BIOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE CUTOFF FORMATION, (PERMIAN) IN LAST CHANCE CANYON EDDY COUNTY, NEW MEXICO

By

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THE CUTOFF FORMATION, (PERMIAN)
IN LAST CHANCE CANYON
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PREFACE

Last Chance Canyon is a unique area that is critical to the understanding of lower Guadalupian sequence stratigraphy.

The Cutoff Formation as exposed here includes facies of the upper San Andres-lower Cherry Canyon facies tract not exposed anywhere else in the Guadalupe Mountains. This study correlates the Cutoff Formation in Last Chance Canyon biostratigraphicly with other exposures of the Cutoff and uses that information along with sedimentological information to establish correlatable depositional sequences.

I wish to thank Dr. Scott Ritter who presented the project to me and assisted in the field and in the laboratory and provided much needed criticism and encouragement. I would also like to thank Dr. Fred Behnken of ARCO Oil and Gas who originated the project and who interceded on my behalf to gain financial and technical assistance, and Dr. Garner Wilde who identified the fusulinids used in this study.

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CHAPTER I

INTRODUCTION

Purpose and Scope of the Project

The purpose of this project is to document the sedimentology and biostratigraphy of the strata in Last Chance Canyon, Eddy County, New Mexico assigned herein to the Cutoff Formation. The geological significance of this area for interpreting the depositional environments in the Middle Permian of West Texas and New Mexico has long been recognized (Hayes, 1959). More recently, efforts by several major petroleum companies to verify subsurface depositional sequence stratigraphy data with surface rocks of equivalent age have renewed interest in this area. While much work has been done in Last Chance Canyon, there is still a need for data obtained directly from the outcrops in this area.

The objectives of this project are to: 1. Determine the age of the Cutoff Formation and correlate it from Last Chance Canyon to the West Face of the Guadalupe Mountains using conodonts. 2. Identify depositional sequences in the Cutoff Formation by determining the depositional environments and sedimentary facies relationships within the formation. Correlation of the Cutoff Formation in Last Chance Canyon to the West Face is complicated because Last Chance Canyon is an isolated outcrop area. Correlation problems in the Guadalupe Mountains are most acute in uppermost Leonardian and lower Guadalupian rocks.

The project is based upon the study of measured sections in Last Chance Canyon in the central Guadalupe Mountains, and at Cutoff Mountain on the west face of the Guadalupe Mountains (Figure 1).

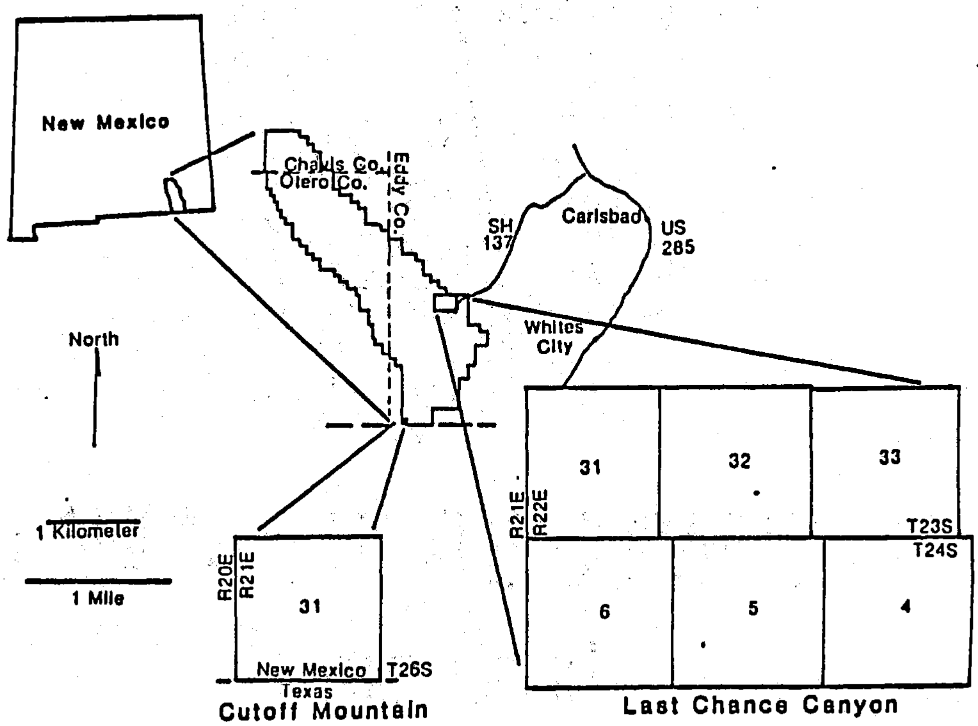


Figure 1. Location of Last Chance Canyon and Cutoff Mountain Study Areas. (Modified from Tye, 1986)

Field Area

Last Chance Canyon Area

Last Chance Canyon is located in the Lincoln National Forest in sections 31, 32, and 33 T23S, R22E, and sections 4, 5, and 6, T24S, R22E, Eddy County New Mexico. In the study area the canyon is about five hundred feet deep. The sides of the canyon are very steep, the upper part of the canyon walls being nearly vertical. The Last Chance Canyon area was chosen because it provides one of few surface exposures of the Cutoff Formation at this position relative to the shelf edge of the Delaware Basin. This makes the area significant to seismic stratigraphers in the Delaware Basin.

Cutoff Mountain Area

The Cutoff Mountain Area is located in section 31, T28S, R21W, Eddy County, New Mexico and is also in the Lincoln National Forest. This area is on the west side of Cutoff Mountain, which forms part of the West Face of the Guadalupe Mountains. The Cutoff Mountain area was selected for comparing the facies of Last Chance Canyon with the West Face of the Guadalupe Mountains. The Cutoff Mountain area is near the type section of the Cutoff Formation.

Structural Setting of the Guadalupe Mountains

The Guadalupe Mountains are an uplifted and gently tilted fault block. The western edge of the block is bounded by the Border Fault Zone (King, 1942), which separates the Guadalupe Mountains from the Salt Basin. The fault zone trends north-northwest, and the Guadalupe Mountain block tilts gently to the east. The Huapache Monocline which runs roughly parallel to the Border Fault Zone lies about 20 miles east of the Salt Basin. It is the surface expression of basement reverse faulting in which the east side of the fault is downthrown (Hayes, 1964). The southern edge of the Guadalupe Mountains is the exhumed Capitan Reef Escarpment.

Last Chance Canyon lies west of the Huapache Monocline. In most of this study area strata are inclined less than five degrees to the east. In the easternmost part of the area, dips increase to 7 degrees to the east.

Cutoff Mountain is located on the west face of the Guadalupe Mountains, adjacent to the Salt Basin. Beds here dip gently to the east. Figure 2 shows the location of these features relative to the study areas.

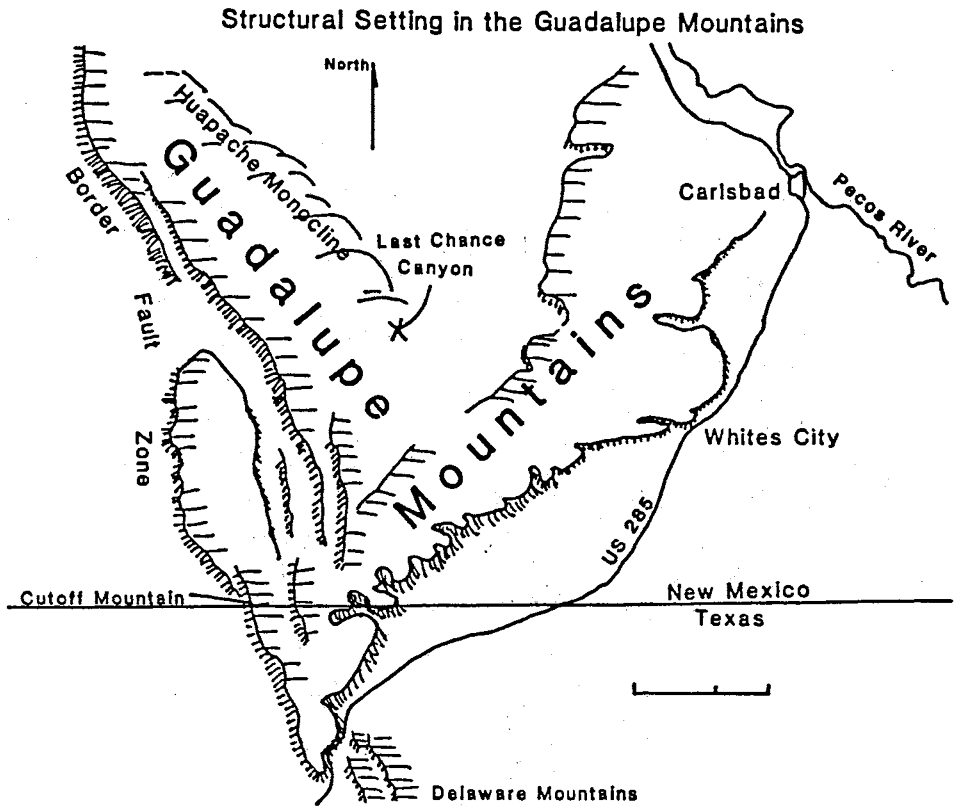


Figure 2. Structural Features in the Guadalupe Mountains (After King, 1948 and Harris, 1982)

Previous Investigations

Stratigraphy of the Guadalupe Mountains

The stratigraphy of the Guadalupe Mountains of Texas and New Mexico has been in a constant state of evolution since the area was first visited by geologists. From 1854 to 1920 several survey groups crossed the area (Hayes, 1964). These groups identified the rocks of the Guadalupes as Permian in age and made extensive paleontological observations. Perhaps the most important of these paleontological studies was that of Girty (1908). Richardson (1904) named the Delaware Mountain Formation and the Capitan Limestone. In the 1920's and '30's petroleum geologists further refined the stratigraphy of the area. The most prolific geologist of this time to work in the Guadalupe Mountains was P. B. King. King (1937)separated the Bone Springs Limestone from the Delaware Mountain Formation named the Brushy Canyon, Cherry Canyon and Bell Canyon Formations of the Delaware Mountain Group and the Goat Seep Dolomite (King, 1942).

The Cherry Canyon Sandstone contains three limestone tongues, the Getaway, South Wells and Manzanita Limestone Members which extend into the Delaware Basin (King, 1942) The Bell Canyon Sandstone has five limestone tongues named the Hegler, Pinery, Rader (King, 1942), McCombs (Newell, et. al., 1953), and Lamar (Lang, 1937). King (1948) also recognized the Victorio Peak and Cutoff Shaly Members of the Bone Springs Limestone. The Victorio Peak Member and the Cutoff Shaly Member have been raised to formation status and are called the Victorio Peak Limestone (King, 1964) and the Cutoff Formation (Harris 1982, 1987). Lang (1937) named the Carlsbad Formation for the back reef carbonates of the shelf area. This term was replaced by the Artesia Group (Tait, 1962) which includes the evaporite and carbonate facies of the Seven Rivers, Yates and Tansill Formations named by Hayes (1957). The Queen Formation was named in 1929 (Crandall, 1929) but not defined until 1953 (Newell et. al., 1953). The Grayburg Formation was originally defined in the subsurface by Dickey (1940). A surface type section was proposed by Moran (1954). The Yeso and San Andres Formations were first recognized in central New Mexico (Lee, 1909). The Glorietta Sandstone Member of the Yeso Formation was identified by Skinner (1946) as part of the Glorietta Sandstone of central New Mexico. This is probably not a correct designation, as the true Glorietta Sandstone pinches out 75 miles to the north (Hayes, 1964). The name Glorietta is retained as the member name since it is used by workers in the Delaware Basin. This usage should be considered informal since the true Glorietta Sandstone has precedence. Figure 3 shows the names and relationship of the formations currently recognized in the Guadalupe Mountains.

The first regional mapping of the Permian rocks in the area was carried out by P. B. King (1942. 1948), who concentrated on the southern Guadalupe Mountains. Boyd (1959), Motts (1962), and Hayes (1964) mapped the range in

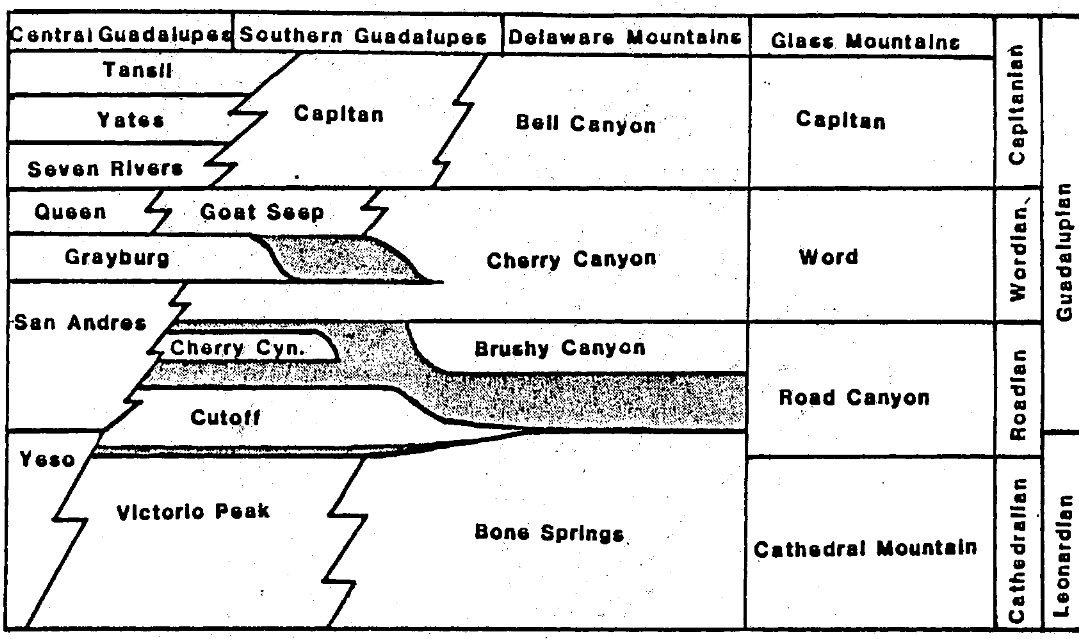


Figure 3. Middle Permian Stratigraphic Nomenclature of West Texas and New Mexico

New Mexico. The 1953 volume The Permian Reef Complex, by Newell et. al. (1953), dealt with the complex facies relationships and paleoecology of the entire Guadalupe Mountains area.

