the naked eye or using low magnification, one can determine characteristics such as color, texture, fossil inclusions, translucency, and bedding and fracture patterns (Blakeman 1975:1).

Solitario

As mentioned before, chert, especially in the Solitario, is so abundant that it is difficult to say where it comes from. We can only determine the source in a general area. In the Solitario the material occurring with the highest frequency is a white siliceous chert known as Caballos Novaculite. Outcrops of this are numerous. It occurs on most of the open, gravel terrace sites, having eroded from the nearby slopes of the chert ridges in the interior of the Solitario. It is likely these materials were obtained from the surface of these sites as well as in outcrop areas. Another chert, the black chert in the Maravillas Formation, occurs below the Caballos Novaculite, and both are found on the sites in raw form. It is interesting to note that both are highly fractured, a property that may account for the consistently small flakes and tools formed from these materials. A third type of chert is a light gray material found in relative abundance and coming from chert nodules eroding out of the Cretaceous limestones in the area. Site 41PS148 (Fig. 6) and a section of the Righthand Shutup were observed as quarry areas for these nodules. The gray chert generally has better knapping characteristics than the novaculite, and many of the larger well-made tools are chipped from this material. Other knappable materials observed on the sites in the Solitario are chalcedony, opalite, and petrified wood, and, although all are to be found locally, no quarry sites were observed.

Food grinding implements are found only on Sites 41PS144 and 41PS150 in the Solitario. Several portable basin and slab metates both of sandstone and unwelded volcanic tuff were observed on these sites. Bedrock mortars in the Solitario were found only in the tuffaceous outcrop at Site 41PS150 (Fig. 3).

Fresno Canyon

Archeological sites in Fresno Canyon (described in more detail by Hudson 1976) offer a wider variety of lithic materials than do those in the Solitario. This may result from the availability of volcanic rocks in the nearby Bofecillos Mountains. Light gray chert is the most frequently used material. No quarry sites were located for this type, but more than likely it is coming from chert nodules in the limestone of the area. In addition to the gray chert, other colors of siliceous chert include brownish and yellowish types. Site 41PS167 is a quarry site for the yellowish variety. Other knappable materials available in the Fresno Canyon area are chalcedony, opalite, limestone, petrified wood, and various colors of agates. All are available locally. Black, red, and black- and red-banded volcanic glass occurs throughout the area at the base of the lava flows (Dwight Deal 1975:personal communication. See also Geologic Section of Fresno Canyon Report). The source was not discovered during the survey, but the abundance of these materials on the sites suggests that it was readily available.

Groundstone implements were observed at many of the large open sites as well as sheltered sites. Materials for these included unwelded tuffs, sandstone, and limestone for the metates, and unwelded tuffs and igneous rocks for manos. Bedrock mortars were observed in both limestone streambeds and in unwelded tuffaceous outcrops.

In summary, it is difficult to determine the actual sources of many of the lithic materials found on sites in the Solitario and in Fresno Canyon. This is due to the geological diversity, the numerous outcrops within the areas, and to the easy availability of the cherts and siliceous volcanic glass.

Specific materials may have been desired for certain purposes, and prehistoric inhabitants in the study area did show a preference for the siliceous and volcanic glass materials. This is obviously a function of the better fracturing qualities of these rocks. Most of the finished artifacts (i.e., projectile points, thinned bifaces, scrapers, etc.) are formed from gray chert and novaculite.

There is also much variation within the major groups of materials. For instance, there are numerous color shades in gray chert and in Caballos Novaculite. To make it even more difficult, these variations in color sometimes occur within each outcrop. Microscopic, and possibly trace element, analysis would be required to determine parent sources for some of these lithic materials, but this is not necessary in such a small area as long as one is dealing with local materials. Only when exotic materials appear on the sites should such an effort be made.

DISCUSSION

Information gathered from archeological sites in the Solitario and upper Fresno Canyon tentatively suggest a long history of cultural occupation. Sites occur in rockshelters, alluvial silt terraces, colluvial gravel terraces, uplands, and constricted canyons, representing nearly all the physiographic and environmental areas to be found in the vicinity.

Although it would be difficult to place these sites in any chronological order at this time, diagnostic artifacts observed on sites suggest at least intermittent occupation over long periods of time. These artifacts, along with the large quantities of chipping debitage found on most sites, suggest that the prehistoric inhabitants in Fresno Canyon and the Solitario probably had an economy based on small-game hunting and foraging, utilizing every available natural resource. Doubtless the inhabitants manipulated their environment to some degree, but, for the most part, the present evidence suggests that they followed what archeologists have termed an Archaic hunting/gathering mode of subsistence. Judging from the homogeneity of the artifact inventory, there seems to have been a persistence of cultural systems based on subsistence patterns that were strongly influenced by the environment. No evidence of domestication of plants or animals has been recorded in the area, and no ceramics usually associated with agricultural societies were found on any sites. The xerophytic climatic conditions and the apparently simple technological level show numerous similarities with the Desert Culture of the western United States which adapted to a similar arid or semiarid habitat (Martin and Plog 1973:69-80).

Likely, these prehistoric inhabitants were formed into small groups of kin-related people whose search for food was almost continuous. Lack of a dependable long-term food source necessarily kept these groups small and undoubtedly kept them moving about seasonally, exploiting different resources at certain times of the year. Like the Desert Culture, they no doubt kept their personal property minimal and portable. It is important to look at these sites within these areas not as entities but as part of a larger settlement system. These sites cannot be explained separately for they fit into a pattern governed by two environments, a social one and a natural one (Plog and Hill 1971:9). Sites are located with respect to natural resources, in addition to being located with respect to each other.

