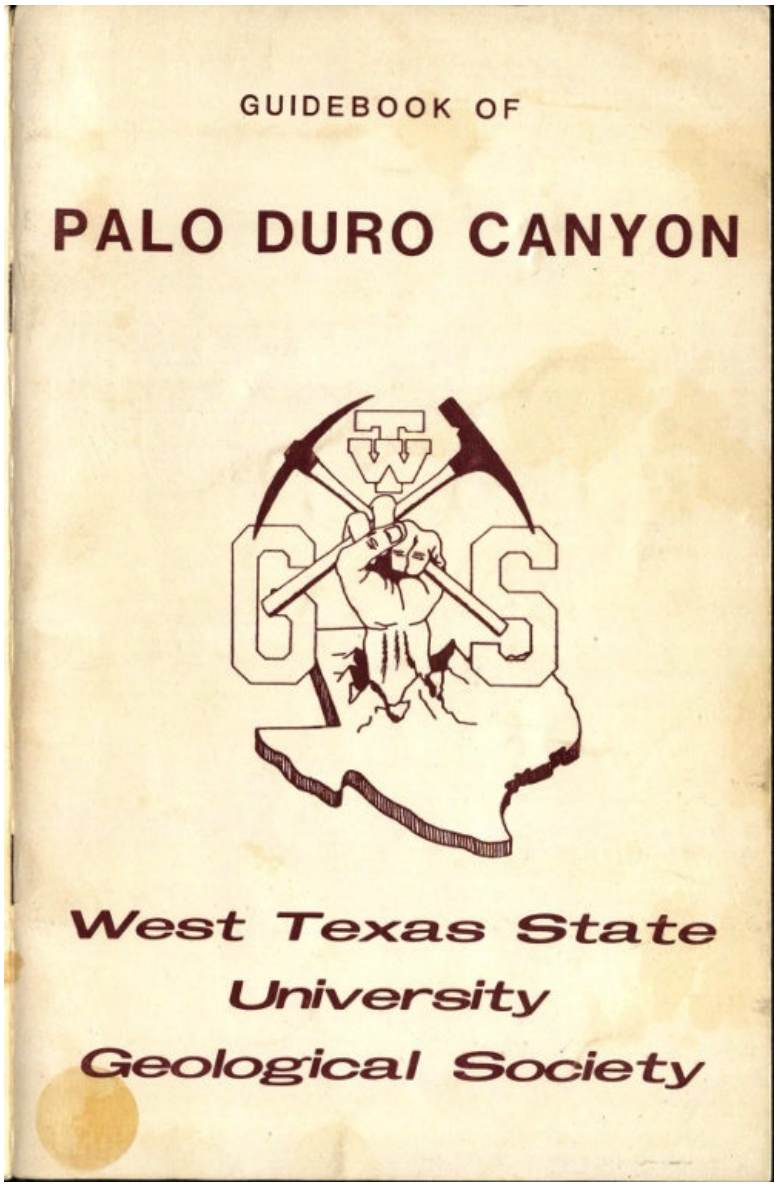
Title: Guidebook of Palo Duro Canyon

Author: West Texas State University. Geological Society

Release date: November 19, 2015 [EBook #50487]

Language: English

Credits: Produced by Stephen Hutcheson, Dave Morgan and the Online Distributed Proofreading Team at http://www.pgdp.net



GUIDEBOOK OF
PALO DURO CANYON

West Texas State University
Geological Society

DEPARTMENT OF GEOSCIENCES

The Department of Geosciences (geology, geography, anthropology) is housed in the Science Center on the campus of West Texas State University. Additional departmental space is found in the Killgore Research Center and Old Main. The Department offers a program of study leading to a Bachelor of Science and Bachelor of Arts degrees in geology and geography and a Bachelor of General Studies degree in anthropology. Most students are enrolled in the Bachelor of Science in geology degree, designed to meet the needs of students preparing for a professional career in geology. It requires a minimum of 39 semester hours of geology, plus supporting coursework in other sciences, mathematics, and technical writing or cartography. The Department also offers a Master of Science degree in geology. Recent thesis topics include *Geology of Fortress Cliff Quadrangle, Randall County, Texas* and *Sedimentology and Petrology of the Javelina Formation, Big Bend National Park, Brewster County, Texas*.

Members of the departmental faculty have a wide range of academic interests and come from a variety of colleges and universities. Special interests of the faculty include stratigraphy, biostratigraphy, geomorphology, sedimentology, structural geology, tectonics, igneous and metamorphic petrology, petroleum geology, paleontology, cartography, archaeology, and Indians and their culture of the south central United States. In addition, the Department retains a broad concern for earth-science education, and offers courses in introductory earth science and geology to meet student needs in the University general education and in teacher education.

The Department supports students with teaching and graduate assistantships, undergraduate laboratory assistants, and scholarships. Information regarding degree programs and financial aid can be obtained from the Department of Geosciences, West Texas State University, Box 938, Canyon, Texas 79016 or by calling the departmental office at 806-656-2581.

FOREWORD

The West Texas State University Geological Society was organized in 1958 by students of the Department of Geology. The objective of the Society is to promote interest in geology as an academic subject and as a professional career. In order to present the concepts of geology to interested groups, the Palo Duro Canyon Guidebook is sponsored by the WTSU Geological Society.

The Geological Society is indebted to Professor Jack T. Hughes and to Mr. Jerry Harbour for their work in the first edition of this guidebook.

> DO YOU HAVE A GROUP OR KNOW OF A GROUP WHO WOULD LIKE A GUIDED FIELD TRIP OF PALO DURO CANYON? CONTACT THE WEST TEXAS STATE UNIVERSITY GEOLOGICAL SOCIETY AT 656-2581 FOR INFORMATION.

TABLE OF CONTENTS

Text

Illustrations

INTRODUCTION

Palo Duro Canyon State Park is located 13 miles east of Canyon, Texas, on State Highway 217 and 17 miles southeast of Amarillo, Texas. The park encompasses about 15,000 acres of eastern Randall and western Armstrong counties.

The initial park area was purchased by the State of Texas in 1931. In 1973 the park boundary was extended to incorporate a famous topographic structure, the Lighthouse (frontispiece). Excellent picnic and camping facilities are available within the Park.

Extending away from the canyon rim is a gently undulating land surface called the Llano Estacado or Staked Plains. It is part of the High Plains, a vast piedmont plain which extends along the eastern base of the Rocky Mountains from Wyoming to Texas. The eastern edge of this plain is, in places, an abrupt escarpment (cliff) known as the caprock. Palo Duro Canyon is a westward extension of this escarpment that has been carved into the High Plains by the Prairie Dog Town Fork of the Red River.

In the park area the canyon is several miles wide. The canyon rim is about 3,500 feet above sea level and the canyon floor, although highly irregular is approximately 2,700 feet above sea level. The maximum depth of the canyon is about 800 feet. The United States Geological Survey has published an excellent topographical contour map of the canyon, the Fortress Cliff Quadrangle. It can be purchased at the park or from the United States Geological Survey.

The Park area normally receives about 20-30 inches of rainfall per year and has a frost free period of approximately 200-240 days per year. The yearly temperature ranges from 0-70°F in the winter and from 65 to 100°F in the summer. The weather is considered fair about 75% of the time. The nights are cool even in the summer.

ECOLOGY

Palo Duro Canyon is part of the escarpment system that forms the eastern boundary of the Llano Estacado or Staked Plains. The Staked Plains in this area is a nearly-level to gently-rolling terrain covered with a mantle of calcareous loess (a wind-blown silt) that has given rise to deep soils with a clay-loam surface and a clay subsoil. These soils are ideally suited to the growth of short grasses, especially blue grama and buffalo grass. Mesquite, yucca, prickly pear cactus, and forbs are common invaders of overgrazed areas.