Since the early 1960's most of the work in the Guadalupe Mountains has dealt with the sedimentology and diagenesis of the rocks. More recently, the application of sequence stratigraphy has renewed interest in stratigraphic puzzles which were never satisfactorily solved. Among these is the age and stratigraphic significance of the rocks in Last Chance Canyon below the Cherry Canyon Sandstone Tongue, identified in this paper as the Cutoff Formation. These rocks have been called Bone Springs (King, 1942), San Andres Limestone (Dunbar and Skinner, 1937), (Hayes 1959, 1964), (Sarg and Lehmann, 1986) and Cutoff Formation (Spinosa, Furnish, and Glenister, 1975). These rocks have been assigned to both the Leonardian and Guadalupian Series.

Chronostratigraphic units in the Permian System

In 1939 the Standard Permian Reference Section of North America was established (Adams, et. al., 1939). In this section, the Permian system was divided into four series. In descending order these are: the Ochoan Series, the Guadalupian Series, the Leonardian Series, and the Wolfcampian Series. The Wolfcampian Series is named for the Wolfcamp Formation of the Glass Mountains. No Wolfcampian strata are exposed in the Guadalupe Mountains (Dunbar and Skinner, 1937).

The Leonardian Series is named for the Leonard Formation (now Group), also of the Glass Mountains (Adams, et. al., 1939). The ammonoid *Perrinites* and primitive *Parafusulina* are diagnostic of the Leonardian Series as originally defined, along with the brachiopods, Prorichthofenia and Scacchinella (Adams, et. al. 1939). In the Guadalupe Mountains, the Leonardian Series includes the Bone Springs Limestone and its lateral equivalents the Victorio Peak Limestone and the Yeso Formation (Hayes, 1964).

The Guadalupian Series, as originally proposed, included the Delaware Mountain Group and Capitan Limestone in the type area at the southern end of the Guadalupe Mountains (Adams, et. al. 1939). In defining the Guadalupian Series in the Guadalupe Mountains, Adams divided the series into two paleontological units. From Adams, et. al., 1939:

> "The lower unit, which includes the lower and middle formations of the Delaware Mountain Sandstone, the equivalent Word Formation, and certain limestones of the marginal belt, contains the ammonoid Waagenoceras and is characterized by species of the genus Parafusulina that are markedly more advanced than the primitive species of the same genus in the underlying Leonardian Series".

Thus, when the Guadalupian Series was defined, the Word Formation of the Glass Mountains was included in it. The lower part of the Word Formation has been redefined as the Road Canyon Formation (Cooper and Grant, 1966).

The Ochoan Series included "all Permian sediments of post Guadalupe age" (Adams et. al, 1939), which are mostly evaporites in the Delaware Basin.

The system proposed by Adams et. al. (1939) has some significant flaws which have caused problems for subsequent workers. Furnish (1973) described the problem of defining the base of the Guadalupian Series as having "reached historic proportions". The root of this problem is that the Guadalupian and Leonardian Series were defined by lithostratigraphic units rather than chronostratigraphic markers such as fossils. In addition, the type areas for these units are over 150 miles apart (Furnish, 1973). The discovery of Leonardian brachiopods and ammonoids in the Road Canyon Formation (Cooper and Grant, 1966, 1972) and of Guadalupian fusulinids in the Road Canyon and Cutoff Formations (Wilde, 1955, 1975) have led to dispute over the age of these formations. King speculated in 1942 that Adams et. al. (1939) was incorrect in correlating the basal Delaware Mountain Group with the basal Word Formation (Road Canyon).

Furnish (1973) attempted to rectify this problem by correlating the major provinces of Permian carbonates to the Permian type area in the Soviet Union and to the Permian Reference Section of North America using ammonoids. The resulting system established the Amarassian, Capitanian and Wordian stages of the Guadalupian Series and the Roadian, Leonardian, and Aktastinian Stages of the Artinskian Series. This reduction of the Leonardian to stage rank has caused confusion among North American stratigraphers and has not been widely accepted by fusulinid workers (Cys, 1981, 1987). The Leonardian Series has been retained in North America (Cys, 1981, 1987, Ross, 1987), while the name Cathedralian (Ross, 1987) has been suggested for the proposed Leonardian Stage of Furnish (1973) (Figure 4).

Various fossils have been used to indicate either a Leonardian or Guadalupian age in rocks of the Delaware Basin and surrounding areas. The ammonoids Perrinites and Waagenoceras have been used to indicate Leonardian and Guadalupian strata respectively (Furnish, 1973, Adams, et. al. 1939). Both of these ammonoids have been recovered from the Road Canyon Formation. The brachiopod assemblage of the Road Canyon Formation was determined to be of a Leonardian rather than Guadalupian nature, (Cooper and

Stage	Series	Principle Formations*
Ochoan		
Guadalupian	Amarassian	Bell Canyon Sandstone
	Capitanian	Capitan Limestone Bell Canyon Sandstone
	Wordian	Word Formation Cherry Canyon Sandstone Brushy Canyon Sandstone
Leonardian	Roadian	Road Canyon Formation Cutoff Formation
	Cathedralian	Cathedral Mountain Formation Bone Springs Limestone
	Aktastinian	Skinner Ranch Formation Hess Formation
Wolfcampian		

*At North American Reference Sections

Figure 4. Middle Permian Series and Stage Names (Ross, 1987).

Grant, 1966), and the boundary between the two series was moved to the top of that formation. Cooper and Grant (1973) noted that while a great number of Leonardian brachiopod genera terminate in the Road Canyon Formation, a large number of Guadalupian genera are also found in this formation. The transition of primitive to advanced forms of <u>Parafusulina</u> mentioned by Adams et. al. (1939) in defining the Leonardian and Guadalupian Series' occurs at the base of the Road Canyon Formation (Wilde, 1975).

The boundary between the Neogondollela idahoensis - Neostreptognathodus sulcoplicatus, and Neogondolella serrata conodont assemblage zones which is found in the Road Canyon Formation (Wardlaw and Grant, 1987), has been suggested as a possible boundary between the Leonardian and Guadalupian (Grant and Wardlaw, 1984, Wardlaw and Grant, 1987). The first occurrence of Neogondollela serrata, which is the proposed boundary, is found in the middle of the Road Canyon Formation in the Glass Mountains (Wardlaw and Grant, 1987) and near the base of the Cutoff Formation in the Guadalupe Mountains (Behnken, 1975, this paper). Since this paper primarily uses conodonts as biostratigraphic indicators, the first occurrence of Neogondollela serrata (Clark and Ethington) is used as the base of the Guadalupian Series. The widespread distribution of the species, its ease of identification, and relative abundance compared to other possible index fossils makes N. serrata an excellent index fossil. The Roadian Stage, which has been defined lithostratigraphically, therefore straddles the Leonardian-Guadalupian boundary. Other possible index fossils should be considered as to how they correlate chronostratigraphically with the first occurrence of

Neogondolella serrata.

Field Work and Laboratory Methods

In the field, 30 sections were measured using a Brunton compass and Jacob's staff. Samples to be processed for micro-fossils and for thin sections were collected from these sections with a hand pick. Micro-fossil samples ranged from one to three kilograms in weight. Reconnaissance mapping was done using topographic maps and aerial photographs. Two geologic cross sections were later constructed from the map and measured sections.

In the lab, one kilogram micro-fossil samples were dissolved in 800 ml of formic acid diluted in approximately 8 liters of tap water. The insoluble residues were passed through 18 gauge and retained by 170 gauge sieves. The larger fraction of the residue was examined for macro-fossils. The fines were dried and examined under a binocular microscope at 12X magnification. All conodonts were picked for later identification. The best preserved conodonts were photographed under the Scanning Electron Microscope. These photographs were used for species identification.

Rock samples from which thin sections were to be made were sent to the ARCO lab. Included with these were several samples containing fusulinids from which oriented samples were made. Fusulinids were identified from these sections by Dr. Garner Wilde. Thin sections were examined for textural and compositional data under the petrographic microscope.

CHAPTER II

STRATIGRAPHY OF LAST CHANCE CANYON

Four formations are recognized in Last Chance Canyon. They are the Grayburg Formation, the Cherry Canyon Sandstone Tongue, the San Andres Limestone and the Cutoff Formation. The Grayburg caps the canyon walls throughout most of the area. The San Andres Limestone is laterally equivalent to the Cherry Canyon Sandstone Tongue, with the Cherry Canyon found only in the eastern one third of the study area. The San Andres Limestone extends over and under the Cherry Canyon, and includes a prominent tongue separating the Cherry Canyon into upper and lower units. The Cutoff Formation is also laterally equivalent to the San Andres Limestone, but this transition occurs west of the study area in the Brokeoff Mountains (Boyd, 1958).

Two other units, a sandstone and underlying limestone, which were not identified, lie below the Cutoff Formation. These have been called lower San Andres Limestone by Hayes (1959, 1964), and Sarg and Lehmann (1986). However they are lithologically distinct, and stratigraphically separated from the San Andres Limestone by the Cutoff Formation.

They may be the Glorietta Sandstone and Victorio Peak Limestone which occupy the same stratigraphic positions on the west face of the Guadalupe Mountains. Unfortunately no fossils were obtained from these units and hence no positive correlation is possible here. Plate 1 (in pocket) is a geologic map of the Last Chance Canyon area showing all formations and the field units delineated in the Cutoff Formation.

Pre-Cutoff Formation Strata

The oldest formation exposed in Last Chance Canyon is an unidentified limestone. It is exposed at the base of a cliff on the west side of Last Chance Creek in the southwest 1/4, section 32, T23S, R22E. near the mouth of Baker Pen Draw. The limestone forms the floor of the canyon in this area and, except for the stream bank, is covered by recent stream deposits and vegetation. At this location only 3 meters of the unit are exposed. This unit consists entirely of a dense, massively bedded medium grey lime mudstone.

Located above the limestone is a distinct unit composed of sandstone and sandy dolomite. It forms the floor of Last Chance Canyon in most of the study area. This unit is uniformly 55 feet thick. The lower portion is dominated by sandy dolomite which contains silicified burrows. The upper portion is mostly medium to thick bedded sandstone. The medium bedded sandstone is very resistant and contains spherical chert nodules up to 4 cm in diameter. The thicker beds have large trough-like bedforms, suggesting large scale trough crossbedding, though no actual cross bed sets are visible.

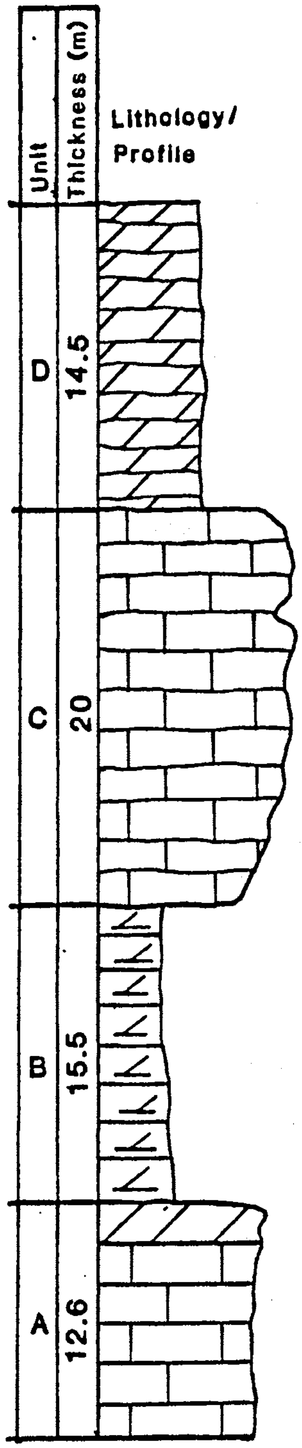
Cutoff Formation

The strata lying above the unidentified sandstone are herein, assigned to the Cutoff Formation. This assignment is based on biostratigraphic and lithostratigraphic correlation of sections measured in Last Chance Canyon with a section measured on Cutoff Mountain near the type section of the Cutoff Formation. On the west face of the Guadalupe Mountains, the base of the Cutoff Formation is an erosional unconformity on the Bone Springs Formation and the Victorio Peak Limestone (Harris, 1982). In Last Chance Canyon the lower surface of the Cutoff Formation, which shows no evidence of erosion, is interpreted to be a disconformity. In this paper the Cutoff Formation, in Last Chance Canyon, is divided into four field units designated in ascending order A, B, C, and D. The field units are easily distinguished by their lithology, color, and weathering profile and can be correlated with similar units at the type section of the Cutoff Formation. Figure 5 (p. 21) is a generalized section through the Cutoff Formation in Last Chance Canyon that illustrates the field units.