Several hypotheses are suggested by the information gathered from these sites. One is that the Solitario was a special utilization area characterized by limited activity sites, generally of a utilitarian nature, and that temporary forages were made into it by people living outside the Solitario rim to obtain particular foods and/or to gather desirable lithic materials. The present land forms and resources suggest that more desirable and permanent living conditions could have been found in Fresno Canyon, largely because of more reliable water sources. Except for several isolated areas (for example Site 41PS150), the Solitario presently is suitable only for short-term occupation. As presented in the discussion of the Shutups, access into the Solitario is most easily gained through them. Routes coming in from the north are also probable since the rim is less steep in this area.

It can be seen that the Solitario and Fresno Canyon areas are two quite distinct areas. Information in Appendix 1 will help clarify these differences. Some of the distinctions noticed during the survey are that few of the open sites in the Solitario exhibit any vertical depth. In fact, only one, Site 41PS144, shows any depth at all. Also, the rockshelters in the Solitario generally tend to be smaller and show fewer signs of occupation (cultural debris, smoke-black, etc.) than do those of Fresno Canyon. Interesting to note, also, is that no pictograph sites were recorded in the Solitario, while three sites in Fresno Canyon had pictographs. A scarcity of ground stone artifacts was observed in the Solitario also.

All of these observations support the hypothesis that the Solitario was primarily a special utilization area with intermittent water sources. Fresno Creek to the west is a major drainage for the area, and it likely was a more permanent water source.

Chronologically, the only definite dating of any of the sites is Site 41PS169, where the pictographs of men on horseback (see Appendix 2) indicate at least post-European contact. Other than this, no attempt will be made at this time to date any of the sites except to say they range from historic times back possibly as far as 5 to 10 thousand years ago.

RECOMMENDATIONS

In any archeological study the ultimate goals are to produce an accurate description and reconstruction of prehistoric cultures. The preliminary nature of this survey represents a first step towards the realization of these goals. Several tentative suggestions are made here in order to familiarize readers with some of the questions of concern to archeologists while trying to reconstruct past human cultural patterns.

Studies involving prehistoric environmental adaptations are presently being pursued by many archeologists as a means of reconstructing aboriginal societies. With help from scientists of various disciplines, such as botany, biology, geology, and palynology, to name a few, archeologists are able to gather a substantial amount of information with which to work. Questions such as what the environment looked like at various stages of human occupation; what environmental resources were used; how society was organized to exploit these resources, and how the resources affected social organization and site distribution are presently being posed (Martin and Plog 1973:155).

It is difficult to determine the function and chronology of each site when only a general reconnaissance such as this has been performed. It is obvious that much additional work is needed. A preliminary surveys only enables general inferences about prehistoric cultures.

Archeology is a fragile resource that cannot withstand any outside pressures. To alter land forms by construction or to allow relic-collecting (vandalism) on archeological sites will have a detrimental effect on the cultural resources. Archeological sites are nonrenewable resources and a site, once disturbed, is destroyed forever. In a sense, professional archeologists who excavate sites also destroy them; if the information is not properly collected, there is no way to go back with a different approach. If for any reason an excavation or survey is not properly executed, valuable information will be irretrievably lost.

The State of Texas is responsible for conducting organized research on public lands and for protecting cultural resources. Generally, research should be in the form of intensive surface surveys with subsurface testing and subsequent excavations of selected or endangered sites. Stabilization of these sites where necessary also is important. The educational potential of these significant archeological resources should not be ignored but pursued, so that the cultural history of the area may be reconstructed and preserved.

Recommendations for individual sites of the Solitario and the upper Fresno Canyon area are given in Appendix 1. Subsequent work should consist of an intensive on-foot survey with controlled surface collecting and limited subsurface testing to determine the archeological potential of each site. Special attention should be devoted to those areas that were not surveyed, for instance, the numerous ridge tops and uplands in the Solitario and the uplands to the west of Fresno Creek. Also important are the mouths of the Lefthand and the Lower Shutups and the ridges above them. Without adequate information from all environmental niches in both areas, only a small portion of the prehistoric record can be established. The Solitario and Fresno Canyon areas have long been important to the history of the area, geologically, biologically, and culturally. It is to be hoped more intensive research will be conducted to help us understand and more fully appreciate it.

ACKNOWLEDGMENTS

The primary purpose of this archeological reconnaissance has been to locate and describe the archeological resources of the Solitario and upper Fresno Canyon areas in Brewster and Presidio counties, Texas, and to evaluate the desirability and feasibility of a more intensive archeological investigation of these aboriginal sites. This research can help in the development of a more complete record of the cultural history of the prehistoric inhabitants who once occupied the study area.

In the field, much appreciated assistance was provided by Mike Mallouf, archeologist for the Texas Historical Commission, who was present during all of the field work. Success in the field was also made possible by the thoughtful and cooperative assistance of botanists Mary Butterwick and Stuart Strong; zoologists Wayne Hanselka, Jack Burns, and Jim Scudday, and geologist Dwight Deal. Much appreciation goes to Ralph Hager and Joe Mimms of the Big Bend Ranch on whose land the survey was made. Ralph made our stay enjoyable and provided much assistance in locating some of the important sites.