Many shallow lake basins (playas) dot the plains with a flora different from the surrounding areas. In the playas, plains grasses are displaced by forbs that are suited to withstand the prolonged flooding within the shallow basins.

Near the canyon, the deep soils can be seen grading into shallow, grayish-brown, gravelly-loam soils. The abundance of grasses decreases and mid grasses such as little bluestem and sideoats grama increase. The mid grasses are better able to absorb nutrients from the less fertile soils near the canyon rim than are the short grasses. Especially conspicuous are increasing numbers of shrubs, particularly the evergreen and scale-leaved junipers. Just along the rim of the canyon, the shrubby mountain mahogany is found.

The rugged terrain of the sides of the canyon, extending from the Ogallala downward through the Trujillo and Tecovas formations to the upper part of the Quartermaster Formation, shows a variety of soil types. On the steeper slopes, plants are unable to gain a foothold as erosion removes soil material as fast as it is formed. On less-steep areas, the well-drained escarpment soil is suited for the development of scarp woodland. The deep, woody roots of trees and shrubs are better able to obtain the deeply infiltrating moisture from these soils than are the shallow and fibrous roots of grasses. The common plants on the level areas are junipers, squaw-bush, and little-leaved sumac. On the drier slopes, feather peabush, catclaw, and salt-bush are found. Groves of oak occur, but not in the abundance found along the escarpment further to the south.

Below the canyon slopes and extending to the creek are a wide variety of soils and a great diversity of plants. Most of the plants of the plains and escarpment are found here. Some of the soils of the nearly level areas are deep, high in fertility, and hold large amounts of water. Tall grasses, such as indiangrass and switchgrass, occur admixed with mid grasses; a rank growth of vine-mesquite grass often occurs in the areas where runoff water collects; and alkali sacaton grass grows on saline soils. Other trees and shrubs include hackberry, soapberry, wafer ash, button bush, foresteria, and Texas buckthorn. Along the creek, cottonwoods, willows, and salt cedar are common.

Because of the varied topography, diversity of plant life, and geographical locations, the canyon affords an ideal habitat for wildlife. Some of the mammals that occur here are the coyote, porcupine, jackrabbit, cottontail rabbit, raccoon, opossum, ringtailed cat, striped skunk, gray fox, white-footed mouse, woodrat, and bat. Mammals that were once common but are now absent or extremely rare are the bison, black bear, black-footed ferret, lobo wolf, cougar, and bobcat. The moose and American elk were introduced into the canyon but are no longer to be found. White-tailed deer, mule deer, and aoudad sheep have also been introduced and are still present. The mule deer is the most common. A great many types of birds are found either as residents of or migrants to the canyon. A few are the golden eagle, red-tailed hawk, sparrow hawk, Mississippi kite, turkey vulture, blue quail, killdeer, nighthawk, roadrunner, red-headed woodpecker, golden-fronted woodpecker, canyon wren, mockingbird, robin, cardinal, meadowlark, Bullock's oriole, painted bunting, white-crowned sparrow, and lark sparrow.

HISTORY OF MAN IN THE AREA

Archeological studies indicate that the earliest known inhabitants of Palo Duro Canyon lived in the canyon from about 10,000 to 5,000 B.C. These early men hunted bison and now-extinct elephant-like mammoths that roamed the area during the Pleistocene Ice Age. Their stone weapons and artifacts have been found in the canyon. Presumably these primitive people, like those who came later, were attracted by streams and springs in the canyon, and by game that came to feed there. Rock exposed in the canyon provided material for tools and weapons.

Through the centuries, various tribes of Plains Indians, including Apache, Cheyenne, Arapahoe, Kiowa, and Comanche, made use of the canyon as a camping ground. After the arrival of the white man, the canyon became a favorite resting place for buffalo hunters and Indian traders who travelled the Plains. White men first established residence there in 1876.

The last Indian battle in Texas was fought in the canyon south of the Park. Col. Ranald Mackenzie and his raiders, on September 25, 1874, attacked a large encampment of Comanche, Cheyenne, Kiowa, and Arapahoe in the canyon. They destroyed about 100 lodges and 1400 horses and mules. The damage inflicted was severe and by the following spring most of the Indians were returned to the reservation in Oklahoma.

GEOLOGIC HISTORY

The age of the earth is calculated in terms of billions of years. For convenience, geologic time is divided into units, called PERIODS, of different lengths (Figure 1). Sediments deposited during each period and the fossilized remains of animals and plants found in these sediments give a partial record of the events and life of that period.

A nearly homogeneous (uniform composition) rock layer may be identified as a FORMATION. Formations are usually spread over a wide area like a large blanket and are stacked on top of each other with the oldest at the bottom and the youngest at the top. When viewed in the walls of the canyon, they resemble a huge layer cake and may be traced along the canyon walls.