Field Units in Last Chance Canyon

Unit A. The lowest unit of the Cutoff Formation is a limestone. It is about 12.6 meters thick throughout the area. This unit is a dense mudstone having few features other than sparse fossils visible on some bedding planes. The rock is uniformly medium grey in color, dark grey on a fresh surface. Bedding is even, with all beds being about 25 centemeters thick. In Baker Pen Draw and the upper part of Roberts Canyon these grey mudstones become increasingly dolomitic. Their color changes from grey to buff tan. Bedding becomes more indistinct and irregular and the unit takes on a more massive appearance.

There is a thin black shale near the base of unit A which yields conodonts, ostracodes, and fusulinids. The upper meter of unit A is a fossiliferous dolowackestone with a silicified fauna which includes fusulinids, gastropods, brachiopods, corals, and trilobites. This dolowackestone serves as a good marker where unit A is exposed.



Description

Silty dolo-wackestone containing abundant fossil fragments and Ophiomorpha burrows.

Wackestone containing abundant sand sized fossil fragments and Ophiomorpha burrows. Irregularly bedded. Upper surface is channeled. Lower 2 meters may contain intraformational conglomerates with clasts up to 10 cm in diameter.

Dolomitic shales and mudstones.

Mudstones and wackestones containing fusulinids crinoids, bryzoa and trilobites. Upper meter is a dolo-wackestone-packstone.

Figure 5. Generalized Section of the Cutoff Formation in Last Chance Canyon

Unit A is interpreted to be a subtidal normal marine shelf limestone deposit. The upper beds of the unit have a more diverse fauna and are fossil rich compared to the rest of the unit. Fossils on the upper surface of unit A show little evidence of transport, with delicate bryzoa and trilobites up to 3 cm in length being well preserved. Beds just below the top surface are fusulinid/crinoidal packstones composed of transported grains. The presence of these beds may indicate increased circulation and more normal marine water conditions during deposition of the top beds of unit A than during deposition of the rest of the unit.

Basinward of Last Chance Canyon, the lower Cutoff Formation is a laminated lime mudstone with few fossils. Harris (1982) has interpreted this to indicate anoxic water conditions in the basin during deposition of these rocks. These abnormal basin water conditions encroached upon the shelf, resulting in less than normal oxygen content and therefore a restricted fauna. Harris (1982) notes that the upper surface of his unit 1 in the basin, which is unit A in this study, contains some fossils, indicating more normal marine conditions than in the lower part of the unit. Harris' observations and interpretations indicate a trend, which if continued further onto the shelf to a position such as that occupied by Last Chance Canyon matches the distribution of fossils in Unit A at Last Chance Canyon.

Unit B. The second unit of the Cutoff Formation in Last Chance Canyon is a shaly laminated dolomicrite. Unit B ranges from 6 to 18 meters in thickness. Its base is uniform on the fossiliferous marker bed of unit A. Where unit B is protected by overhangs, it weathers as a cliff with bedding well exposed and preserved. The even beds are 20 to 25 centemeters thick and are separated by thin shale stringers. The rock is greyish brown in color in the center of exposed beds but is a yellow brown along the bed boundaries. On a fresh surface the rock is a dark grey. Where unit B is not well protected, it weathers as a slope. In these areas the fissile nature of the rock is more evident. The degree of fissility ranges from very fine (almost papery) to nonfissile. Generally the fissile beds are darker. Fissile laminae and small-scale bedding surfaces are irregular and are bounded by bed sets having parallel bedding surfaces. In the southeast part of the study area the upper 3 meters of unit B is a black mudstone which weathers to form a deep recess beneath unit C. This mudstone is not fissile but rather weathers into coarse (5-10 cm) angular rubble which covers the slope in the recess.

Rock from unit B does not readily dissolve in formic acid. This is may be due to a high clay content and the low porosity and permeability of the rock.

In Last Chance Canyon, above the mouth of Baker Pen Draw, unit B reaches its maximum thickness of 18 meters. Here the lower part contains 10 irregular beds containing fusulinids and other unidentifiable fossil fragments in a black shaly matrix. These beds are from 1 to 8 centemeters thick and extend the width of the outcrop (25 meters), though they are broken into lenses from 15 centemeters to 5 meters in length. The beds are contained within the thicker shale beds typical of the unit and have irregular upper and lower surfaces. They may be separated by several beds which do not contain fossil debris. The interval containing the fusulinid beds is about 3 meters thick, with the fusulinid beds spaced 20 to 40 cm apart. The only other fossils observed in unit B were a few isolated brachiopods in the upper 5 meters of the unit.

Unit B thins toward the east even where its upper surface is conformable. The fusulinid rich beds are not found in the eastern part of Last Chance Canyon, where unit B is thinner. This indicates that unit B is gently downlapping onto Unit A. Sarg and Lehmann (1986) also concluded that unit B downlaps onto unit A.

Petrographic examination of the lighter colored mudstones revealed the rock to be a dolomicrite in which secondary intracrystalline porosity has been filled by microcrystalline calcite (Figure 6). The rock had a very dark dirty appearance which is due to the presence of clay particles concentrated in irregular laminae. About one percent of the rock is taken up by oil-filled pores. This accounts for nearly all of the porosity in this rock. No thin sections were made in the black mudstones or fissile shales.

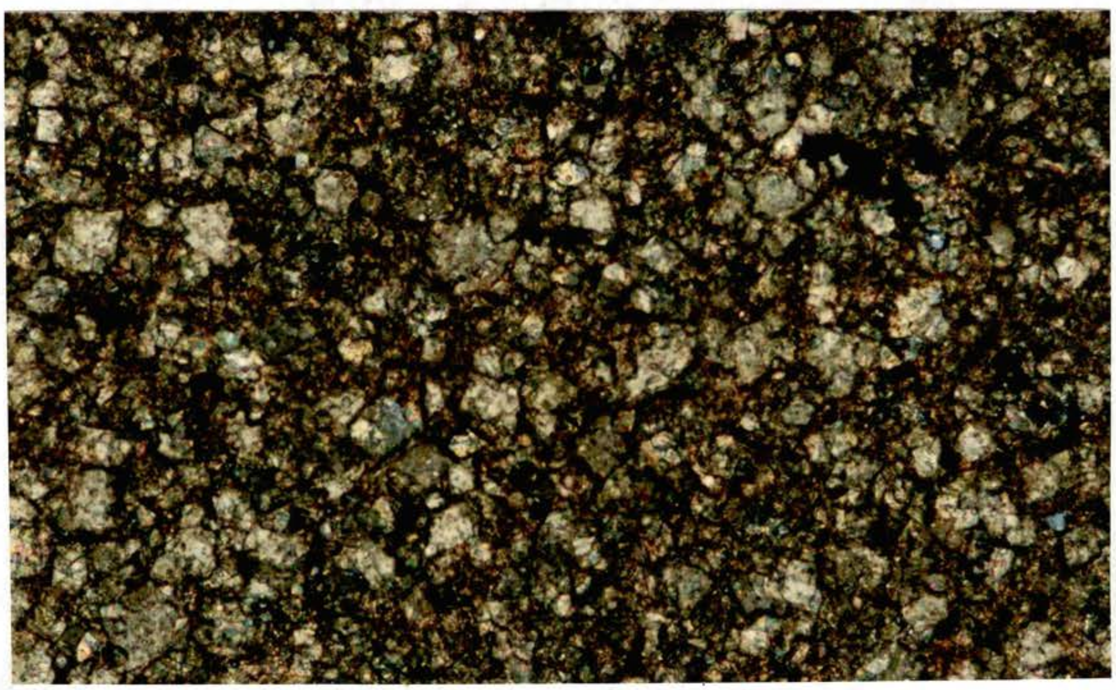


Figure 6. Photomicrograph of Sample from Unit B Taken Under Crossed Polarized Light. Field of the Photo is .3 mm Across.

Unit B is interpreted to be a deep-water carbonate deposited by density flows and hemipelagic sedimentation. The only sedimentary structures in unit B are the irregular laminae observed in thin section, the irregular bedding pattern within the parallel bed set boundaries, and the possibly graded fossil-rich beds. This indicates episodic deposition in a current, possibly by a bottom-hugging density current. The poor quality of the sedimentary structures prevents analysis of the depositional currents. Since dolomitization has obscured most of the original rock texture very little more can be said about the sedimentology of unit B. The fusulinid-rich beds in the lower part of the unit indicate that bottom currents were capable of transporting carbonate clasts up to 3 mm in diameter. The presence of clay-sized particles indicates that the energy in this depositional environment was variable. The black mudstones in the southeast part of the study area may be hemipelagic in origin as they show no evidence of current deposition.

Unit C. Unit C is a cliff-forming dolomitic lime wackestone to limy dolomicrite that ranges in thickness from 0 to 90 feet. With the exception of two conglomerates near the base of the unit, unit C is a medium grey dolomitic lime wackestone containing sparse silicified corals, brachiopods and Ophiomorpha burrows up to 3 cm in diameter. Fusulinids are abundant in the upper 2 meters of unit C on the north wall of Wilson Canyon but are not found anywhere else in this unit. The rock commonly has a patina which obscures bedding and gives the unit a massive appearance. Unit C may thin from 60 feet to 0 in less than 100 yards. Unit C is divided into two subunits: C1 and C2. C2, which is less than 5 meters thick, the highest. Bedding in units C1 and C2 is very irregular and wavy. Where unit C thins, C1 is draped by C2 which cuts into unit B. In areas where unit C is thickest, unit C1 lies conformably on unit B. Units B and C thicken and thin together, though the change in thickness is more drastic in unit C. Where the two units are thinnest, their boundary is the erosional surface beneath C2. This erosion surface may have over 30 meters of relief and may be marked by conglomeratic deposits of less than one meter in thickness in the deepest part of the erosional trough.

The conglomerates are best displayed in Last Chance Canyon about one half mile above the Sitting Bull Falls road (center, section 33, T23S, R22E), and in the upper part of Roberts Canyon in the northeast part of the study area (sec 1/4, ne 1/4, sec. 31, T23S, R22E). The conglomerates are quite distinct from the rest of unit C and are found only where unit C2 has cut through C1 and into unit B. In Roberts Canyon, the conglomerate is clast supported and contains clasts up to 6 inches in diameter which contain abundant cephalopods, brachiopods and other macrofossils (Figure 7, p. 29). The Last Chance Canyon conglomerate is 12 inches thick. It contains clasts from 1/2 to three inches in diameter and is mud supported. Neither the matrix or the clasts are distinct from the rest of unit C. This conglomerate has a leopard rock appearance (Figure 8, p. 29). A similar texture is observed in the rest of unit C but is limited to isolated patches which do not extend laterally. Subjacent to the conglomerate in Last Chance Canyon is a dense featureless mudstone. It extends for 50 feet in the deepest part of the erosional cut and has a coutinuous stringer of chert 1/4 inch thick on top of it. The maximum thickness of this mudstone is 1 meter. In both Roberts and Last Chance Canyons the conglomerates are overlain by C2 beds which, in Last Chance Canyon, are irregular and contain small stacked concave-upward channel-forms up to 10 meters across.

Petrographically the wackestone is composed of sand sized grains of skeletal origin floating in a dolomicrite matrix (Figure 9, p. 33). Calcite grains account for about 55 percent of the rock. The rock has a porosity of

Figure 7. Conglomerate at the Base of Unit C in Roberts Canyon

Figure 8. Conglomerate at the Base of Unit C in Last Chance Canyon

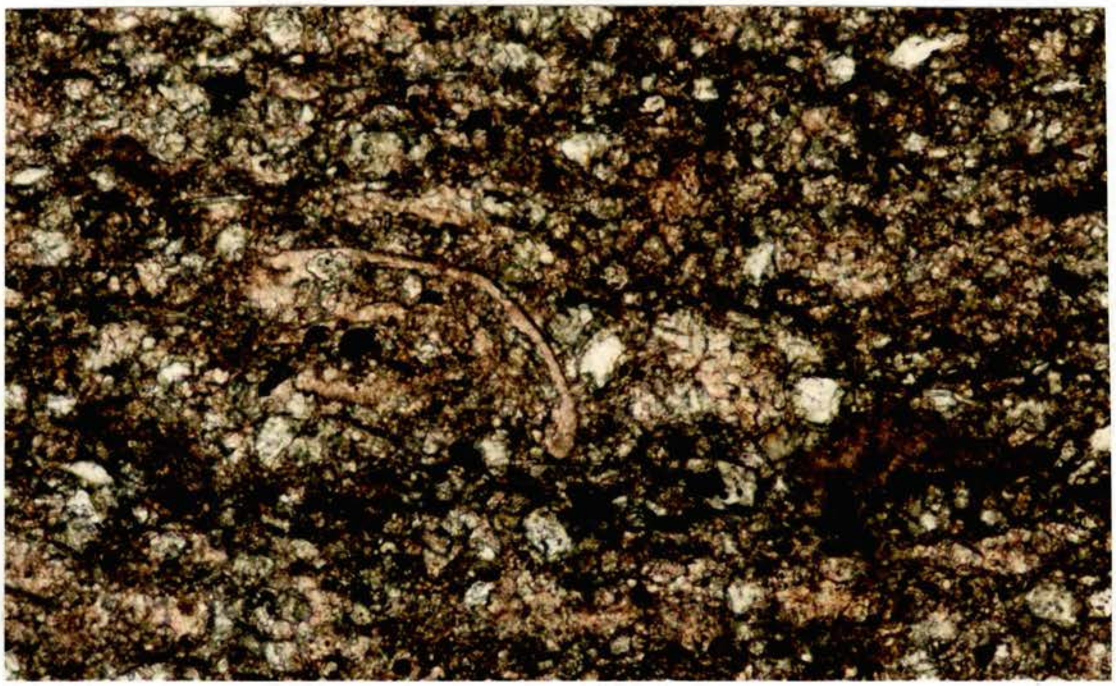


Figure 9. Photomicrograph of sample from Unit C Taken Under Crossed Polarized Light. Field of Photo is .3mm Across

2 percent with most of this filled by oil. Secondary calcite, which has filled in the intracrystalline secondary porosity, accounts for 10 percent of the rock. In some zones dolomite has replaced both the matrix and the grains making the rock a dolomicrite. It is assumed that the original texture of the dolomicrites was similar to that of the wackestones. The upper contact with unit D is conformable where unit C is thicker than 20 m, but is erosional where unit C thins. Unit D drapes over and onlaps against the sides of channels cut into unit C. Figure 10 demonstrates the geometry of the unconformity

between units B, C, and D.