Albert Rubio of Austin deserves special thanks for giving freely of his time to photograph some of the archeological sites in the area.

Also, thanks go to Bob Mallouf and Curtis Tunnel of the Texas Historical Commission who contributed many useful suggestions and criticisms, in addition to editing the final draft of this report. Barbara Walker, also of the Texas Historical Commission, assisted in the editing and did much of the typing.

REFERENCES

Albritton, Claude C. and Kirk Bryan. 1939. Quaternary stratigraphy of the Davis Mountains, Trans Pecos Texas. *Bulletin of the Geological Society of America* 50:1423-1474.

Blair, W. Frank. 1950. The biotic provinces of Texas. *The Texas Journal of Science* 2(1):93-117.

Blakeman, Crawford. 1975. The application of macroscopic analysis to the classification of chert from archeological sites. *Paper presented at the 1975 meeting of the Society for American Archeologists, Dallas.*

Campbell, T. N. 1970. Archeological Survey of the Big Bend National Park, 1966-1967. *Report submitted to the National Park Service by The University of Texas at Austin.*

Carr, John T., Jr. 1967. *The climate and physiography of Texas.* Austin: Texas Water Development Board, Report 53.

Coffin, Edwin F. 1932. *Archeological exploration of a rock shelter in Brewster County, Texas.* New York: Indian Notes and Monographs, Museum of the American Indian, Heye Foundation.

Davis, Emma L. 1963. The desert culture of the western great basin: a lifeway of seasonal transhumance. *American Antiquity* 29:202-212.

Epstein, Jeremiah F. 1969. *The San Isidro Site: an early man campsite in Nuevo Leon, Mexico.* Anthropology Series, No. 7, Department of Anthropology, The University of Texas at Austin.

———. 1963. Centipede and damp caves: excavations in Val Verde County, Texas, 1958. *Bulletin of the Texas Archeological Society* 33(for 1962):1-29.

Fletcher, Henry T. 1931. Some types of archeological sites in Trans-Pecos Texas. *Bulletin of the Texas Archeological and Paleontological Society* 3:7-17.

Hudson, William R., Jr. 1976. A preliminary Archeological Reconnaissance of Upper Fresno Canyon.

Jackson, A. T. 1938. *Picture-writing of Texas Indians.* Austin: University of Texas Publication No. 3809.

Kelley, J. Charles. 1959. The desert culture and the balcones phase: archaic manifestations in the southwest and Texas. *American Antiquity* 24(3):276-288.

Kelley, J. Charles, T. N. Campbell, and Donald J. Lehmer. 1940. The association of archeological materials with geological deposits in the Big Bend region of Texas. Alpine: *Sul Ross State Teachers College Bulletin* 21(3).

Kirkland, Forrest, and W. W. Newcomb, Jr. 1967. *The rock art of Texas Indians.* Austin: University of Texas Press.

Lehmer, Donald J. 1960. A review of Trans-Pecos archeology. *Bulletin of the Texas Archeological Society* 29(for 1958):109-144.

Martin, Paul S. and Fred Plog. 1973. *The archeology of Arizona: a study of the southwest region.* New York: Natural History Press.

Marmaduke, William S. and Hayden Whitsett. 1975. *An archeological reconnaissance in central Davis Mountains, Texas.* Austin: The University of Texas Natural Areas Survey, Division of Natural Resources and Environment.

Maxwell, Ross A. 1968. *The Big Bend of the Rio Grande: a guide to the rocks landscape, geologic history, and settlers of the area of Big Bend National Park.* Austin: Bureau of Economic Geology Guidebook 7. The University of Texas at Austin.

Plog, Fred, and James N. Hill. 1971. Explaining variability in the distribution of sites. In *The Distribution of prehistoric population aggregates,* edited by George J. Gummerman. Arizona: Anthropological Reports 1:7-36.

Redman, Charles L. 1973. Multistage fieldwork and analytical techniques. *American Antiquity* 38(1):61-79.

Sayles, E. B. 1935. *An archeological survey of Texas.* Globe, Ariz.: Medallion Papers, No. 17. Gila Pueblo.

Setzler, Frank M. 1935. A prehistoric cave culture in southwestern Texas. *American Anthropologist* 37(1):104-110.

Smith, Victor J. 1927. Some notes on dry rock shelters in western Texas. *American Anthropologist* 29(2):286-290.

------. 1931. Archeological notes on the Big Bend region. *Bulletin of the Texas Archeological and Paleontological Society* 3:60-69.

------. 1942. Evidence of European influence in the pictographs of west Texas. *Bulletin of the Texas Archeological and Paleontological Society* 14:38-46.

Story, Dee Ann, and Vaughn M. Bryant, Jr. 1966. A preliminary study of the paleoecology of the Amistad Reservoir area. *Final report of research under the auspices of the National Science Foundation.*

Shun, Dee Ann, and Edward R. Jelks (Editors). 1962. *Handbook of Texas archeology: type descriptions.* Austin: Texas Archeological Society Special Publications, No. 1, and Texas Memorial Bulletins, No. 4.