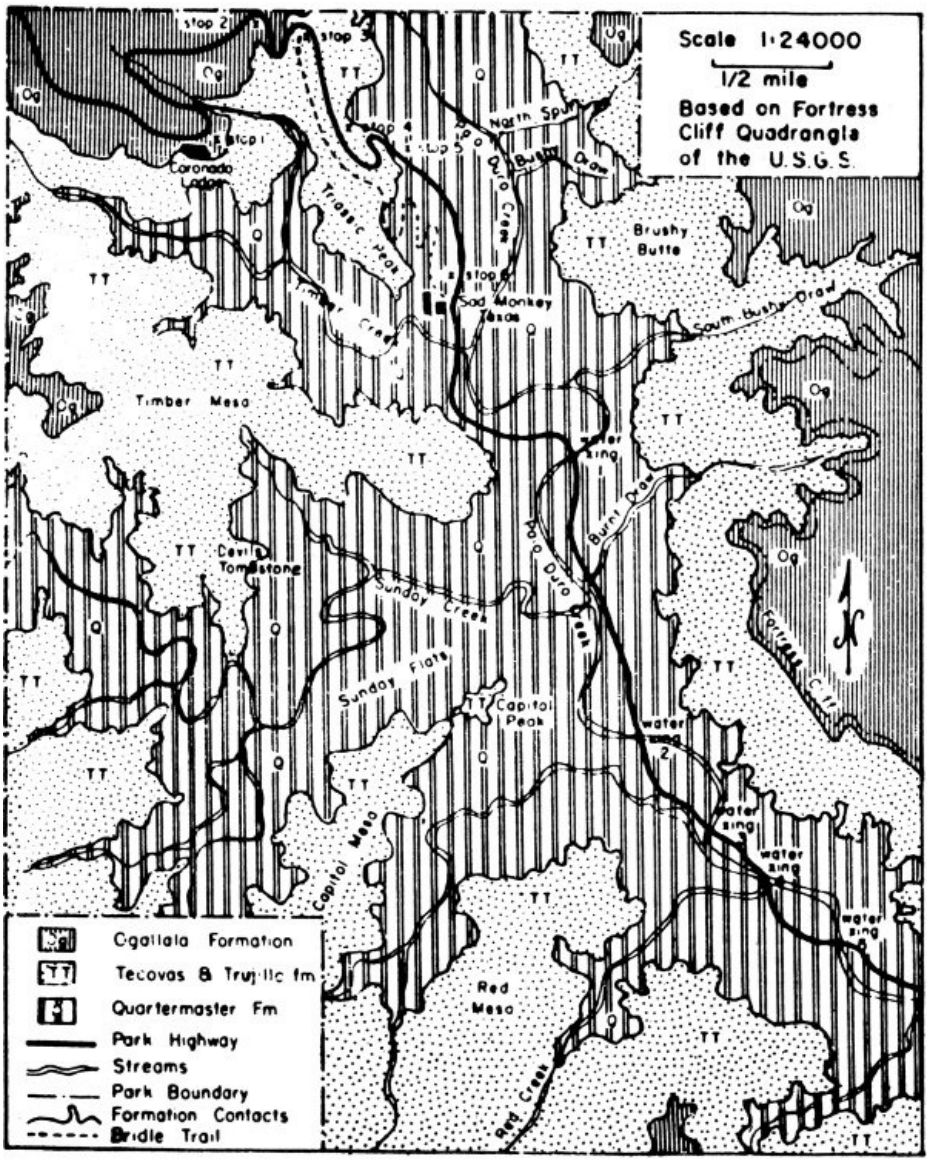


FIGURE 1. GEOLOGIC MAP OF PALO DURO CANYON

High-resolution Map

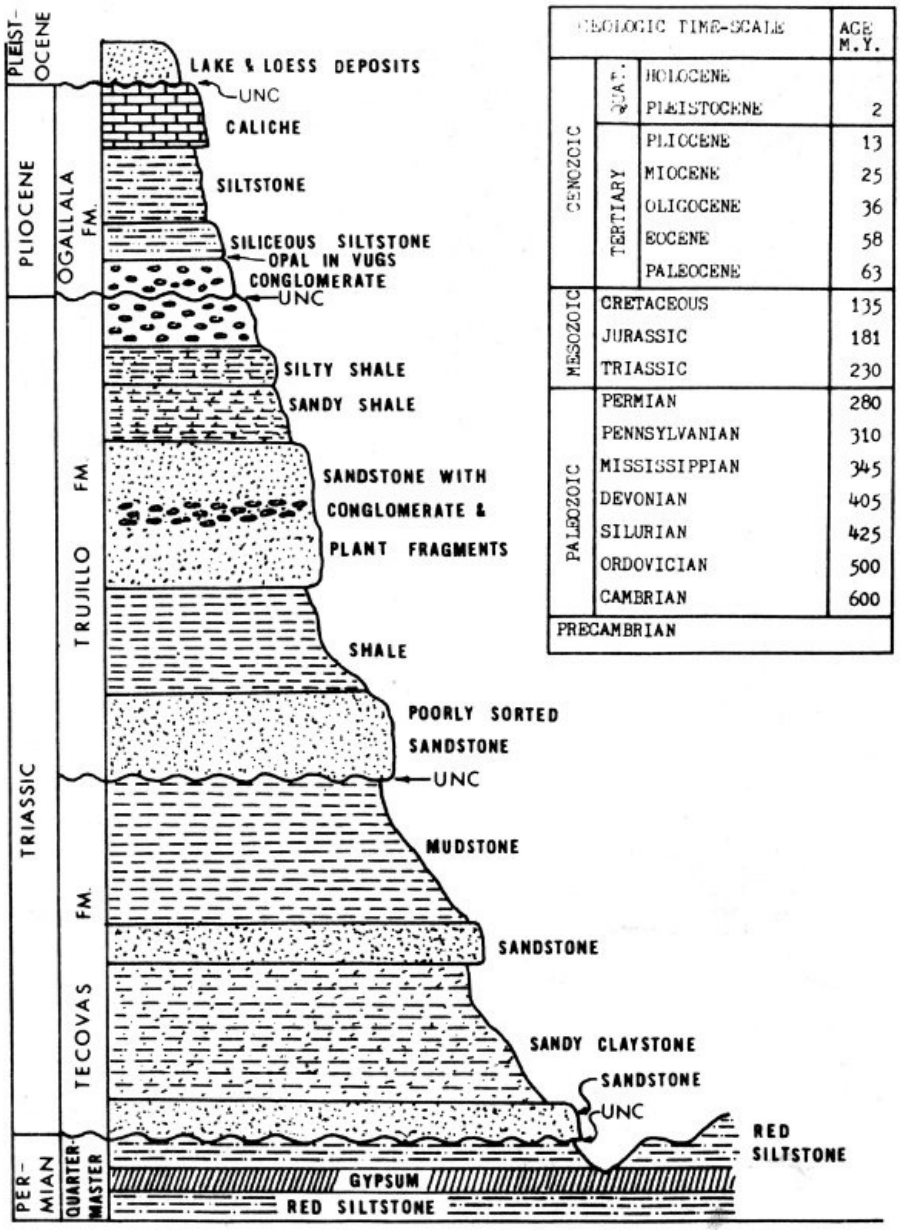


Figure 2. Stratigraphic section at Palo Duro Canyon with Geologic Time-scale for reference.

GEOLOGIC TIME-SCALE	AGE M.Y.
CENOZOIC	
QUAT.	
HOLOCENE	
PLEISTOCENE	2
TERTIARY	
PLIOCENE	13
MIOCENE	25
OLIGOCENE	36
EOCENE	58
PALEOCENE	63
MESOZOIC	
CRETACEOUS	135
JURASSIC	181
TRIASSIC	230
PALEOZOIC	
PERMIAN	280
PENNSYLVANIAN	310
MISSISSIPPIAN	345
DEVONIAN	405
SILURIAN	425
ORDOVICIAN	500
CAMBRIAN	600
PRECAMBRIAN	

The lowest and oldest exposed formation in Palo Duro Canyon is the Quartermaster. It was deposited near the edge of a shallow sea that occupied a wide area in Texas some 280 to 230 million years ago (Figure 3). This was during the Permian Period, the last period of the Paleozoic Era. The sediments in the park area were carried from the east and deposited in a nearshore environment. Sedimentary structures, such as crossbeds and ripplemarks, are present throughout the Quartermaster Formation. Halite casts suggest that there was a high rate of evaporation as sedimentation occurred. Gypsum (altered anhydrite) is also interpreted to be an evaporite deposit. The gypsum is now seen as horizontal white layers of alabaster and satin-spar varieties within the Quartermaster Formation.

The Quartermaster Formation is mostly siltstone and shale, and is commonly a distinctive red color. This red color is the result of combining oxygen from the air with the iron in the sediments (oxidation) much as a nail rusts after it has been exposed for a long period. The bedded gray zones represent times when there was enough fresh water from the land to offset temporarily the oxidation process. Smaller circular gray areas have organic nuclei that produced local areas of chemically altered iron by a process called reduction.

At the close of the Permian Period and the Paleozoic Era, the Panhandle region was uplifted and a period of widespread erosion followed. Consequently there are no sediments in this area to represent the early or middle portions of the Triassic Period. Breaks, such as this, in the sedimentary record are called UNCONFORMITIES. They may have been caused by a lack of deposition in the area or by an interval during which erosion removed earlier sediments.