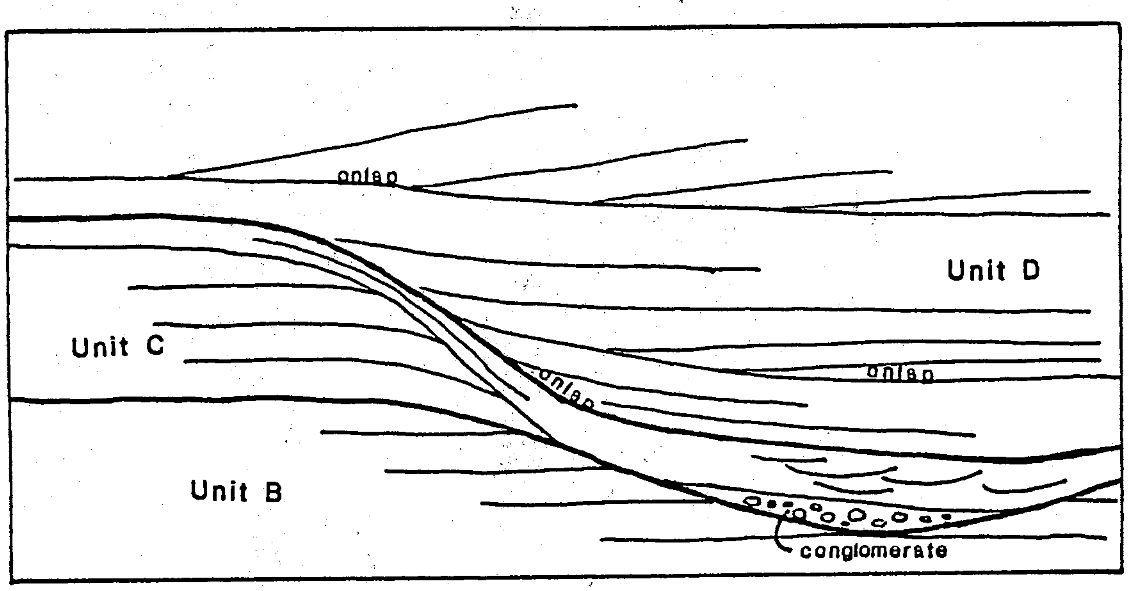


Figure 10. Relationship of Bed Surfaces Between Units B, C, and D.

Unit C is interpreted to be an upper slope deposit resulting from carbonate mud and skeletal debris being shed from higher on the slope and from the shelf. The presence of Ophiomorpha burrows indicates that water conditions were favorable for marine organisms however. Sedimentation rates may have been such, however, that most benthic organisms could not survive. Brachiopods and rugose corals are the only common fossils in unit C and these are widely spaced. They may have been transported from higher on the slope with the rest of the sediment.

The areas where unit C thins are interpreted to be submarine channels cut into the unit contemporaneously with its deposition. Four such channels are identified in the study area. They are all parallel and trend in a southeasterly direction. The channels are numbered 1, 2, 3 and 4 from east to west. The largest is the easternmost; only its core is exposed. This channel, identified as channel 1, is exposed in the north wall of Last Chance Canyon below the mouth of Wilson Canyon. The west wall of Last Chance Canyon between Wilson and Roberts Canyons gives a cross sectional view of the west side of channel 2 (Plate 2, in pocket). Channel 2 is also exposed in Roberts Canyon which runs parallel to it. The third channel (channel 3) is seen in cross section in the west wall of Last Chance Canyon below the mouth of Baker Pen Draw. The east bank of Channel 3 is exposed in the south wall of Last Chance Canyon opposite the mouth of Roberts Canyon. The fourth channel (channel 4) runs up Baker Pen Draw and Last Chance Canyon in the western part of the study area. Plate 3 shows the location of the channels in map view.

Channels 1 and 2 are the only channels in which conglomerates were observed. The conglomerate in Last Chance Canyon may be composed of clasts derived from unit

C. The conglomerate in Roberts Canyon is composed of clasts that were not derived from unit C or any other rock exposed in Last Chance Canyon, but were carried in from some shelfward facies. Channel 3 contains onlapping channel fill sediments of unit C2 and unit D. Channel 4 is obscured by modern canyon cutting. It is deeper than channel 3 but seems to otherwise be similar.

Unit D. Unit D of the Cutoff Formation is a dolomitic lime mudstone and wackestone which onlaps onto unit C. In Channel 2, which cuts through unit C, Unit D comes in contact with unit B. In this channel, unit D can be divided into two subunits separated by a thin shale layer. Below the shale, unit D contains silt, very fine sand sized quartz, and sand sized carbonate grains totaling less than five percent of the rock. Above the shale, the grain content of the rock ranges between 10 and 20% except where dolomitization has masked grains. Between the mouths of Roberts and Wilson Canyons the thin shale in unit D marks an onlap surface. However, neither the shale nor this onlap surface are recognized elsewhere in the study area. Unit D contains at least three intraformational onlap surfaces which cannot be traced or correlated reliably

In Last Chance Canyon below the mouth of Roberts Canyon, unit D is bounded on top by the Cherry Canyon

Sandstone. Here unit D is about 40 ft thick. Above the mouth of Roberts Canyon, where the Cherry Canyon is no longer present, the top unit D is placed at the downlap surface which continues from the base of the Cherry Canyon. Where this surface cannot be identified, unit D can be distinguished from the San Andres Limestone only by the presence of intraformational onlap surfaces.

Both the Cherry Canyon Sandstone and the Cutoff Formation are facies equivalents of the San Andres Limestone (Boyd, 1958). The transition from the San Andres of the shelf to the Cherry Canyon and Cutoff of the shelf edge and slope is gradual, and occurs first in the higher beds (Boyd, 1959). Generally the upper San Andres beds form vertical cliffs, whereas the beds of Cutoff unit D and their equivalents in the San Andres form slopes. The base of the cliffs do not follow a single bed but do seem to stay in the same general stratigraphic position. This may be controlled by some variation in the lithology of the two units.

Unit D is interpreted to be a clastic deposit composed of carbonate sand and mud. These onlapping sediments are backfilling into channels cut into unit C.

Plate 4 (in pocket) is a cross section of the Cutoff Formation in Last Chance Canyon.

<u>Correlation with Cutoff Mountain Section</u>

The type section for the Cutoff Formation was originally defined by King (1942). This section was redescribed by Harris (1982) who was able to define and correlate several field units in the Cutoff Formation on the west face of the Guadalupe Mountains. The section measured in this study is near the type section, section N of Harris. Figure 11 is a comparison of the Cutoff Mountain section measured in this study and Harris' section N. Harris' correlation units 1, 2, 3, 4, and 5 are all identifiable in the section measured for this study, however, as in Harris' section N, correlation unit 3 is not distinct from unit 2 below and 4 above. In this paper, Harris' unit 1 is identified as unit A, units 2, 3 and 4 are identified as B. Harris' unit 5 is correlated with units C and D.

Unit A, on Cutoff Mountain, is correlated with unit A in Last Chance Canyon based on conodont biostratigraphy (this paper). Unit A on Cutoff Mountain is a dark grey lime mudstone bounded above and below by unconformities. On Cutoff Mountain this unit contains very few fossils whereas in Last Chance Canyon fossils are abundant in the upper meter. This is due to the basinward position of Cutoff Mountain relative to Last Chance Canyon and to the poor water conditions in the basin (Harris, 1982), compared with the shelf.

On Cutoff Mountain, unit B is composed of, in ascending order, deep water carbonaceous and siliciclastic black shale, deep water limestones interbedded with shale, and another interval of black shales similar to the basal one. They correlate with the carbonaceous shales and mudstones in Last Chance Canyon which were deposited in deeper water than the underlying sediments. The facies change from the mudstones of Last Chance Canyon to the shales of Cutoff Mountain is due again to the basinward position of Cutoff Mountain relative to Last Chance Canyon.

Units C and D cannot be distinguished on Cutoff Mountain. At Cutoff Mountain, the upper Cutoff Formation is a limestone and dolomite containing fossils only in the lower 5 meters. No channels or onlapping are observed in this limestone which is 32 meters thick. Figure 17 shows the correlation of the Cutoff Formation from Last Chance Canyon to Cutoff Mountain.

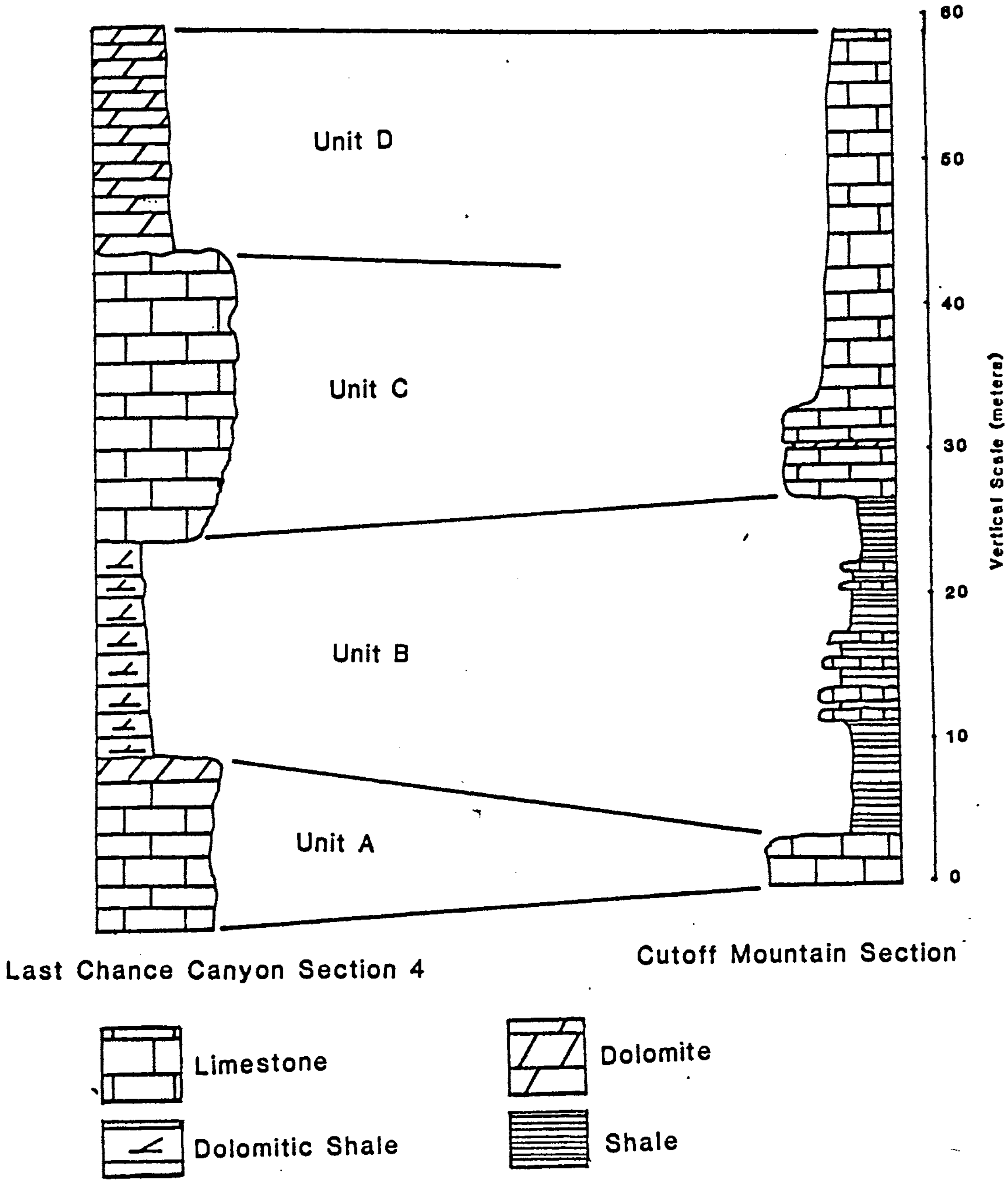


Figure 11. Correlation of Cutoff Formation from Last Chance Canyon to Cutoff Mountain

Cherry Canyon Formation

In the eastern third of the study area, the Sandstone Tongue of the Cherry Canyon Formation overlies the Cutoff Formation. The Cherry Canyon Sandstone Tongue in Last Chance Canyon has been divided into two informal units based on bed geometries (Sarg and Lehmann, 1986). The lower unit is called the lowstand delta, and has been interpreted to be a lowstand clastic wedge deposited in a shallow submarine canyon or estuary Sarg (1986-1988).