APPENDIX I

PREHISTORIC SITES IN THE SOLITARIO, THE SHUTUPS, AND UPPER FRESNO CANYON
from surface observations only

Site Number	Site Elevation (Above MSL)	Horizontal* Distance From Water (Meters)	Vertical* Distance Above Water (Meters)	Kind** of Site	Occupation Area (Approx. Sq. Meters)	CULTURAL DEBRIS: Perishables	Ground or Pecked Stone	Chipped Stone Artifacts	Fire-cracked Rock	Flaking Debitage	Rock Art	Lithic*** Materials Present on Site	Present Condition	Recommendations
THE SOLITARIO														
41PS141	4550	None (30)	None (10)	GT	1,000	None	None	Yes	None	Yes	None	N, G, M	Construction Damage	No further work
41PS142	4550	None (20)	None (5)	GT	2,400	None	None	Yes	None	Yes	None	N, M	Eroded	No further work
41PS143	4370	None (15)	None (10)	GT	500	None	None	Yes	None	Yes	None	G, N	Partially Eroded	Controlled collection
41PS144	4280	None (3)	None (6)	GT	1,500	None	Yes	Yes	Yes	Yes	None	N, G	Slightly Eroded	Controlled collection and limited testing
41PS145	4490	None (400)	None (65)	SH	75	None	None	Yes	Yes	Yes	None	G	Intact	Controlled collection and limited testing
41PS146	4280	None (15)	None (10)	GT	1,800	None	None	Yes	Yes	Yes	None	N, G	Eroded	No further work
41PS147	4221	None (10)	None (30)	GT	100	None	None	None	None	Yes	None	N, G	Eroded	Controlled collection
41PS148	4480	None (200)	None (40)	SH	15	None	None	Yes	None	Yes	None	G	Partially Eroded	Controlled collection
41PS149	4520	None (20)	None (15)	UL	100	None	None	Yes	None	Yes	None	N, G	Eroded	Controlled collection
41PS150	4440	None (20)	None (30)	SH	20,000	None	Yes	Yes	Yes	Yes	None	N, G, R, B, P, Ch, A	Intact	Controlled collection and limited testing
41PS151	4360	None (25)	None (15)	GT	30,000	None	Yes	Yes	Yes	Yes	None	N, G, B, Ch	Partially Eroded	Controlled collection and limited testing
41PS152	4320	None (200)	None (50)	UL	100	None	None	Yes	None	Yes	None	N, G	Eroded	Controlled collection and limited testing
41BS473	4360	None (5)	None (8)	GT	4,000	None	None	Yes	None	Yes	None	G, N, M	Eroded	Controlled collection
41BS474	4340	None (5)	None (4)	GT	500	None	None	Yes	None	Yes	None	G, N, M	Eroded	No further work
41BS475	4360	None (8)	None (10)	GT	2,500	None	None	Yes	None	Yes	None	N, G, P	Partially Eroded	Controlled collection
41BS476	4420	None (60)	None (30)	UL	15,000	None	None	Yes	None	Yes	None	N, G, P, Ch	Partially Eroded	Controlled collection
41BS477	4400	None (20)	None (10)	SH	1,200	Yes	Yes	Yes	Yes	Yes	None	G, N, M, A, B	Partially Vandalized	Controlled collection and limited testing
41BS478	4800	None (1000)	None (150)	SH	50	None	None	None	None	None	None	None	Eroded	No further work
41BS479	4280	None (175)	None (40)	SH	300	Yes	Yes	Yes	Yes	Yes	None	N, M, R	Intact	Controlled collection and limited testing
THE SHUTUPS														
41PS49	400	None (10)	None (7)	SH	25	None	None	Yes	None	Yes	None	G	Partially Eroded	Controlled collection and limited testing
41PS153	4200	None (30)	None (70)	SH	50	None	Yes	None	None	Yes	None	None	Partially Eroded	No further work
41PS154	4340	None (5)	None (4)	SH	5	None	None	None	None	None	None	None	Eroded	No further work
41PS155	4350	None (3)	None (5)	SH	7	None	None	None	None	None	None	None	Eroded	No further work
41BS480	3800	None (30)	None (15)	SH	1,250	Yes	Yes	Yes	Yes	Yes	Yes	N, G, B	Severely Vandalized	Controlled collection and limited testing