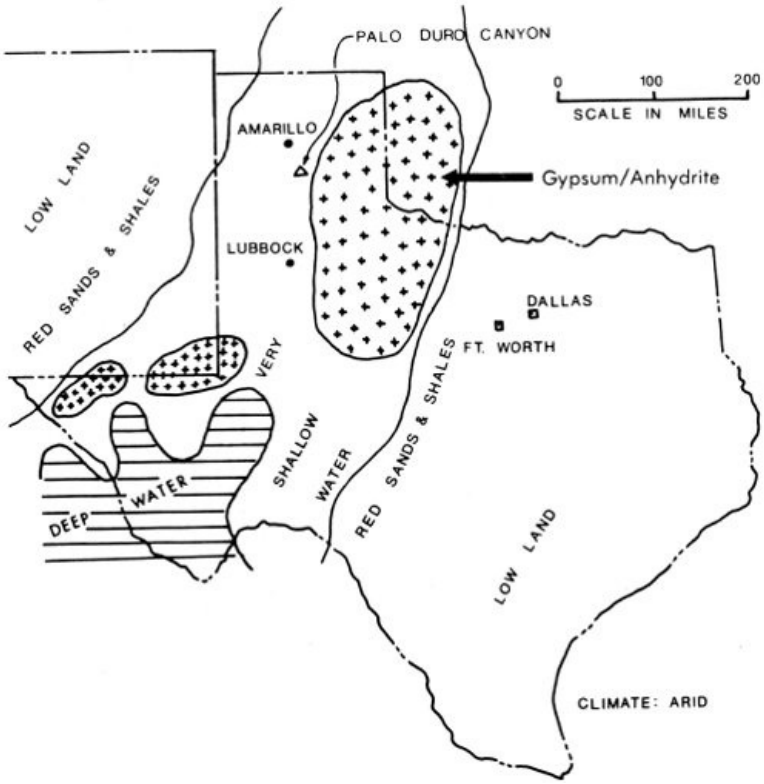


Figure 3. Paleogeographic map of the Permian Period (240 m.y.)

The Tecovas Formation was deposited in swamps, lakes, and streams approximately 200 million years ago during the Late Triassic (Figure 4). The Tecovas is mostly purplish lavender, yellow, orange, and buff siltstone and shale. The bright-colored shale of the Tecovas Formation is easily followed for many miles. Amarillo (the Spanish word for yellow) got its name from Amarillo Creek where the yellow bed of the Tecovas Formation crops out far from Palo Duro Canyon. The shale of the Tecovas forms the less steep portions of the canyon walls and often is covered by talus (weathered, broken rock) or vegetation. The uppermost Tecovas is usually mantled with boulders from the overlying sandstone of the Trujillo Formation.

The Tecovas Formation contains numerous concretions or irregularly shaped, weathered rocks. The unusual shape of a concretion is the result of the hardening of the sediments around a nucleus. As the rock weathers, the resistant material surrounding the nucleus remains. Most of the concretions are composed of limonite, hematite, manganite or calcite. Some of the calcite concretions are a variety termed “septarian.” These concretions have calcite ridges in a honeycomb pattern throughout the rock. Some of the concretions are simply nodular or spherical aggregates. Also in the Tecovas, geodes filled or lined internally with calcite crystals are found.

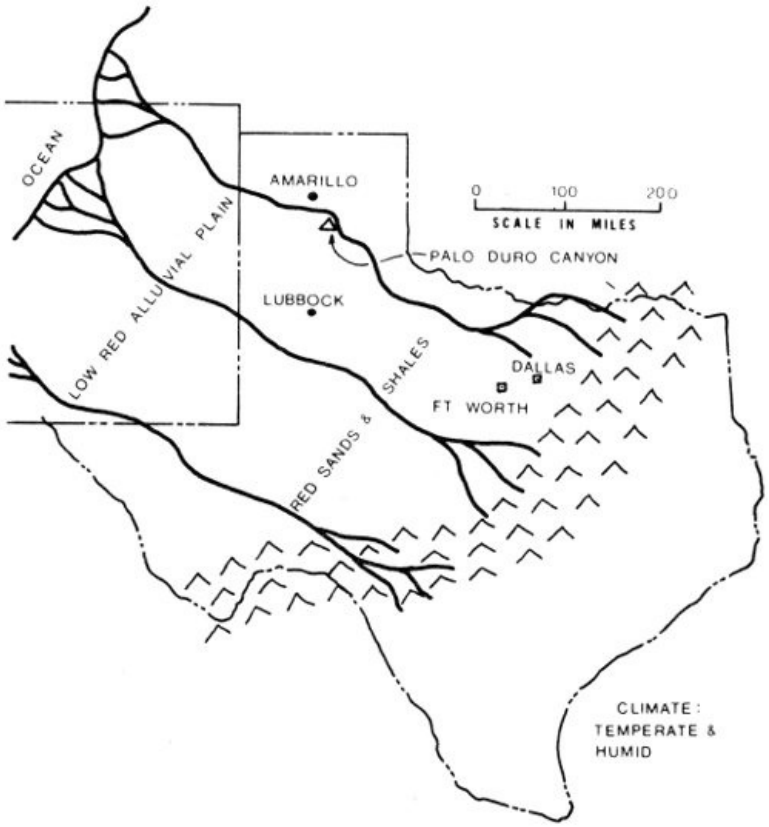


Figure 4. Paleogeographic map of the Triassic Period (181 m.y.)

Overlying the Tecovas is the Trujillo Formation. It was deposited by streams that probably originated in an ancient highland southeast of the present Panhandle. These streams were flowing more than 181 million years ago. The sandstone contains some alternating layers of shale and marl-pebble conglomerate. The Trujillo Formation is a resistant formation and forms some of the upper portions of the canyon walls. The steep portions are, in part, the result of a persistent fracture system common in the Trujillo Formation. The sandstone and conglomerate of the Trujillo characteristically exhibit well-developed crossbedding. Their gray color is sometimes obscured by a crust of red mud or iron stain. The uppermost red shale contains mineralized wood. The gray micaceous sandstone has many round sandstone concretions. Some of these are septarian concretions with cracks filled by calcite. Others may contain leaf imprints. 12

There is no evidence that Jurassic sediments were ever deposited in the region. Cretaceous rocks are also missing in this area although water-worn fossil oysters occur in the gravel at the base of the overlying Ogallala. These fossils indicate that marine Cretaceous sediments were deposited nearby and possibly covered the Triassic deposits in the region. The rocks were then eroded away some time between the end of the Cretaceous Period and the beginning of the Pliocene Epoch, a span of about 50 million years.

During the Pliocene Epoch, approximately 2-10 million years ago, the Rocky Mountains were again uplifted. Sediments in streams and floodplains were deposited on the erosional surface of the Trujillo Formation (Figure 5). These stream-deposited sediments are the Ogallala Formation.

The Ogallala Formation, which forms the upper part of the sequence of rocks exposed in the canyon, is present throughout most of the Panhandle. The formation is important as it is the principal aquifer of the Panhandle and supplies many farms and cities in the region with water. The Ogallala is a siltstone and sandstone that has, in places, been cemented by silica which came from groundwater. The formation contains many pockets of common opal and the basal part is in many places almost a chert. There are also some thin gray shale lenses.

13

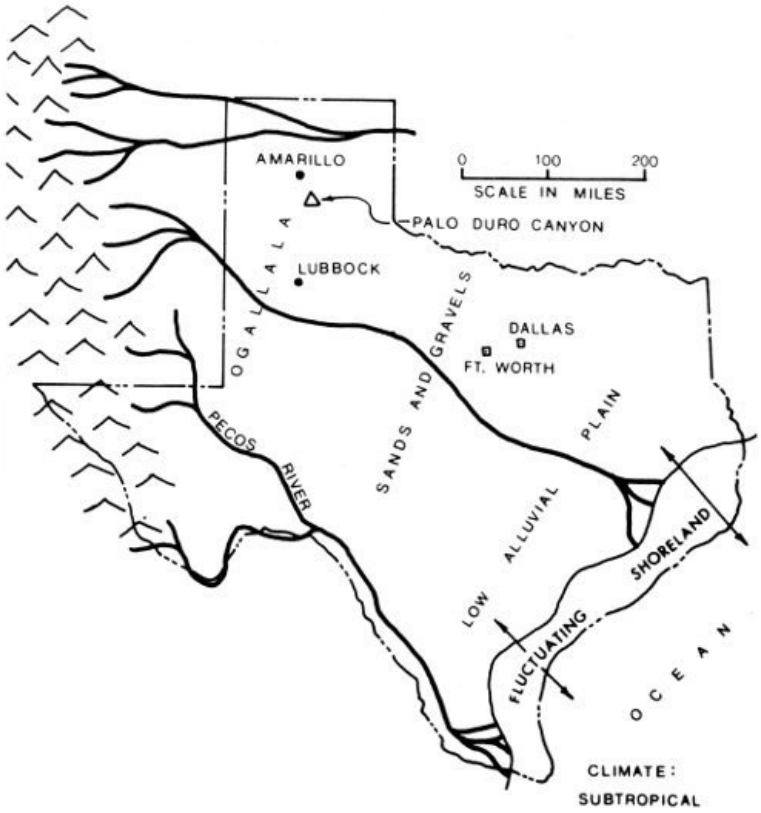


Figure 5. Paleogeographic map of the Pliocene (10 m.y.)