The upper Cherry Canyon Sandstone is called the highstand delta and is interpreted as a progradational highstand deposit (Sarg and Lehmann, 1986, Sarg, 1988). Plate 5 shows the Cherry Canyon Sandstone Tongue on the north wall of Last Chance Canyon.

<u>Lowstand Delta</u>

The lowstand delta is predominantly a sandy limestone and dolomite. It contains abundant fossils in some beds. Most fossils are preserved only as molds. The lowest beds of the lowstand delta are sandy dolomites similar to unit D of the Cutoff Formation. These beds terminate at a onlap surface at the top of the Cutoff. Above the dolomite beds are several sandy limestone beds one to three feet thick.

These beds have a massive appearance and weather like sandstones. Petrographic examination reveals that the sand content of the rock is less than 40%. The lowstand delta is exposed on the north wall of Last Chance Canyon and in Wilson Canyon. It grades laterally into the San Andres Formation to the west in Wilson Canyon. The uppermost beds are succeeded by the downlapping highstand delta.

Highstand Delta

The upper part of the Cherry Canyon Sandstone Tongue, identified as the highstand delta, is a quartz sandstone, grayish-orange in color, fine grained, and indistinctly bedded (Sarg, 1986). The highstand delta is about 85 meters thick at the eastern margin of the study area (Sarg, 1986), and grades laterally into the San Andres Formation in Wilson Canyon. The highstand contains few fossils, but fusulinids were collected and identified from the lower part of the unit. The highstand delta differs from the lowstand delta in that it is more quartz rich, contains fewer fossils, and downlaps conspicuously onto the lowstand.

San Andres Formation

The San Andres Formation in Last Chance Canyon is a lateral facies equivalent to unit D of the Cutoff Formation and to the lowstand and highstand deltas of the Cherry Canyon Sandstone Tongue. The San Andres extends across the top of the Cherry Canyon Sandstone Tongue, and tongues of the San Andres extend into the Sandstone Tongue on the north wall of Last Chance Canyon (Hayes, 1959). East of the study area, the San Andres thickens in to form large foreset beds which parallel those in the Cherry Canyon. These foresets toplap into the overlying Grayburg Formation. The San Andres Formation is composed of limestones and dolomites containing abundant silicified burrows and other fossils in all but the uppermost part. The upper San Andres does not contain chert but does contain abundant fusulinid grainstones and oolites (Sarg, 1986).

Attempts have been made to separate the San Andres Limestone into an informal upper member and a lower cherty member (Hayes, 1959) and into an upper, middle, and lower member (Sarg and Lehmann, 1986). In this study the San Andres Formation is divided according to its lateral equivalents, ie. the Cutoff Formation, or the Cherry Canyon Sandstone Tongue.

Grayburg Formation

The uppermost formation exposed in Last Chance Canyon is the Grayburg Formation. It generally forms the rim of the canyon and can be distinguished by a prominent white sandstone bed a few feet above the base of the formation. The Grayburg Formation was not directly observed as a part of this study.

CHAPTER III

BIOSTRATIGRAPHY OF THE CUTOFF FORMATION

The Cutoff Formation at both Last Chance Canyon and Cutoff Mountain was sampled for conodonts in an attempt to establish biostratigraphic equivalence between the two sections. The conodonts were also studied to establish a correlation between the Guadalupe Mountains and the Road Canyon Formation of the Glass Mountains. The Last Chance Canyon section was also sampled for fusulinids which were used to correlate this section with previously collected sections in the Glass Mountains and the Guadalupe Mountains. No fusulinids were observed at the Cutoff Mountain section.

Conodonts

Conodonts were present in low abundances in most units of the Cutoff Formation at Last Chance Canyon and Cutoff Mountain. Table I shows the distribution of conodonts recovered from the Cutoff Formation in Last Chance Canyon. Table II shows the same information for the Cutoff Mountain section.

TABLE I

CONODONT DISTRIBUTION IN
LAST CHANCE CANYON
SECTIONS

Unit & Sample	Neogondolella idahoensis	Neogondolella gracilis	Neogondolella serrata	Hindeodus excavatus	Xaniognathus abstractus
Unit D					
LCD-13		1	8	6	41
LCD-12		6	66	1	8
LCD-11		1		6	16
LCD-10				1	
LCD-9				5	
LCD-8				14	
LCD-7			1	2	
LCD-6				2	
LCD-5	1		4	3	1
LCD-4				42	
LCD-3				8	
LCD-2				4	
LCD-1				3	
Unit C					
LCC-8		1		15	
LCC-7				17	
LCC-6				13	
LCC-5				15	
LCC-4				2	
LCC-3				2	
LCC-2	1		1	2	
LCC-1				47	
Unit A					
LCA-2	4				
LCA-1	12	6	16		2

TABLE II

CONODONT DISTRIBUTION IN CUTOFF MOUNTAIN SECTION

Unit & Sample	Neogondolella idahoensis	Neogondolella gracilis	Neogondolella serrata	Hindeodus excavatus	Xaniognathus abstractus
Unit C/D					
CM-7			1		
CM-6			5	2	7
CM-5			16		3
CM-4			6		3
CM-3	1	1		3	
Unit B					
CM-2		1	5	3	1
Unit A					
CM-1	10	4		2	6

The three most common genera of conodonts in the Formation in Last Chance Canyon are Neogondolella, Hindeodus, and Xaniognathus. While all three might be used to establish paleoenvironmental conditions, only Neogondolella can be used for stratigraphic correlation and relative age dating. Hindeodus and Xaniognathus did not evolve fast enough at this time to be of use. These species are figured and described in Chapter 6 of this paper. Figure 12 shows the ranges of conodont species in the Cutoff Formation.

Conodont Biostratigraphy

Three species of the conodont genus Neogondollela were recovered from the Cutoff Formation. N. idahoensis and N. gracilis were recovered from units A and B at the Cutoff Mountain section. N. serrata was recovered from all units of the Cutoff Formation except unit A at Cutoff Mountain and from all but unit B in Last Chance Canyon from which no identifiable conodonts were recovered. Specimen of N. idahoensis were most abundant in unit A at both field areas. All specimen of N. idahoensis which were found above unit A in Last Chance Canyon were broken and abraded, showing evidence of transport. N. gracilis is also more common in unit A, but its distribution is more a function

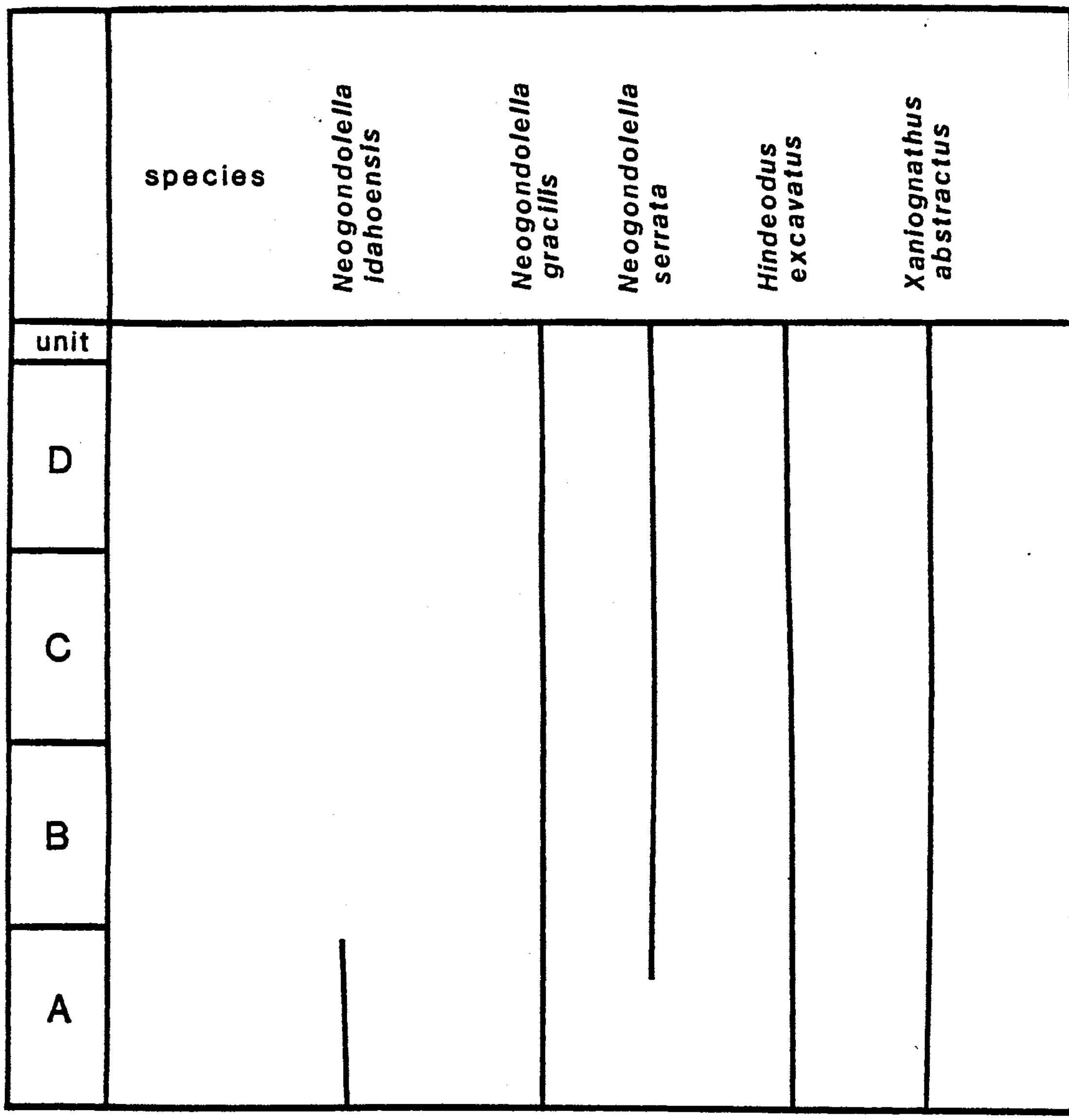


Figure 12. Conodont Ranges in the Cutoff Formation.

of population size than stratigraphic position since larger conodont populations were recovered from this unit.

The first occurrence of N. serrata marks the base of the Guadalupian Series (Grant and Wardlaw, 1984). Wardlaw and Grant (1987) have identified the boundary between the N. idahoensis and N. serrata zones in the type section of the Road Canyon Formation in the Glass Mountains. The first appearance of N. serrata is found about one third of the way up in the type section of the Road Canyon Formation (Wardlaw and Grant, 1987). The boundary occupies a similar position in other Road Canyon sections in the Glass Mountains. In the Cutoff Formation, this boundary is found in the lower part of unit A. A sample from the basal two meters of unit A on Cutoff Mountain yielded N. idahoensis (9 elements) and N. gracilis (4 elements). A sample from the upper meter of unit A on Cutoff Mountain yielded no conodonts. A sample taken about eight meters from the top of unit A in Last Chance Canyon yielded N. serrata (14 elements), N. idahoensis (12 elements), and N. gracilis (6 elements). A sample from the top of unit A in last Chance Canyon produced only N. serrata. N. gracilis has been shown to exist concurrently with N. serrata in the Mead Peak Member of the Phosphoria Formation in Idaho and Wyoming (Wardlaw and Collinson, 1984). The Cutoff

Formation was therefore deposited at the same time as the upper part of the Road Canyon Formation. The Leonardian-Guadalupian boundary occurs within unit A of the Cutoff Formation.

Paleoenvironmental Implications of Cutoff Conodont Assemblage

The presence of *Hindeodus* and *Xaniognathus* in the Cutoff Formation along with *Neogondollela* has some paleoenvironmental implications. Wardlaw and Collinson (1984) demonstrated 5 biofacies based on the distribution of *Hindeodus*, *Xaniognathus*, *Neostreptognathodus*, *Merrilina/Stepanovites*, and *Neogondollela* in the Phosphoria Formation of Idaho and Wyoming. The biofacies are, from near shore to furthest off-shore:

1) No conodonts.
2) *Hindeodus* only.
3) *Hindeodus* and (or) *Neostreptognathodus* and or *Merrilina/Stepanovites*.
4) Any of the above but either *Neogondollela* or *Xaniognathus*.
5) *Neogondollela* and *Xaniognathus*.