FRESNO CANYON

41PS30	3360	10	20	GT	5,000	None	Yes	Yes	None	Yes	None	N, G	Partially Eroded	Controlled collection
41PS32	3400	700 (80)	10 (40)	Sh	50	None	None	Yes	None	Yes	None	N, G, B, R	Eroded	Controlled collection
41PS35	3280	30	80	GT	7,500	None	None	Yes	None	Yes	None	G, N, Ch	Partially Eroded	Controlled collection
41PS39	3300	250	35	GT	1,000	None	None	Yes	None	Yes	None	G, N	Eroded	Controlled collection
41PS40	3692	None (15)	None (20)	Sh	1,000	None	Yes	Yes	Yes	Yes	Yes	N, G, L	Partially Eroded	Controlled collection
41PS41	3760	20	30	GT	7,500	None	None	Yes	None	Yes	None	N, G, R	Partially Eroded	Controlled collection
41PS46	3820	300 (50)	60 (10)	Sh	20	None	Yes	Yes	Yes	Yes	None	N, G, B, R, Ch	Intact	Controlled collection and limited testing
41PS47	3840	30	80	R	30,000	None	Yes	Yes	Yes	Yes	None	N, G, B, R, Ch	Partially Eroded	Controlled collection and limited testing
41PS156	4240	300	20	ST	5,000	None	Yes	Yes	Yes	Yes	None	G, N, B, Y, R, P	Partially Vandalized	Controlled collection and limited testing
41PS157	3800	None (50)	None (40)	GT	15,000	None	None	Yes	None	Yes	None	G, N, Ch	Eroded	Controlled collection
41PS158	3400	None (20)	None (10)	GT	600	None	None	None	None	Yes	None	G, N	Eroded	No further work
41PS159	3360	None (10)	None (4)	ST	7,500	None	None	Yes	Yes	Yes	None	N, G, Ch, P	Partially Intact	Controlled collection and limited testing
41PS160	3360	None (2)	None (5)	GT	1,500	None	None	None	None	Yes	None	G, N	Eroded	Controlled collection
41PS161	3500	45	50	SH	100	Yes	Yes	Yes	Yes	Yes	None	G, N, L	Intact	Controlled collection and limited testing
41PS162	3260	400	30	GT	2,000	None	None	Yes	Yes	Yes	None	G, N, R, Y	Partially Eroded	Controlled collection and limited testing
41PS163	3120	200	40	GT	10,000	None	None	Yes	None	Yes	None	G, N, Y, R, Ch	Eroded	Controlled collection
41PS164	3160	250	20	Sh	200	None	Yes	Yes	None	Yes	Yes	N, G	Eroded Vandalized	Controlled collection
41PS165	3160	5	5	Sh	35	None	Yes	Yes	None	Yes	None	G	Partially Eroded	Controlled collection and limited testing
41PS166	3000	20	5	ST	20,000	None	Yes	Yes	Yes	Yes	None	G, N, R, Y, P, B, Ch, M, A	Partially Eroded	Controlled collection and limited testing
41PS167	3200	20	30	GT	100	None	None	None	None	Yes	None	Y	Partially Eroded	Controlled collection
41PS168	3700	500	100	Rg	1,000	None	None	Yes	None	Yes	None	G, B	Partially Eroded	Controlled collection
41PS169	4100	400 (30)	30 (15)	Sh	8,000	Yes	Yes	Yes	Yes	Yes	Yes	G, N, P, B	Intact	Controlled collection and limited testing

*Numbers in parenthesis indicate hypothetical distances from water at time of prehistoric occupation

**Kinds of Sites (by land form)
GT – Gravel Terrace
ST – Silt Terrace
R – Canyon Rim Site
Rg – Ridge Site
Sh – Shelter Site
UL – Unusual Location Site

***Types of lithic materials on site (refer to section on lithic materials)
M – Maravillis Chert
N – Caballos Novaculite
G – Gray Chert
R – Reddish Chert
B – Black Chert
Y – Yellow Chert
L – Limestone
P – Petrified Wood
A – Agate
Ch – Chalcedony