Scattered over the Ogallala are Late Pliocene and Pleistocene playa lake deposits up to 3 million years old. Some of these are fresh water lake deposits of silt, limestone, and wind-transported sediments or loess. Below these sediments is a layer of caliche which was deposited by evaporation of groundwater rich in calcium carbonate during Late Pliocene and Pleistocene time.

Less than one million years ago, during the Pleistocene Epoch of the Quaternary Period, the Prairie Dog Town Fork of the Red River began eroding headward into the Llano Estacado (Figure 6). The caprock escarpment is the result of differing resistance to erosion. The faster erosion of softer layers under the more resistant Ogallala and Trujillo formations forms the steep slopes of the escarpment.

The Prairie Dog Town Fork of the Red River is the small stream flowing in Palo Duro Canyon. Throughout the past million years it has been slowly excavating the canyon. The rate of change has been slow but continuous, carving the steep colorful walls of Palo Duro Canyon, an area of geologic interest and great scenic beauty.

PALEONTOLOGY

During the Permian Period the area that is now Palo Duro Canyon State Park, was a nearly-flat land surface along the edge of a restricted sea. The scarcity of fossils in the Quartermaster Formation indicates that plant and animal life was sparse. The environment was probably unsuited for plant life. It is thought that groundwater near the surface evaporated, leaving large amounts of salt as a residue. Since plants could not grow, animals would not have frequented the area either.

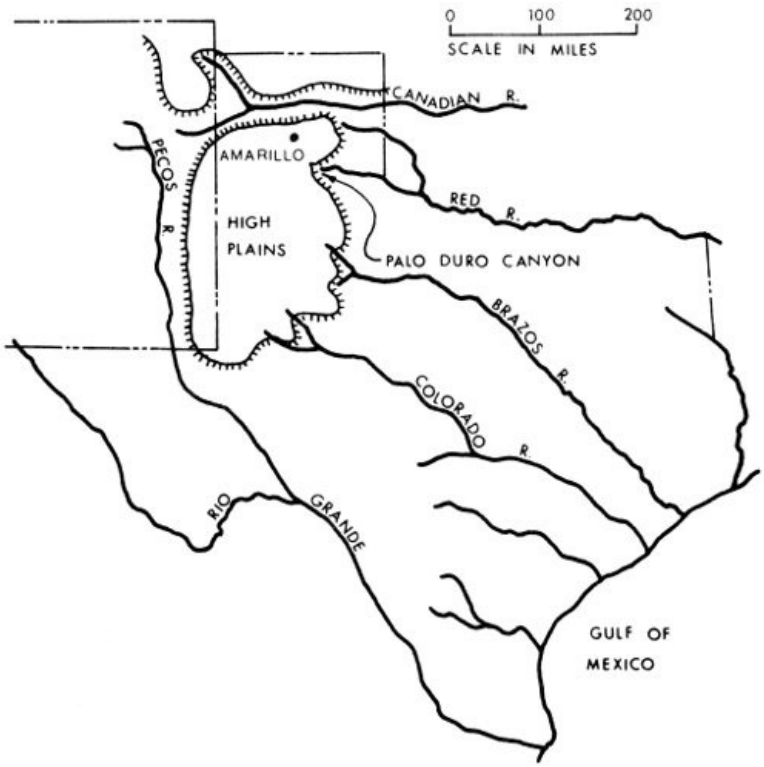


Figure 6. Headward erosion by the Pecos, Colorado, Brazos, Red and Canadian Rivers isolate the High Plains by the end of the Pleistocene (10,000 years ago) and cut Palo Duro Canyon.

Fossils and rocks of the Tecovas Formation indicate that the sediments were deposited in a swamp and stream environment (Figure 7). As time went on and the land continued rising, the climate became drier and some of the earlier life forms disappeared. 16

Remains of *Metoposaurus* (‘*Buettneria*’), the last of a long line of giant amphibians, are found here. These animals lived in large ponds. *Metoposaurus* buried themselves in the bottom of a pond and waited for fish to pass. With the aid of a third eye in the middle of its head, the animal could direct its huge mouth to its prey. *Metoposaurus* was so bulky that it is thought that it did not leave the water because its weak legs could not support its weight on land.

Living in shallower areas of the swamp were a group of semiaquatic reptiles known as phytosaurs. Phytosaurs looked very much like giant crocodiles with a nostril on the top of their heads, which permitted them to lie submerged just below the surface of the water. They probably fed on fish and smaller reptiles. Phytosaurs reached a length of 50 feet.

A heavily armored aetosaur, *Desmatosuchus* also lived in the Park area during the Triassic. They attained a length of about 10 feet. These reptiles probably were herbivorous (plant eating). A unique feature of *Desmatosuchus* was a fringe of backward-pointing horns around their necks. These possibly served to protect them from the carnivorous (meat eating) phytosaurs.

17

Figure 7. Life of Late Triassic time, showing restorations of the animals and plants that are now found as fossils in the Chinle beds of New Mexico and Arizona. In the water is the gigantic labyrinthodont amphibian, *Eupelor*, an animal some six feet or more in length. Lying on the bank is the crocodile-like thecodont reptile, *Phytosaurus*, large individuals of which may be twenty or thirty feet long. Behind the phytosaur, in the distance, is the armored thecodont, *Desmatosuchus*, ten feet long, and in the foreground is the small, bipedal thecodont, *Hesperosuchus*. In the left background are two individuals of the early saurischian dinosaur, *Coelophysis*, reptiles about ten feet in length. These animals lived in a tropical environment of moderate topography, crossed by many sluggish rivers and dotted with lakes. Numerous volcanoes rose above the general level of the land. Large, araucarian trees were abundant, stout scouring rushes or horsetails ten or fifteen feet high were everywhere, and the ground was covered with abundant ferns.

Also found in the Tecovas and Trujillo formations are fossil lung-fish teeth. Lung-fish are a type of fish that can breathe air, enabling them to move from pond to pond. Footprints of a chicken-sized dinosaur have also been found. The Middle Triassic flora was dominated by giant palm-like trees. Also found are remains of a few large ferns and horsetails. As the climate became drier and the swamps began to disappear, coniferous (evergreen) trees such as *Araucarioxylon* became plentiful. These trees can be found in the canyon today as petrified wood.

The Ogallala in the park contains very few fossils. A giant tortoise was found near the bend where the road begins to descend into the canyon. Fossil seeds may be seen in the exposure of the Ogallala near the Coronado Lodge.

More extensive Late Pliocene fossil beds are exposed south of the park in Cita Canyon. These beds are younger than the Ogallala and are stream and basin deposits. The fauna and flora found here suggest a broad, flat, grassy plain much like the present landscape (Figure 8). Remains of mastodons, large, elephant-like animals with long upper tusks that were used to dig up roots, are found here. Saber-tooth cats, also present, preyed upon the mastodons. The remains of these, as well as bones of camels, pony-sized horses, and sloths 10 feet high have been found in the vicinity of the canyon. Some of these animals are thought to have lived in the Panhandle a mere 10,000 years ago.