All four units recognized in the Cutoff Formation yielded Neogondollela, Hindeodus and Xaniognathus. Several fragments which may be Merrilina or Stepanovites were also recovered but their identity is uncertain. No neostreptognathodids were found in the Cutoff Formation at either location, although Fred Behnken has reported Neostreptognathodus from unit B and C in Last Chance Canyon (pers. com. 1989). Despite the fact that the distribution of conodonts in the Cutoff Formation does not fit exactly with the Wardlaw and Collinson model, the relative abundances of the various genera do suggest some parallels. The uppermost fusulinid rich beds of unit D contain Xaniognathus and Neogondolella in relatively high abundance along with a few hindeodids. The lower beds in unit D are dominated by hindeodids. Unit D on Cutoff Mountain is dominated by Neogondolella and Xaniognathus. Unit C is dominated by Hindeodus in Last Chance Canyon along with a few specimen of Neogondolella. The thin conglomerate at the base of unit C in Roberts Canyon was especially rich in Hindeodus and contains no other conodonts. The yields from the other units were too small to be of value. If the distribution and relative abundance of these genera are considered sample by sample rather than unit by unit, no meaningful conclusions can be drawn. Some samples contained no conodonts whereas adjacent samples yielded tens of elements. This is due to the small sample size (one kilogram) and the general scarcity of Middle Permian conodonts, rather than paleoenvironmental considerations. More thorough sampling, and larger samples may provide statistically significant populations.

With the data obtained, it can be said that units A and D in Last Chance Canyon and on Cutoff Mountain agree with Wardlaw and Collinson's biofacies 5 which is the furthest off-shore biofacies recognized. Unit C may represent deposition nearer to shore. The hindeodids found in the conglomerates in Unit C may have been transported offshore with the conglomerate clasts. On a ramp shelf margin biofacies such as those in the Wardlaw and Collinson model would be expected to be wider and less sharply defined than on a narrow shelf (Wilson, 1975).

Fusulinids

Several horizons in Last Chance Canyon contain fusulinids. These were sampled by the author and identified by Dr. Garner Wilde from polished slabs and oriented sections. Figure 13 (Garner Wilde, pers. com.) shows the distribution of the species identified. Wilde (pers. com.) identifies three informal fusulinid zones: PG-1, PG-2, and PG-3 in the interval sampled, which

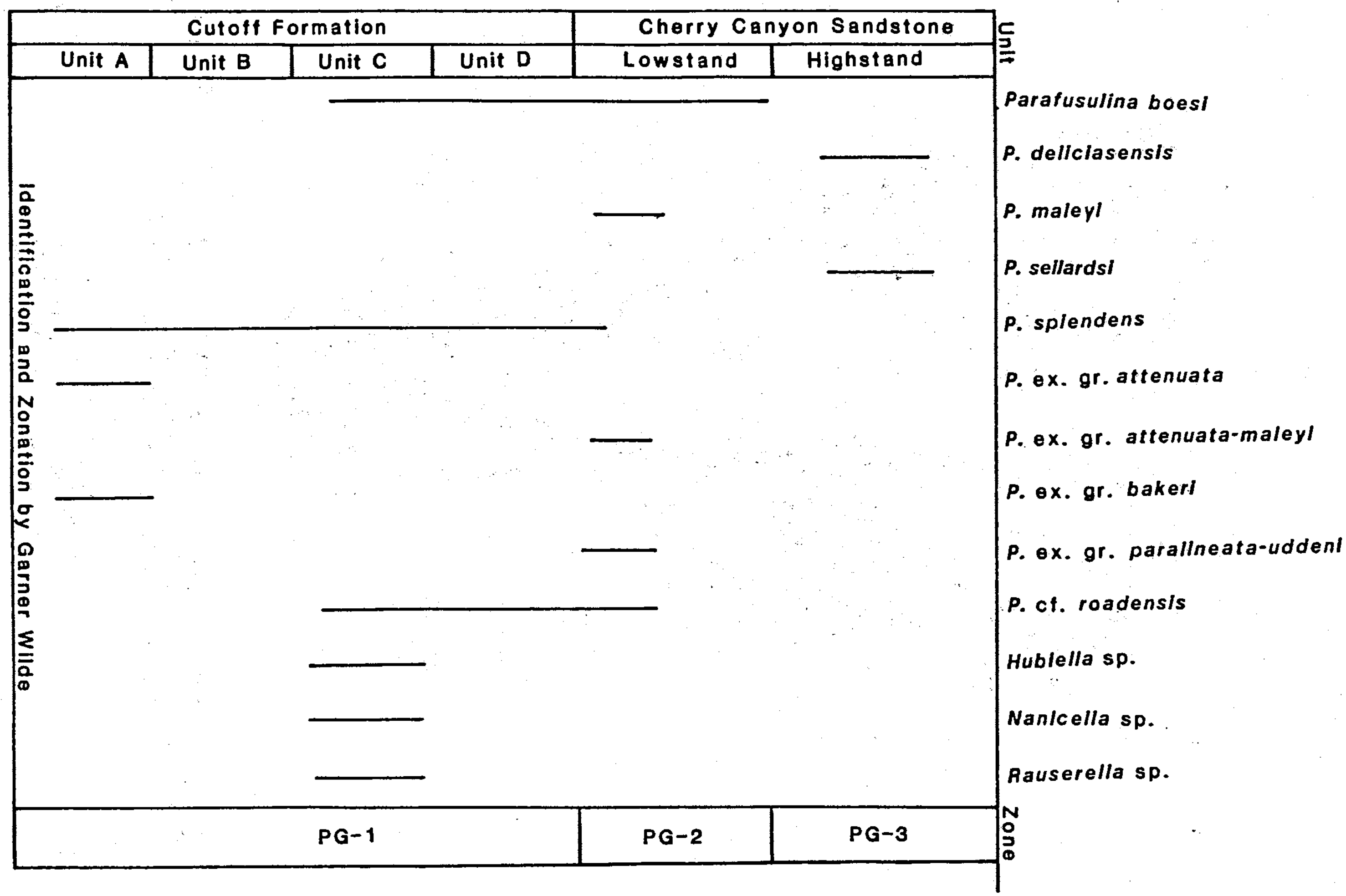


Figure 13. Fusulinid Ranges in Last Chance Canyon

includes the Cutoff Formation and the lower part of the Cherry Canyon Sandstone. The dominant genus of fusulinid in these samples is <u>Parafusulina.</u> Species of this genus indicates a Leonardian or Guadalupian age for these rocks (Adams, et. al., 1939).

<u>Fusulinid Distribution</u>

The dominant species from the Cutoff Formation and Cherry Canyon lowstand delta are <u>P. boesi</u> and <u>P. splendens.</u> These species were first identified in P. B. King's first and second limestone members of the Word Formation (Dunbar and Skinner, 1937). The first limestone member of the Word Formation, named the Road Canyon Member by Cooper and Grant (1964), and later upgraded to formation status (Cooper and Grant, 1966), is the type unit for the Roadian Stage. The Cutoff Formation in Last Chance Canyon contains a PG-1 fusulinid fauna similar to that of the Roadian Stage in the Glass Mountains (Wilde, pers. com.). Wilde identified <u>Parafusulina</u> ex. gr. <u>bakeri</u> from unit A of the Cutoff Formation which Dunbar and Skinner (1937) place in the middle Leonard based on samples taken from talus in the Glass Mountains. Wilde (pers. com.) states that <u>P. bakeri</u> "is Guadalupian rather than Leonardian as originally described". In addition to these fusulinids, Wilde (pers. com.) identified Parafusulina cf. roadensis, P. ex.gr. attenuata, P. splendens, P. boesi, Rauserella sp. Hubiella sp. Nanicella ? sp, P. ex gr. Paralineata uddeni and "Parafusulina n. sp. X" from the Cutoff Formation.

P. boesi and P. splendens have been identified from the San Andres Limestone on the Algerita Escarpment shelfward of Last Chance Canyon (Sarg, 1986) and from the Cutoff Formation near Bartlett Peak on the west face of the Guadalupe Mountains, basinward of Last Chance Canyon (Wilde, 1986).

Cherry Canyon Lowstand Delta

Samples from the Cherry Canyon "lowstand delta" (Sarg and Lehmann , 1986) are in Zone "PG-1 or PG-2" and are identified as "Roadian (?)" in age by Wilde. The lowstand samples contain P. boesi P. maleyi, P. cf. roadensis and P. ex gr. attenuata. P. maleyi is also found in the Brushy Canyon and Cherry Canyon Formations which are Wordian in age (Dunbar and Skinner, 1937).

Cherry Canyon Highstand Delta

The samples from the Cherry Canyon Sandstone Tongue above the lowstand delta are dominated by Parafusulina deliciasensis and P. sellardsi. P. sellardsi is recognized in the third limestone member of the Word Formation (Dunbar and Skinner, 1937). P. deliciasensis is known from the Cherry Canyon Formation in the Delaware Basin. Zone PG-3 includes the Cherry Canyon Sandstone above the lowstand delta. Wilde calls this zone "Middle Guadalupian", which coincides with the third limestone member of the Word Formation. These fusulinids mark a change in the fusulinid fauna from P. boesi-P. spendens to P. deliciasensis-P. sellardsi. This transition marks the boundary between the Lower Guadalupian (Roadian) and the Middle Guadalupian (Wordian), (Wilde, pers. com., 1988). In Last Chance Canyon, the top of the lowstand is a downlap surface (Sarg and Lehmann, 1986) which, according to Van Wagoner et. al. (1988), represents a period of non-deposition without erosion.

Leonardian-Guadalupian Boundary

The base of the Guadalupian Series has been defined in a variety of ways. The original definition (Adams, et. al., 1939) was by lithostratigraphic units and is not acceptable for use in the central Guadalupe Mountains. Methods using macro-fossils are largely unpractical in Last Chance Canyon since identifiable index macro-fossils were not observed. The two methods, one using fusulinids as suggested by Wilde (1955, 1977) and a second using conodonts suggested by Grant and Wardlaw (1984) both indicate that the Cutoff Formation in Last Chance Canyon lies at or above the base of the Guadalupian and is therefore Guadalupian in age. Wardlaw and Grant (1987), note that the concurrent zone of *Neogondolella idahoensis* and *N. serrata* is very thin in the Road Canyon Formation and that the base of this zone is the boundary between the Leonardian and Guadalupian Series. Wardlaw and Grant (1987) make no note of lithologic changes associated with the transition from *N. idahoensis* to *N. serrata.* Since no conodonts were recovered from the base of unit A of the Cutoff Formation in Last Chance Canyon it is impossible to state definitely where in unit A the series boundary lies. Harris (1982) places Unit 1 of section N, which is the equivalent to unit A of the Cutoff Mountain section in this study, in the Leonardian Series and places the boundary at the unconformity on top of unit 1 (unit A). *Neogondolella serrata* was not recovered from unit A on Cutoff Mountain and so that unit would be considered Leonardian under the Grant and Wardlaw (1984) scheme. However, *N. gracilis,* which is considered an upper Roadian conodont (Wardlaw and Collinson, 1984) was recovered from this unit. In addition, _N. idahoensis_, _N. gracilis_, and _N. serrata_ were recovered from the same sample in unit A in Last Chance Canyon. This suggests that the upper part of unit A is Guadalupian (upper Roadian) in age and that the Leonardian-Guadalupian boundary lies within this unit. All fusulinid data, as identified and interpreted by Dr. Garner Wilde (pers. comm. 1988), indicates that the Cutoff Formation in Last Chance Canyon is Guadalupian in age and is time equivalent to the Road Canyon Formation of the Glass Mountains. Again, no fusulinids were recovered from the basal part of unit A at either Last Chance Canyon or Cutoff Mountain, which could have helped establish the exact position of the Leonardian-Guadalupian boundary.

CHAPTER IV

SEQUENCE STRATIGRAPHY

Depositional Setting

The Cutoff Formation was deposited on an erosional surface developed on top of the Leonardian Victorio Peak-Bone Springs carbonate bank (Harris, 1982). The shelf to basin topography of the Cutoff Formation is most similar to a distally stepened ramp (J. F. Read, 1985). The ramp profile does not have a prominent slope break toward the shelf but does steepen near the basin margin at Bartlett Peak (Sarg, 1988). Harris deisgnates the shelf as the area from Bartlett Peak northward. The shelf margin, slope, and basin margin are located south of Bartlett Peak. The slope break (called the shelf margin by Harris) lies near the shelf edge of the underlying Bone Springs-Victorio Peak carbonate bank and below the progradational Capitan Reef shelf edge but basinward of the prograding Grayburg and Goat Seep shelf edges. Based on the backstepping relationship of shelf-to-basin sediments from Victorio Peak-Bone Springs deposition into San Andres-Cutoff deposition, inferred here from the work of Harris (1982) and Sarg and Lehmann (1986), the area of proximal ramp sedimentation during Cutoff deposition lay northeast of Last Chance Canyon, while the area referred to by Harris as the shelf is the broad ramp on which distal ramp sedimentation dominated.

Harris (1982) has interpreted that the basin water during Cutoff deposition was anoxic to dysaerobic. Such a condition would limit the production of carbonate to the proximal ramp where shallow water would be sufficiently oxygenated for biological activity. Reduced carbonate production in a subsiding basin would lead to the formation of a ramp-like profile as opposed to a platform with a steep margin such as the middle to upper Guadalupian reef systems.

Cutoff Depositional Sequences

The Cutoff Formation and Cherry Canyon Sandstone in Last Chance Canyon are examples of depositional sequences as defined by Mitchum, et al (1977). The upper surface of unit B has been interpreted to be a sequence boundary (Sarg and Lehmann, 1986, This paper) and units C, D and the Cherry Canyon lowstand delta to be lowstand deposits of a type 1 sequence (Sarg, 1988, Sarg and Lehmann, 1986, This paper).