THE SOLITARIO

A NATURAL AREA SURVEY
NO. 9

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976

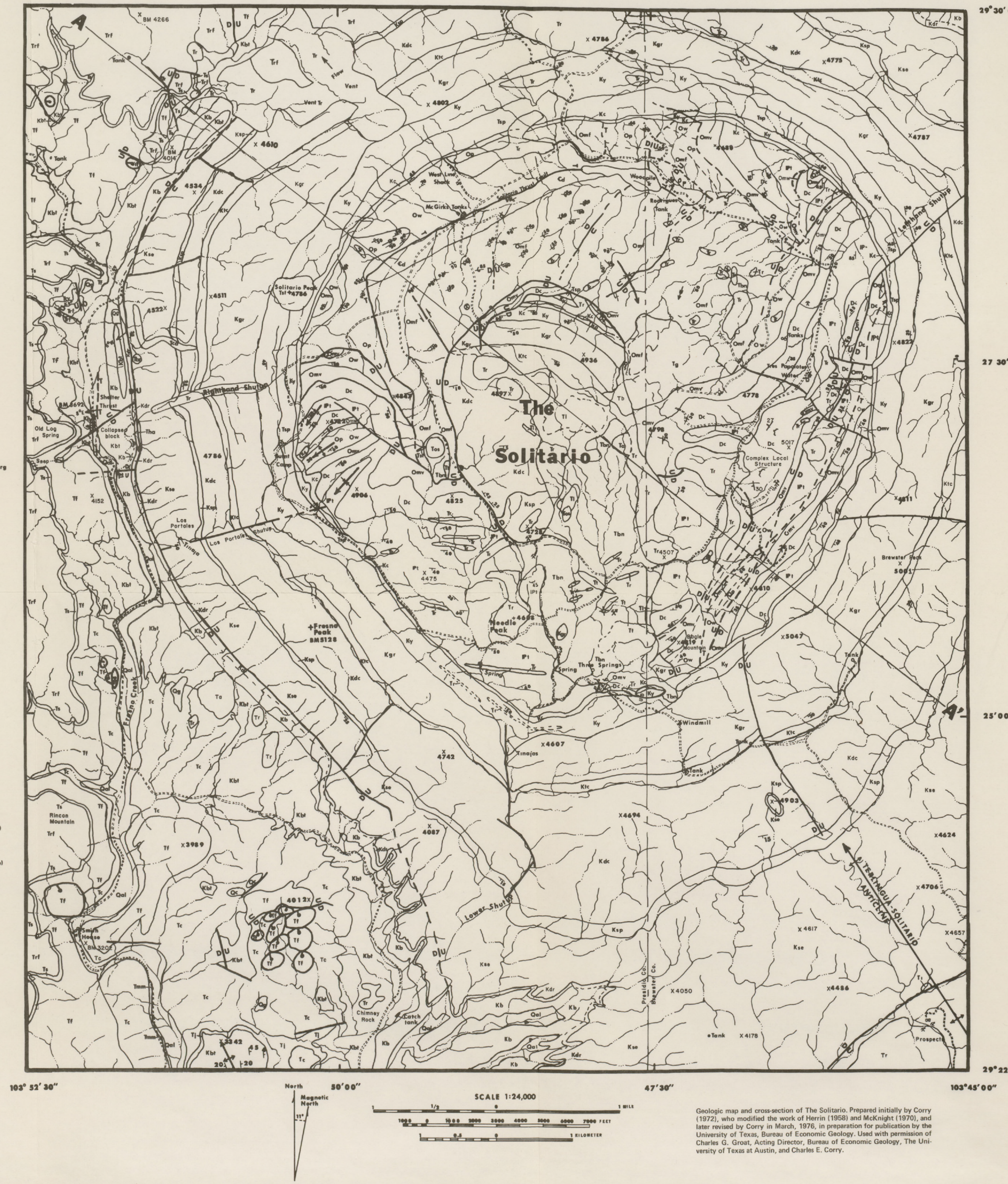

THE SOLITARIO
BREWSTER AND PRESIDIO COUNTIES, TEXAS
AREAS SUBJECTED TO ARCHEOLOGICAL RECONNAISSANCE
Major Tributary Canyon Survey Area
BASE FROM USGS THE SOLITARIO
7½' QUADRANGLE MAP
SCALE 1:24000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
THE
SOLITARIO
FRESNO
CANYON
BLUE
RANGE
Solitario Peak
Fresno Peak
Needle Peak
Eagle Mountain
Rincon Mountain
Chimney Rock
PRESIDIO CO
BREWSTER CO

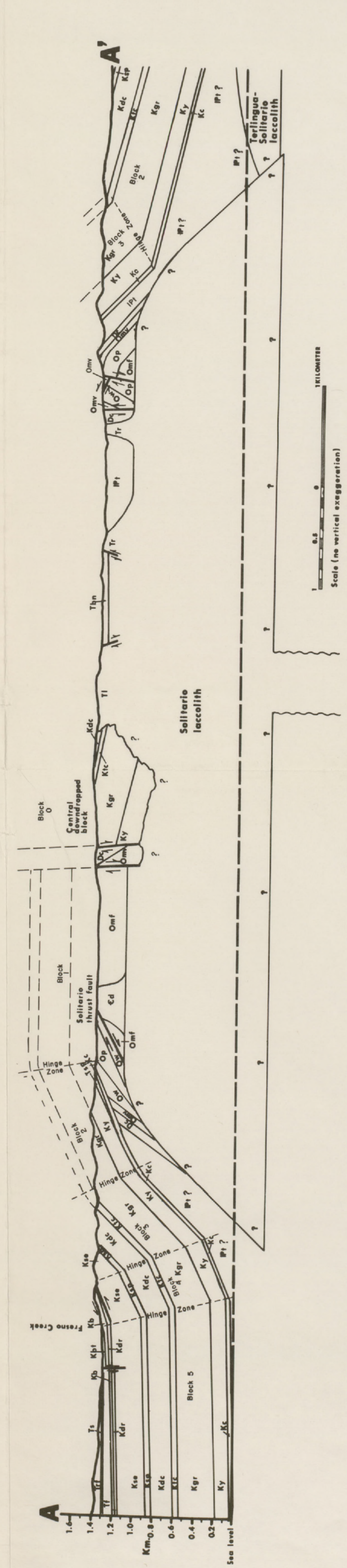
EXPLANATION

	K/Ar Ages			
Quaternary		Qal	Alluvium	
		Qc	Colluvium	
		Qg	Gravels	
			Unconformity	
Tertiary		Tcv	Chalcedony	Intrusives
		Tcd	Clastic dike	
	27 m.y.	Tos	Olivine syenite	
		Tt	Trachyte	
		Tst	Soda trachyte	
		Tg	Granite	
	36 m.y.	Tr	Rhyolite	
		Tl	Latite	
		Tha	Hornblende andesite	
		Ta	Andesite	
		Tb	Volcanic breccia	Buck Hill group
		Tbn	Needle Peak tuff	
	Miocene	Trf	Rawls formation	
		Ts	Santana tuff	
	Oligocene	Tf	Fresno formation	Bofecillos group
		Tmm	Mitchell Mesa tuff	
	Eocene	Tc	Chisos formation	
		Tj	Jeff conglomerate	
	Paleocene	Tsp	Solitario Peak rhyolite	
			Unconformity	
Upper Cretaceous		Kbt	Boquillas formation	Terlingua group
			Disconformity	
Lower Cretaceous		Kb	Buda limestone	Washita group
		Kdr	Del Rio clay	
		Kse	Santa Elena limestone	
		Ksp	Sue Peak formation	
		Kdc	Del Carmen limestone	Fredricksburg group
		Ktc	Telephone Canyon formation	
		Kgr	Glen Rose formation	Trinity group
		Ky	Yucca formation	
		Kc	Shutup conglomerate	
			Unconformity	
Mississippian—Pennsylvanian		IPt	Tesnus formation	Ouachita facies
			Unconformity	
Devonian—Mississippian		Dc	Caballos novaculite	
			Unconformity	
Ordovician		Omv	Maravillas chert	
		Ow	Woods Hollow shale	
		Op	Fort Pēna formation	
		Omf	Marathon formation	
Cambrian		Cd	Dagger Flat sandstone	