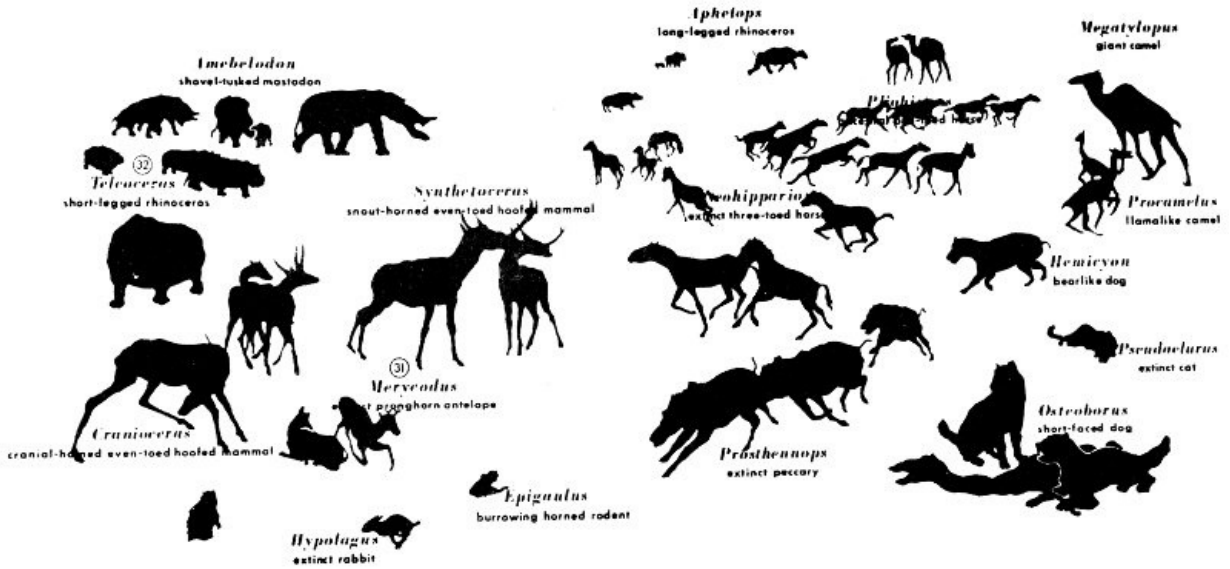


Figure 8.

Amebelodon: shovel-tusked mastodon
Teleoceras: short-legged rhinoceros
Synthetoceras: snout-horned even-toed hoofed mammal
Cranioceras: cranial-horned even-toed hoofed mammal
Merycodus: extinct pronghorn antelope
Hypolagus: extinct rabbit
Epigaulus: burrowing horned rodent
Aphelops: long-legged rhinoceros
Prosthennops: extinct peccary
Osteoborus: short-faced dog
Pseudaelurus: extinct cat
Hemicyon: bearlike dog
Procamelus: llamalike camel
Megatylopus: giant camel
Pliohippus: ancestral one-toed horse
Neohipparion: extinct three-toed horse

20

FIGURE 22.41 Pliocene Mammals. Early Pliocene life of the southern High Plains. (Mural by J. H. Matternes, courtesy U.S. National Museum.)

Due to limited outcrops in the Canyon proper, Pleistocene fossils are very rare. An excellent collection of fossils from Palo Duro Canyon and the Panhandle area is on display at the Panhandle-Plains Historical Museum. 21

Spectacular Palo Duro, “grand canyon” of the Panhandle Plains, is an exciting experience. One of the nation’s most magnificent scenic attractions, it provides delightful drives and opportunities for hiking, horseback riding and camping in season. Visit Palo Duro and enjoy it.

Diamond Shamrock

QUALITY ROCK SHOP

OVERNIGHT CAMPING
LAPIDARY EQUIPMENT
QUALITY AGATE & JADE, FOREIGN & DOMESTIC
CUSTOM SILVER, GOLD AND TURQUOISE WORK

2 Miles West of Canyon on U.S. Highway 60
Route 1, Box 211, Canyon, Texas 79015

MAGGIE & WHITEY VOELM
(806) 655-7631

Search Drilling Co.

Rotary Drilling Contractors
Oil & Gas Producers

SUITE 400
WELLINGTON SQUARE OFFICE PARK
1616 S. KENTUCKY
AMARILLO, TEXAS 79102
(806) 359-7645

YUCCA PETROLEUM CO.

300 Diamond Shamrock Building
P.O. BOX 2585 AMARILLO, TEXAS 79105
Telephone: (806) 376-5431

Argonaut

Energy Corporation

GLEN S. SODERSTROM, President
LORNE E. TJERNAGEL, Exec. Vice-President
R. L. PATTERSON, Vice-President of Production

1209 West 7 St. Suite 200
Amarillo, Texas 79101
806/373-6885

W.M. QUACKENBUSH

Petroleum Geologist

2315 Harmony
Amarillo, Texas 79106
806-355-2931

JACK G. JONES

CONSULTING PETROLEUM GEOLOGIST

Office: AC 806/352-6891
5500 Meadow Green Dr.
Post Office Box 8145
Amarillo, Texas 79109

TUTHILL & BARBEE

PETROLEUM GEOLOGISTS

S. KEITH TUTHILL
BILL J. BARBEE

300 Fisk Bldg.

Amarillo, Texas
PH. 373-3023

CAMBRIDGE & NAIL

PETROLEUM EXPLORATION SERVICES

803 Bank of the Southwest Bldg.
AMARILLO, TEXAS 79109
806 355-9297

Geologist: THOMAS R. CAMBRIDGE
Landman: A. L. NAIL

PAGE PETROLEUM LTD.

901 BANK OF THE SOUTHWEST BUILDING
AMARILLO, TEXAS 79109
806-366-9586

11TH FLOOR ROYAL BANK BLDG., 335-8TH AVE. S.W.
CALGARY, ALBERTA T2P 1C9
403-269-8221

ALPAR RESOURCES, INC.

Box 1046
Perryton, Texas 79070

Panhandle Geological Society

Box 2473 Amarillo, Texas
Petroleum Library 5th Floor Petroleum Bldg.
Field trip Guidebooks, Cross-Sections and Other Publications
GEOLOGY STUDENTS INVITED AND WELCOME

DUDLEY R. STANLEY

Consulting Geologist

5500 Meadowgreen Drive Box 7586
Amarillo, Texas 79109
355-8051

PARADOX PETROLEUM CO.