Unit A of the Cutoff Formation is interpreted here to be a lowstand/transgressive autochthonous carbonate deposit on the distal ramp. Such a shallow water carbonate is deposited on the distal ramp when lowstands of sea level cause basin-ward a shift of shllow water facies (Sarg, 1988). Such autochthonous lowstand deposits are predicted to be micrite rich in a closed carbonate basin (Sarg, 1988). In the Cutoff Formation, unit A is a lime mudstone with the exception of the upper meter which is a packstone and wackestone. The packstone is interpreted to be a shallow water carbonate sand. The wackestone, which forms the upper surface of unit A, is composed of fusulinids, brachiopods, bryzoa, and trilobites which show no evidence of transport. This surface represents the maximum transgression in this sequence.

Unit B is interpreted to represent highstand sedimentation across the drowned lowstand bank. Unit B downlaps onto unit A (Sarg and Lehmann, 1986, This paper) and was deposited in deeper water as is indicated by the lithology of the two units. Harris (1982) has indicated that mudstones in the Cutoff Formation were deposited from suspension rather than as flow deposits, but that bottom currents capable of erosion and deposition of coarser material existed on the slope and shelf edge. Data from

Last Chance Canyon indicate that the mudstones of unit B were deposited by currents rather than from suspension. The equivalent mudstones and shales observed on Cutoff Mountain, are much more argillaceous than unit B in Last Chance Canyon and may reflect deposition from suspension basinward of the flow deposits. Cutoff Mountain is at the most shelfward extent of Harris' study area.

The contact between units B and C is a sequence boundary which is marked by a shift from deep water mudstones to shallower water, higher energy wackestones and conglomerates indicating a relative fall in sea level. The energy of this depositional environment was such that channels were cut into unit C contemporaneously with deposition. The deepest of these channels contain conglomerates, clasts of which originate from the shelf and from unit C itself. The upper bed of unit C in Wilson Canyon contains abraided fusulinids and rounded limestone clasts and is interpreted to be a debris flow deposit (Garner Wilde, pers. comm., 1988). Unit C correlates with all or part of the upper limestone unit on Cutoff Mountain which Harris designates as unit 5.

Unit D of the Cutoff Formation in Last Chance Canyon onlaps onto and backfills the channels cut into unit C The change from unit C to D marks the beginning of marine transgression as sediments begin to onlap up the slope. This continued during deposition of the Cherry Canyon lowstand delta (Sarg and Lehmann, 1986)

The lowstand/transgressive sediments of units C and D differ from those of unit A in that they are allocthonous in nature and reflect a higher energy depositional system. This may be due to an increase in the shelf to basin gradient during Cutoff deposition. The 30 to 40 meter thick distal ramp deposits of units A and B are facies equivalents of over 250 meters (Sarg, 1988) of proximal ramp deposits to the north. This is the result of nearly continuous carbonate production in the proximal areas, where water conditions remained favorable for biological activity, as compared to less than favorable conditions on the distal ramp. Water during post Cutoff deposition returned to more normal marine conditions and this allowed for increased carbonate production and consequent progradation of the carbonate shelf edge. Unit D may correlate with Harris' unit 5 on Cutoff Mountain, however, this correlation is uncertain.

A downlap surface exists at the top of the lowstand\transgressive package which includes units C, D, and the Cherry Canyon lowstand delta. Above this downlap surface is the progradational upper San Andres-Cherry

Canyon-Grayburg highstand facies. The Cherry Canyon Sandstone unconformably overlies the Cutoff Formation on the west face. The downlap surface at the base of the upper San Andres-Cherry Canyon highstand in Last Chance Canyon is interpreted to correlate with the erosional surface between the Cutoff Formation and the Cherry Canyon Sandstone on the west face. Figure 14 illustrates the sequence stratigraphy of the lower Guadalupian strata in the Guadalupe Mountains.

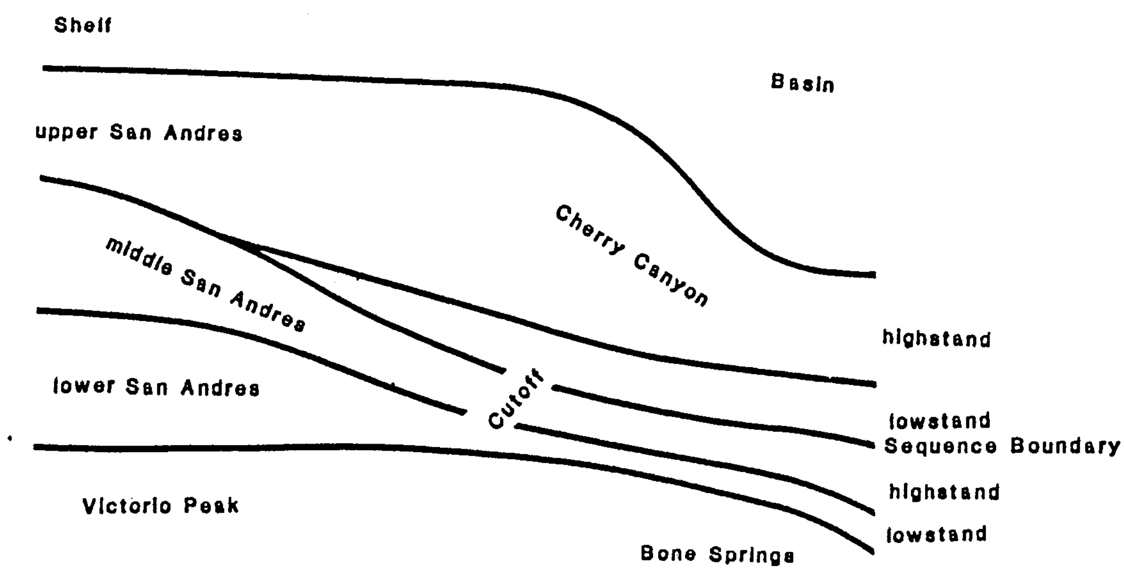


Figure 14. Lower Guadalupian Depositional Sequences in the Guadalupe Mountains.

CHAPTER V

CONCLUSIONS

The Cutoff Formation is divided into four lithologic correlation units labeled A, B, C, and D in ascending order. Unit A in Last Chance Canyon is shown to correlate biostratigraphically with the same unit on Cutoff Mountain. The occurrence of upper Leonardian and lower Guadalupian conodonts in the lower unit of the Cutoff Formation at both Last Chance Canyon and Cutoff Mountain, specifically *Neogondolella idahoensis* (Roadian, Leonardian) *N. gracilis* (Roadian, Guadalupian) and *N. serrata* (Roadian/Wordian, Guadalupian) indicates that the Leonardian-Guadalupian boundary lies within unit A of the Cutoff Formation. The same boundary has been placed in the Road Canyon Formation of the Glass Mountains in West Texas which is the type section of the Roadian Stage (Wardlaw and Grant, 1987).

Unit B is correlated lithostratigraphically since no conodonts were recovered from this unit in Last Chance Canyon. Unit B is a shaly dolomitic mudstone in Last Chance Canyon and a black calcareous shale on Cutoff Mountain.

Units C and D, which are mudstones and wackestones in Last Chance Canyon, are correlated with the upper unit of the Cutoff Mountain section which is also a lime mudstone and wackestone. The two units cannot be distinguished from each other on Cutoff Mountain. Unit D in Last Chance Canyon and unit C\D on Cutoff Mountain bear Neogondolella serrata, N. gracilis and the fusulinids Parafusulina boesi and P. maleyi.

The Cutoff Formation includes strata from two depositional sequences. Unit A is interpreted to be a lowstand and transgressive deposit, the upper surface of which is marked by a condensed section of benthic organisms. Unit B represents the highstand deposits of the same depositional sequence and is a deep water lime mudstone and shale. This sequence has been recognized shelfward on the Algerita Escarpment (Sarg and Lehmann, 1986) and is recognized in this study on the West Face of the Guadalupe Mountains at Cutoff Mountain. The correlation units in this system have been traced into the basin facies of the Cutoff Formation (Harris, 1982).

The contact between units B and C is recognized as a sequence boundary (Sarg and Lehmann, 1986, This paper). This boundary is recognized on the Algerita Escarpment (Sarg and Lehmann, 1986) and at Cutoff Mountain. The surface is marked in Last Chance Canyon by the change from highstand deep water shales and mudstones to lowstand mudstones and wackestones which have been incised by submarine channels. On Cutoff Mountain the surface is marked by the change from pelagic black shales (unit B) to nonlaminated carbonate mudstones (unit C).

Units C and D are interpreted to be lowstand and transgressive deposits of a depositional sequence. Unit C is a lowstand wedge deposit of mudstones and wackestones the upper surface of which has been channelized. Thin limestone conglomerates have been deposited in the largest channel observed. Unit D onlaps onto unit C and onlaps into the channels cut into unit C. This transgressive deposit is capped by the Cherry Canyon Sandstone lowstand delta (Sarg 1986) which is a sandy facies of the transgressive stage of this sequence.

The transgressive deposits are overlain by the downlapping Cherry Canyon Sandstone highstand delta (Sarg, 1986) which is part of a progradational facies that includes the upper San Andres Limestone in Last Chance Canyon and the lower Grayburg Formation on the West Face of the Guadalupe Mountains (Sarg, 1988). The downlap surface between the Cherry Canyon highstand and lowstand is correlated with the unconformity between the Cutoff

Formation and the Cherry Canyon Sandstone on the west face of the Guadalupe Mountains.

CHAPTER VI

SYSTEMATIC PALEONTOLOGY

Genus NEOGONDOLELLA

Bender and Stoppel, 1965

Diagnosis: This genus has a unimembrate apparatus composed of segminiplanate elements occupying the Pa position. The large platform narrows in the anterior 1/3 or 1/4 of its length. This narrowing platform may be serrate. The carina is low with denticles increasing in size anteriorly except for the anteriormost one or two (Wardlaw and Collinson 1984). Adcarinal troughs may be well or poorly developed. The platform surface is covered by reticulate micro-ornamentation which may or may not be present in the adcarinal trough and platform serrations.

Neogondolella idahoensis

(Youngquist, Hawley and Miller, 1951)

Figure 15.

Diagnosis: Species of *Neogondolella* in which the platform margin and basal loop are flattened on the posterior end giving it a squared-off shape. The platform tapers anteriorly. Anterior margin serrations may be present.

Remarks: In this study N. idahoensis was recovered from unit A of the Cutoff Formation at Cutoff Mountain and Last Chance Canyon. A specimen from Last Chance Canyon was also recovered from reworked sediments in unit C.

Occurrence: Cutoff Formation (This paper)
Bone Springs Limestone, (Behnken, 1975)
Road Canyon Formation (Wardlaw and Grant 1988), Texas and New Mexico; Mead Peak Member of Phosphoria Formation, Idaho (Youngquist Hawley and Miller 1951, Wardlaw and Collinson, 1984); Chihsia Formation, Maokou Formation, China (Clark and Wang, 1988).

Neogondolella gracilis
(Clark and Ethington, 1962)
Figure 16.

Diagnosis: A Species of Neogondolella which is characterized by a large proclined cusp onto which the platform margins continue as carinae. This species has a high length to width ratio.

Remarks: This species differs from N. idahoensis in that it has a large cusp and lacks the flattened basal loop and squared posterior platform margin. This species has a higher length to width ratio than other neogondolellids observed in the Cutoff Formation. This species was recovered from unit A of the Cutoff Formation on Cutoff Mountain and in Last Chance Canyon.

Occurrence: Cutoff Formation, New Mexico; Mead Peak Member of Phosphoria Formation, Idaho (Youngquist Hawley and Miller, 1951, Wardlaw and Collinson, 1984);

<u>Neogondolella</u> <u>serrata</u>

(Clark and Ethington, 1962)

Figure 17.

Diagnosis: Species of <u>Neogondolella</u> characterized by serrations on the anterior margin. The serrate anterior margin tapers to the anterior end of the element. The non-serrate margins in the middle and posterior of the element are generally parallel. In juvenile specimens the platform has an ovate outline. In gerontic specimens, the anterior margin serrations are less pronounced.

Remarks: This species has a lower length to width ratio than <u>N.</u> <u>gracilis</u>, and lacks the large proclined cusp. It also lacks the flattened basal loop and posterior margin of <u>N.</u> <u>idahoensis</u>. <u>N.</u> <u>serrata</u> was recovered from all units of the Cutoff Formation at Last Chance Canyon with the exception of unit B, from which no identifiable conodonts were recovered. Gerontic specimens were recovered from unit A at Last Chance Canyon which were characterized by more extensive micro-ornamentation and less pronounced serration than the population as a whole. This species was recovered from unit B and unit C\D of the Cutoff Formation at Cutoff Mountain.

Occurrence: Cutoff Formation (This paper, Clark and Behnken, 1979, Behnken, 1975), Brushy Canyon Sandstone, Getaway Limestone (Clark and Behnken, 1979, Behnken, 1975), Road Canyon Formation (Wardlaw and Grant 1988), Texas and New Mexico; Mead Peak Member of Phosphoria Formation, Idaho (Wardlaw and Collinson, 1984); Chihsia Formation, Maokou Formation, China (Clark and Wang, 1988).

Genus HINDEODUS

Rexroad and Furnish, 1964

Diagnosis: A genus with a seximembrate apparatus composed of segminiscaphate Pa elements, angulate Pb elements, dolobrate or digyrate M elements, alate Sa elements which lack a posterior process, digyrate Sb elements, and bipennate Sc elements.

<u>Hindeodus</u> <u>excavatus</u>

(Behnken, 1975)

Figure 18.