SYMBOLS

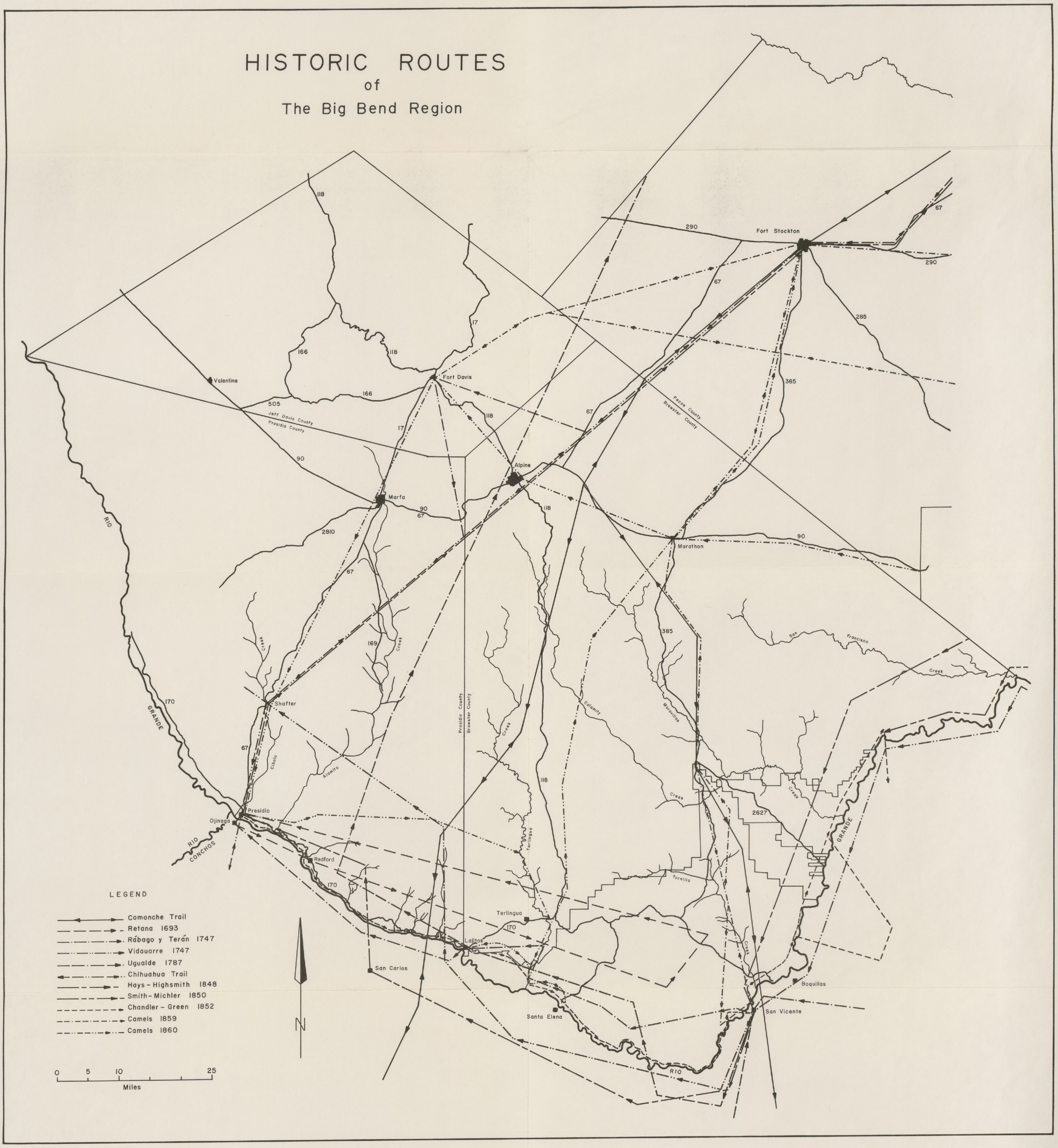
- Contact (dashed where indefinite)
- Normal fault (dashed where indefinite)
- Thrust fault (dashed where indefinite) T on upper plate
- Strike-slip fault (dashed where indefinite)
- Syncline showing direction of plunge
- Anticline showing direction of plunge
- Plunge of minor anticline
- Jeep road
- Intermittent stream
- Shack
- Catch tank
- Tank or tinaja
- Windmill
- Mine (abandoned) or prospect pit
- Attitude of bedding: Normal (25), Vertical (90), Overturned (80)
- Slump in direction indicated
- Spring
- Drill hole
- Petrofabric sample site