P.O. BOX 10025
AMARILLO, TEXAS 79106

George Dobervich
Frank Rapstine
Dan Taylor

PHONE (806) 355-5562

HAWK ENERGY CORPORATION

VERNON H. ROBINETT
BOB CONLEY

Suite 230 / Wellington Square
Amarillo, Texas 79102
806-359-7021

JAMES F. O'CONNELL

CONSULTING GEOLOGIST

355-8051
5772 Canyon E-way
P. O. Box 7006
Amarillo. Texas 79109

Texas Panhandle Sample Log Service

Plotted and described Stratigraphic Sample Logs on current and old wildcat tests drilled in the Oklahoma and Texas Panhandles and Northeastern New Mexico

1011 W. 9th
Amarillo, Texas
373-8522

CHARLES B. MORGAN

CONSULTING GEOLOGIST

355-8051
5772 Canyon E-way
P. O. Box 7586
Amarillo, Texas 79109

IRWIN & ASSOCIATES

GEOLOGICAL
MECHANICAL
CIVIL
ARCHITECTURAL
"*COUNTY MAPS*"
Professional Drafting Service

BILL E. IRWIN

502 Petroleum Bldg.
P. O. Box 14032
Amarillo, Texas 79101
BUS. 806-373-4611
RES. 806-622-0789

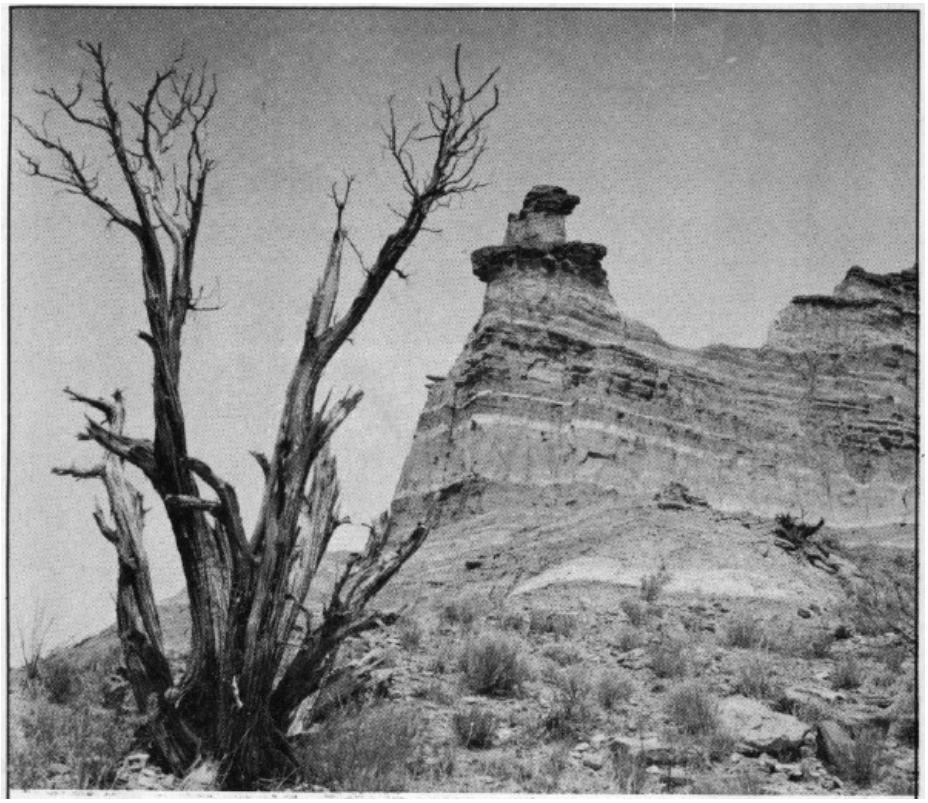
Mesa Petroleum Co.

With Compliments
Mesa Petroleum Co.
One Mesa Square
Amarillo, Texas

BAKER & TAYLOR DRILLING COMPANY

—Combining the finest in drilling equipment and skill to better serve the oil industry—

Offering summer employment to W.T.S.U. students this year—as in the last twenty-five years.



Transcriber's Notes

- Silently corrected several palpable typographical errors.
- Retained the list of corporate sponsors, but with simplified stylesheet.
- The original source had no date or copyright information. Based on external data, original publication of this (revised) edition was within a year or two of 1980.

*** END OF THE PROJECT GUTENBERG EBOOK GUIDEBOOK OF PALO DURO CANYON ***

in the United States and you are located in the United States, we do not claim a right to prevent you from copying, distributing, performing, displaying or creating derivative works based on the work as long as all references to Project Gutenberg are removed. Of course, we hope that you will support the Project Gutenberg™ mission of promoting free access to electronic works by freely sharing Project Gutenberg™ works in compliance with the terms of this agreement for keeping the Project Gutenberg™ name associated with the work. You can easily comply with the terms of this agreement by keeping this work in the same format with its attached full Project Gutenberg™ License when you share it without charge with others.

1.D. The copyright laws of the place where you are located also govern what you can do with this work. Copyright laws in most countries are in a constant state of change. If you are outside the United States, check the laws of your country in addition to the terms of this agreement before downloading, copying, displaying, performing, distributing or creating derivative works based on this work or any other Project Gutenberg™ work. The Foundation makes no representations concerning the copyright status of any work in any country other than the United States.

1.E. Unless you have removed all references to Project Gutenberg:

1.E.1. The following sentence, with active links to, or other immediate access to, the full Project Gutenberg™ License must appear prominently whenever any copy of a Project Gutenberg™ work (any work on which the phrase “Project Gutenberg” appears, or with which the phrase “Project Gutenberg” is associated) is accessed, displayed, performed, viewed, copied or distributed:

> This eBook is for the use of anyone anywhere in the United States and most other parts of the world at no cost and with almost no restrictions whatsoever. You may copy it, give it away or re-use it under the terms of the Project Gutenberg License included with this eBook or online at www.gutenberg.org. If you are not located in the United States, you will have to check the laws of the country where you are located before using this eBook.

1.E.2. If an individual Project Gutenberg™ electronic work is derived from texts not protected by U.S. copyright law (does not contain a notice indicating that it is posted with permission of the copyright holder), the work can be copied and distributed to anyone in the United States without paying any fees or charges. If you are redistributing or providing access to a work with the phrase “Project Gutenberg” associated with or appearing on the work, you must comply either with the requirements of paragraphs 1.E.1 through 1.E.7 or obtain permission for the use of the work and the Project Gutenberg™ trademark as set forth in paragraphs 1.E.8 or 1.E.9.

1.E.3. If an individual Project Gutenberg™ electronic work is posted with the permission of the copyright holder, your use and distribution must comply with both paragraphs 1.E.1 through 1.E.7 and any additional terms imposed by the copyright holder. Additional terms will be linked to the Project Gutenberg™ License for all works posted with the permission of the copyright holder found at the beginning of this work.

1.E.4. Do not unlink or detach or remove the full Project Gutenberg™ License terms from this work, or any files containing a part of this work or any other work associated with Project Gutenberg™.

1.E.5. Do not copy, display, perform, distribute or redistribute this electronic work, or any part of this electronic work, without prominently displaying the sentence set forth in paragraph 1.E.1 with active links or immediate access to the full terms of the Project Gutenberg™ License.

1.E.6. You may convert to and distribute this work in any binary, compressed, marked up, nonproprietary or proprietary form, including any word processing or hypertext form. However, if you provide access to or distribute copies of a Project Gutenberg™ work in a format other than “Plain Vanilla ASCII” or other format used in the official version posted on the official Project Gutenberg™ website (www.gutenberg.org), you must, at no additional cost, fee or expense to the user, provide a copy, a means of exporting a copy, or a means of obtaining a copy upon request, of the work in its original “Plain Vanilla ASCII” or other form. Any alternate format must include the full Project Gutenberg™ License as specified in paragraph 1.E.1.

1.E.7. Do not charge a fee for access to, viewing, displaying, performing, copying or distributing any Project Gutenberg™ works unless you comply with paragraph 1.E.8 or 1.E.9.

1.E.8. You may charge a reasonable fee for copies of or providing access to or distributing Project Gutenberg™ electronic works provided that:

- You pay a royalty fee of 20% of the gross profits you derive from the use of Project Gutenberg™ works calculated using the method you already use to calculate your applicable taxes. The fee is owed to the owner of the Project Gutenberg™ trademark, but he has agreed to donate royalties under this paragraph to the Project Gutenberg Literary Archive Foundation. Royalty payments must be paid within 60 days following each date on which you prepare (or are legally required to prepare) your periodic tax returns. Royalty payments should be clearly marked as such and sent to the Project Gutenberg Literary Archive Foundation at the address specified in Section 4, “Information about donations to the Project Gutenberg Literary Archive Foundation.”

- You provide a full refund of any money paid by a user who notifies you in writing (or by e-mail) within 30 days of receipt that s/he does not agree to the terms of the full Project Gutenberg™ License. You must require such a user to return or destroy all copies of the works possessed in a physical medium and discontinue all use of and all access to other copies of Project Gutenberg™ works.

- You provide, in accordance with paragraph 1.F.3, a full refund of any money paid for a work or a

replacement copy, if a defect in the electronic work is discovered and reported to you within 90 days of receipt of the work.

• You comply with all other terms of this agreement for free distribution of Project Gutenberg™ works.

1.E.9. If you wish to charge a fee or distribute a Project Gutenberg™ electronic work or group of works on different terms than are set forth in this agreement, you must obtain permission in writing from the Project Gutenberg Literary Archive Foundation, the manager of the Project Gutenberg™ trademark. Contact the Foundation as set forth in Section 3 below.

1.F.

1.F.1. Project Gutenberg volunteers and employees expend considerable effort to identify, do copyright research on, transcribe and proofread works not protected by U.S. copyright law in creating the Project Gutenberg™ collection. Despite these efforts, Project Gutenberg™ electronic works, and the medium on which they may be stored, may contain “Defects,” such as, but not limited to, incomplete, inaccurate or corrupt data, transcription errors, a copyright or other intellectual property infringement, a defective or damaged disk or other medium, a computer virus, or computer codes that damage or cannot be read by your equipment.

1.F.2. LIMITED WARRANTY, DISCLAIMER OF DAMAGES - Except for the “Right of Replacement or Refund” described in paragraph 1.F.3, the Project Gutenberg Literary Archive Foundation, the owner of the Project Gutenberg™ trademark, and any other party distributing a Project Gutenberg™ electronic work under this agreement, disclaim all liability to you for damages, costs and expenses, including legal fees. YOU AGREE THAT YOU HAVE NO REMEDIES FOR NEGLIGENCE, STRICT LIABILITY, BREACH OF WARRANTY OR BREACH OF CONTRACT EXCEPT THOSE PROVIDED IN PARAGRAPH 1.F.3. YOU AGREE THAT THE FOUNDATION, THE TRADEMARK OWNER, AND ANY DISTRIBUTOR UNDER THIS AGREEMENT WILL NOT BE LIABLE TO YOU FOR ACTUAL, DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE OR INCIDENTAL DAMAGES EVEN IF YOU GIVE NOTICE OF THE POSSIBILITY OF SUCH DAMAGE.

1.F.3. LIMITED RIGHT OF REPLACEMENT OR REFUND - If you discover a defect in this electronic work within 90 days of receiving it, you can receive a refund of the money (if any) you paid for it by sending a written explanation to the person you received the work from. If you received the work on a physical medium, you must return the medium with your written explanation. The person or entity that provided you with the defective work may elect to provide a replacement copy in lieu of a refund. If you received the work electronically, the person or entity providing it to you may choose to give you a second opportunity to receive the work electronically in lieu of a refund. If the second copy is also defective, you may demand a refund in writing without further opportunities to fix the problem.

1.F.4. Except for the limited right of replacement or refund set forth in paragraph 1.F.3, this work is provided to you ‘AS-IS’, WITH NO OTHER WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PURPOSE.

1.F.5. Some states do not allow disclaimers of certain implied warranties or the exclusion or limitation of certain types of damages. If any disclaimer or limitation set forth in this agreement violates the law of the state applicable to this agreement, the agreement shall be interpreted to make the maximum disclaimer or limitation permitted by the applicable state law. The invalidity or unenforceability of any provision of this agreement shall not void the remaining provisions.

1.F.6. INDEMNITY - You agree to indemnify and hold the Foundation, the trademark owner, any agent or employee of the Foundation, anyone providing copies of Project Gutenberg™ electronic works in accordance with this agreement, and any volunteers associated with the production, promotion and distribution of Project Gutenberg™ electronic works, harmless from all liability, costs and expenses, including legal fees, that arise directly or indirectly from any of the following which you do or cause to occur: (a) distribution of this or any Project Gutenberg™ work, (b) alteration, modification, or additions or deletions to any Project Gutenberg™ work, and (c) any Defect you cause.

Section 2. Information about the Mission of Project Gutenberg™

Project Gutenberg™ is synonymous with the free distribution of electronic works in formats readable by the widest variety of computers including obsolete, old, middle-aged and new computers. It exists because of the efforts of hundreds of volunteers and donations from people in all walks of life.

Volunteers and financial support to provide volunteers with the assistance they need are critical to reaching Project Gutenberg™’s goals and ensuring that the Project Gutenberg™ collection will remain freely available for generations to come. In 2001, the Project Gutenberg Literary Archive Foundation was created to provide a secure and permanent future for Project Gutenberg™ and future generations. To learn more about the Project Gutenberg Literary Archive Foundation and how your efforts and donations can help, see Sections 3 and 4 and the Foundation information page at www.gutenberg.org.

Section 3. Information about the Project Gutenberg Literary Archive Foundation

The Project Gutenberg Literary Archive Foundation is a non-profit 501(c)(3) educational corporation organized under the laws of the state of Mississippi and granted tax exempt status by the Internal Revenue Service. The Foundation’s EIN or federal tax identification number is 64-6221541. Contributions to the Project Gutenberg Literary Archive Foundation are tax deductible to the full extent permitted by U.S. federal

laws and your state's laws.

The Foundation's business office is located at 809 North 1500 West, Salt Lake City, UT 84116, (801) 596-1887. Email contact links and up to date contact information can be found at the Foundation's website and official page at www.gutenberg.org/contact

Section 4. Information about Donations to the Project Gutenberg Literary Archive Foundation

Project Gutenberg™ depends upon and cannot survive without widespread public support and donations to carry out its mission of increasing the number of public domain and licensed works that can be freely distributed in machine-readable form accessible by the widest array of equipment including outdated equipment. Many small donations ($1 to $5,000) are particularly important to maintaining tax exempt status with the IRS.

The Foundation is committed to complying with the laws regulating charities and charitable donations in all 50 states of the United States. Compliance requirements are not uniform and it takes a considerable effort, much paperwork and many fees to meet and keep up with these requirements. We do not solicit donations in locations where we have not received written confirmation of compliance. To SEND DONATIONS or determine the status of compliance for any particular state visit www.gutenberg.org/donate.

While we cannot and do not solicit contributions from states where we have not met the solicitation requirements, we know of no prohibition against accepting unsolicited donations from donors in such states who approach us with offers to donate.

International donations are gratefully accepted, but we cannot make any statements concerning tax treatment of donations received from outside the United States. U.S. laws alone swamp our small staff.

Please check the Project Gutenberg web pages for current donation methods and addresses. Donations are accepted in a number of other ways including checks, online payments and credit card donations. To donate, please visit: www.gutenberg.org/donate

Section 5. General Information About Project Gutenberg™ electronic works

Professor Michael S. Hart was the originator of the Project Gutenberg™ concept of a library of electronic works that could be freely shared with anyone. For forty years, he produced and distributed Project Gutenberg™ eBooks with only a loose network of volunteer support.

Project Gutenberg™ eBooks are often created from several printed editions, all of which are confirmed as not protected by copyright in the U.S. unless a copyright notice is included. Thus, we do not necessarily keep eBooks in compliance with any particular paper edition.

Most people start at our website which has the main PG search facility: www.gutenberg.org.

This website includes information about Project Gutenberg™, including how to make donations to the Project Gutenberg Literary Archive Foundation, how to help produce our new eBooks, and how to subscribe to our email newsletter to hear about new eBooks.