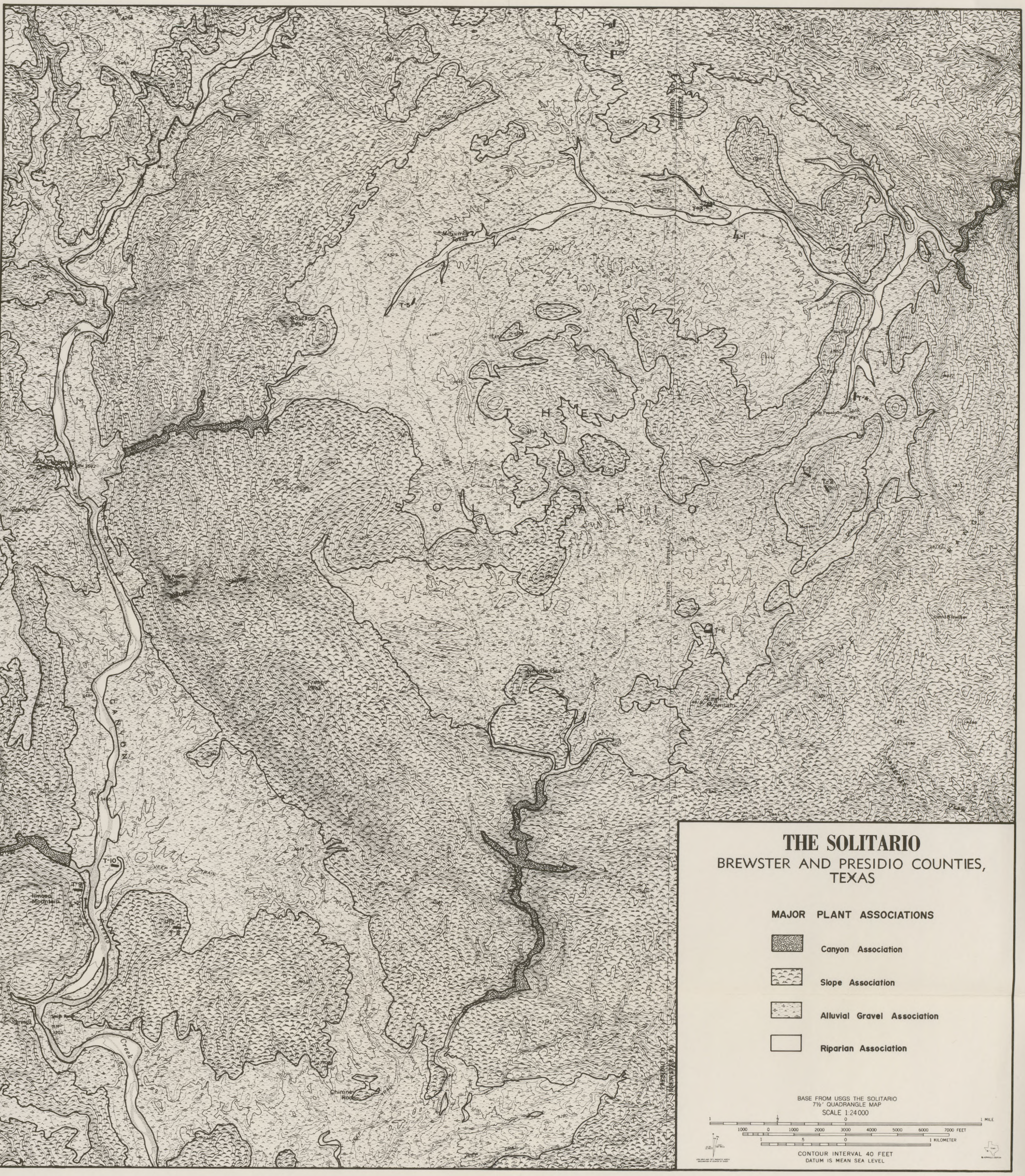


Structural cross section of the Solitario dome.

Geologic map and cross-section of The Solitario. Prepared initially by Corry (1972), who modified the work of Herrin (1958) and McKnight (1970), and later revised by Corry in March, 1976, in preparation for publication by the University of Texas, Bureau of Economic Geology. Used with permission of Charles G. Groat, Acting Director, Bureau of Economic Geology, The University of Texas at Austin, and Charles E. Corry.


HISTORIC ROUTES
of
The Big Bend Region
LEGEND
Comanche Trail
Retana 1693
Rábago y Terán 1747
Vidauarre 1747
Ugualde 1787
Chihuahua Trail
Hays-Highsmith 1848
Smith-Michler 1850
Chandler-Green 1852
Camels 1859
Camels 1860
0 5 10 25
Miles
N
Fort Stockton
Fort Davis
Valentine
Alpine
Marfa
Marathon
Shafter
Presidio
Ojinaga
Redford
Lajitas
Terlingua
San Carlos
Santa Elena
San Vicente
Boquillas
Jeff Davis County
Presidio County
Pecos County
Brewster County
RIO GRANDE
RIO CONCHOS
San Francisco Creek
Calamity Creek
Terlingua
Tornillo
2810
2627
505


THE SOLITARIO
BREWSTER AND PRESIDIO COUNTIES, TEXAS
RANGE CONDITIONS
Igneous hills & mountains
Limestone hills & mountains
Chert hills
Gravel
Clay
Draw
BASE FROM USGS THE SOLITARIO
7½' QUADRANGLE MAP
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
THE
SOLITARIO
FRESNO
PRESIDIO CO
BREWSTER CO


THE SOLITARIO
BREWSTER AND PRESIDIO COUNTIES, TEXAS
MAJOR PLANT ASSOCIATIONS
Canyon Association
Slope Association
Alluvial Gravel Association
Riparian Association
BASE FROM USGS THE SOLITARIO
7½′ QUADRANGLE MAP
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
Chimney Rock
PRESIDIO CO
BREWSTER CO