Diagnosis: This species of <u>Hindeodus</u> has a Pa element with a large cusp and denticles of generally decreasing size anteriorly. Denticles and cusp are laterally flattened. The basal cavity narrows under the cusp. The Pb element has longer denticles separated by two or three shorter denticles. Sa elements have upturned lateral processes which bear denticles that alternate in length. Sb elements have similar denticles of alternating length. The Sc element has longer denticles separated by four or five shorter ones.

Remarks: This species was recovered from Units C and D of the Cutoff Formation in Last Chance Canyon and from all units of the Cutoff Formation on Cutoff Mountain. It was far more abundant in Last Chance Canyon. The complete multi-element assemblage was recovered from the conglomerate at the base of Unit C in Roberts Canyon in the northeast part of the Last Chance Canyon Study area.

Genus XANIOGNATHUS

Sweet, 1970

Diagnosis: Genus has a seximembrate apparatus composed of carminate or angulate Pa element with long ribbed posterior process and short anterior process, Pb element digyrate, M digyrate, Sa alate with very long cusp, Sb, bipennate, and Sc bipennate.

Xaniognathus abstractus

(Clark and Ethington, 1962)

Figure 19.

Diagnosis: This species of *Xaniognathus* is characterized by Pa with a long curved cusp, and Sc element with long curved denticles on the posterior process.

Remarks: The entire assemblage of this species was recovered from fusulinid-rich beds near the top of Cutoff unit D in Last Chance Canyon near the mouth of Roberts Canyon. This species was rare in the lower units of the Cutoff in Last Chance Canyon. This species was recovered from the Cutoff Formation at Cutoff Mountain in the upper and lower limestone units.

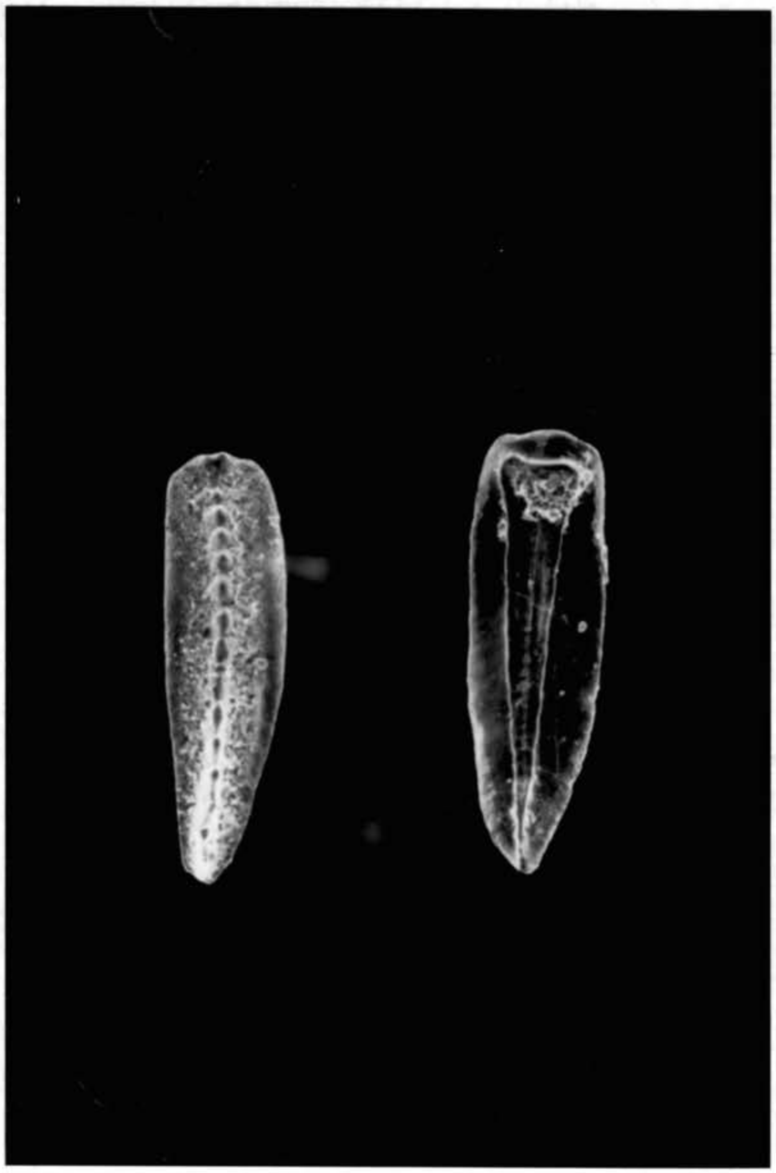


Figure 15. Neogondolella idahoensis

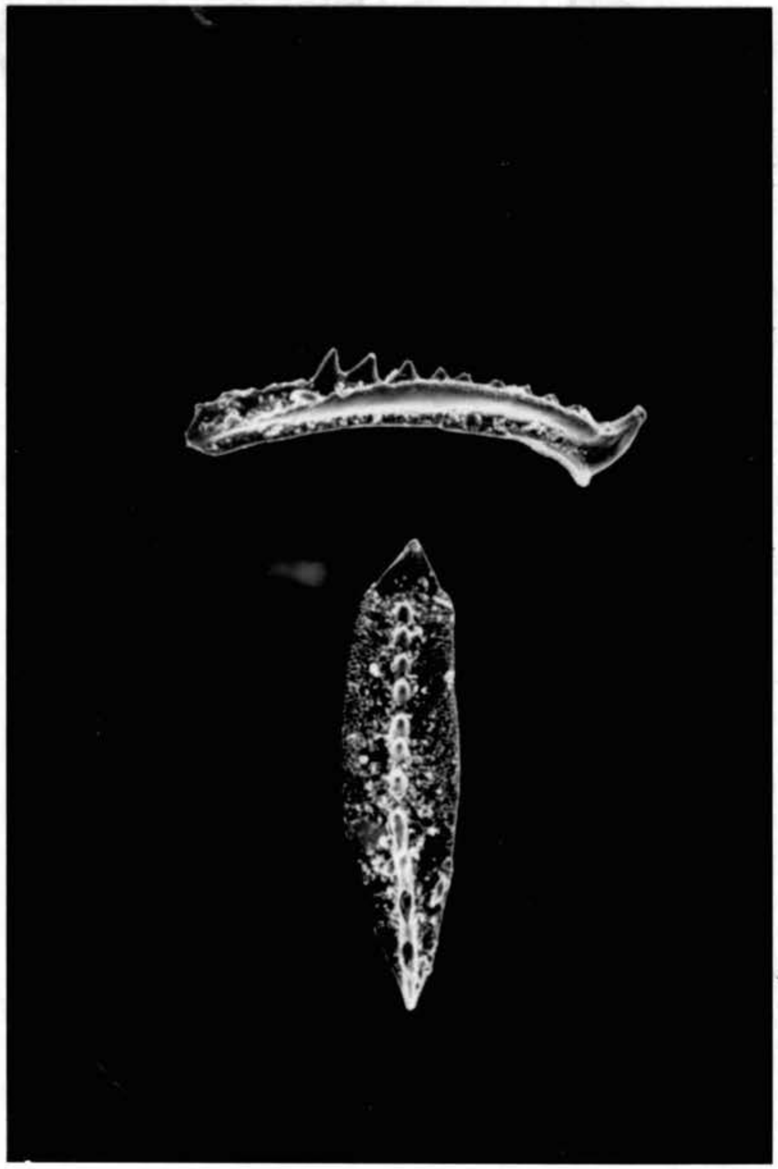


Figure 16. Neogondolella gracilis

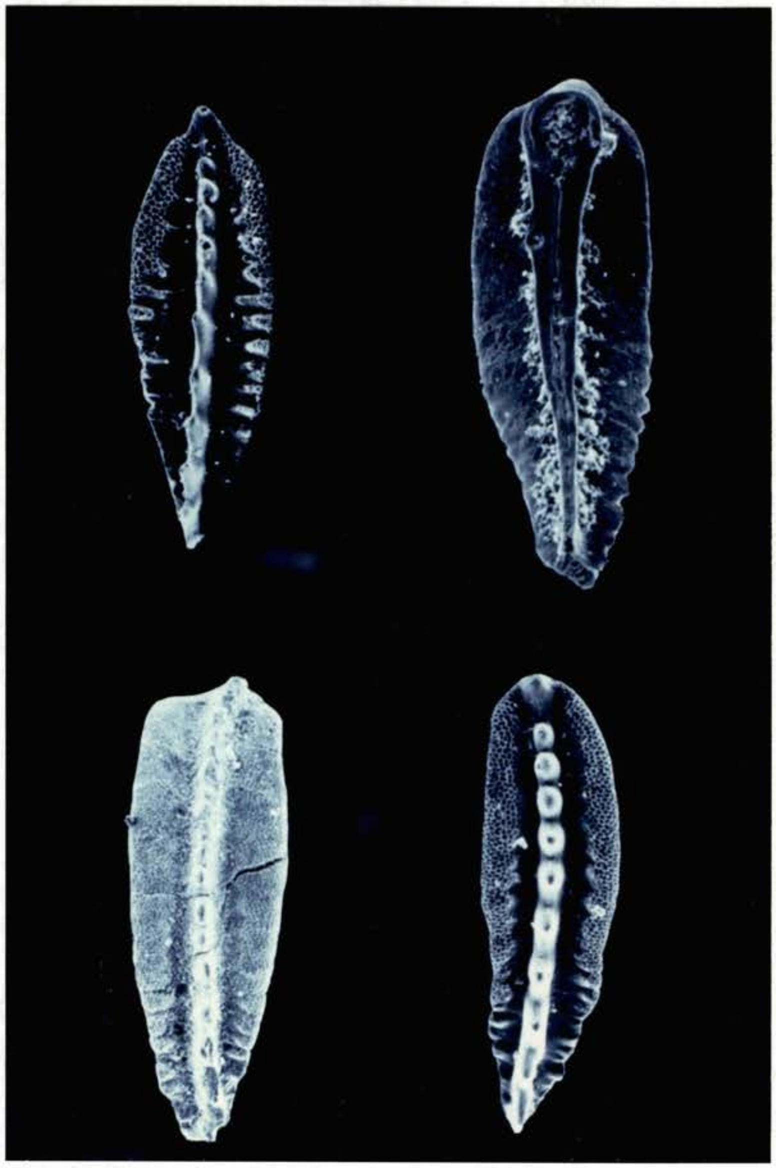


Figure 17. <u>Neogondolella</u> <u>serrata</u>

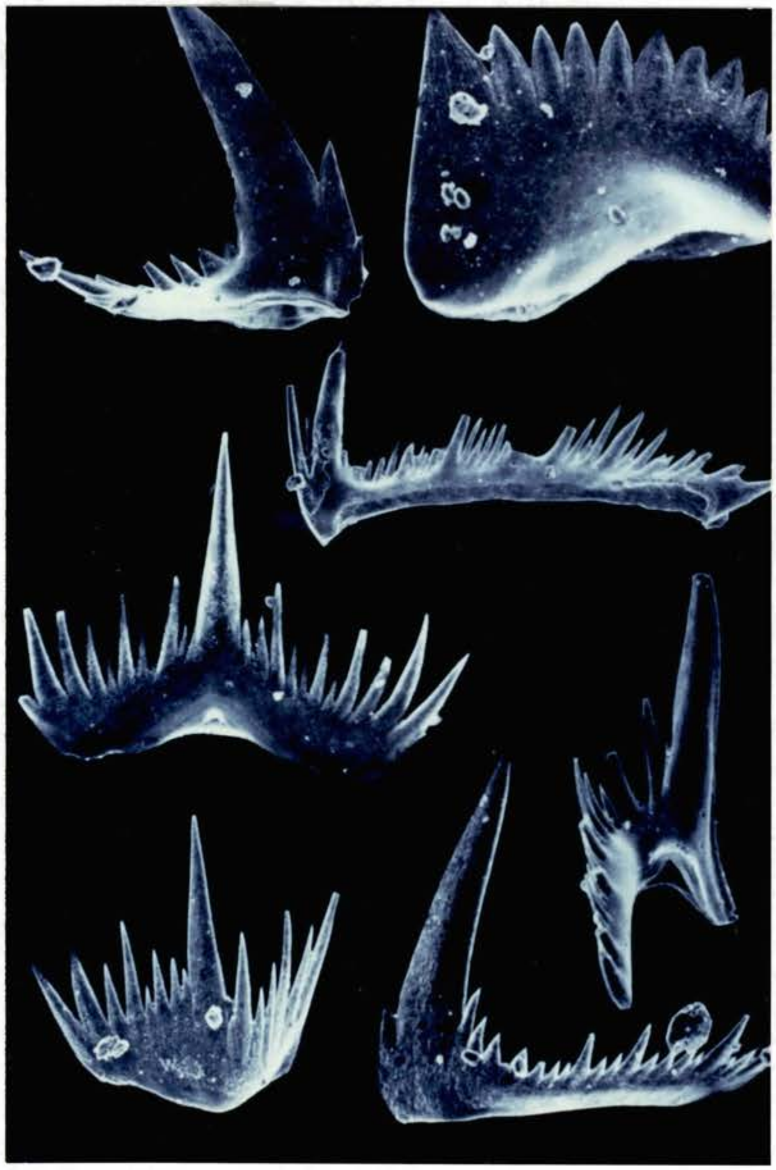


Figure 18. Hindeodus excavatus

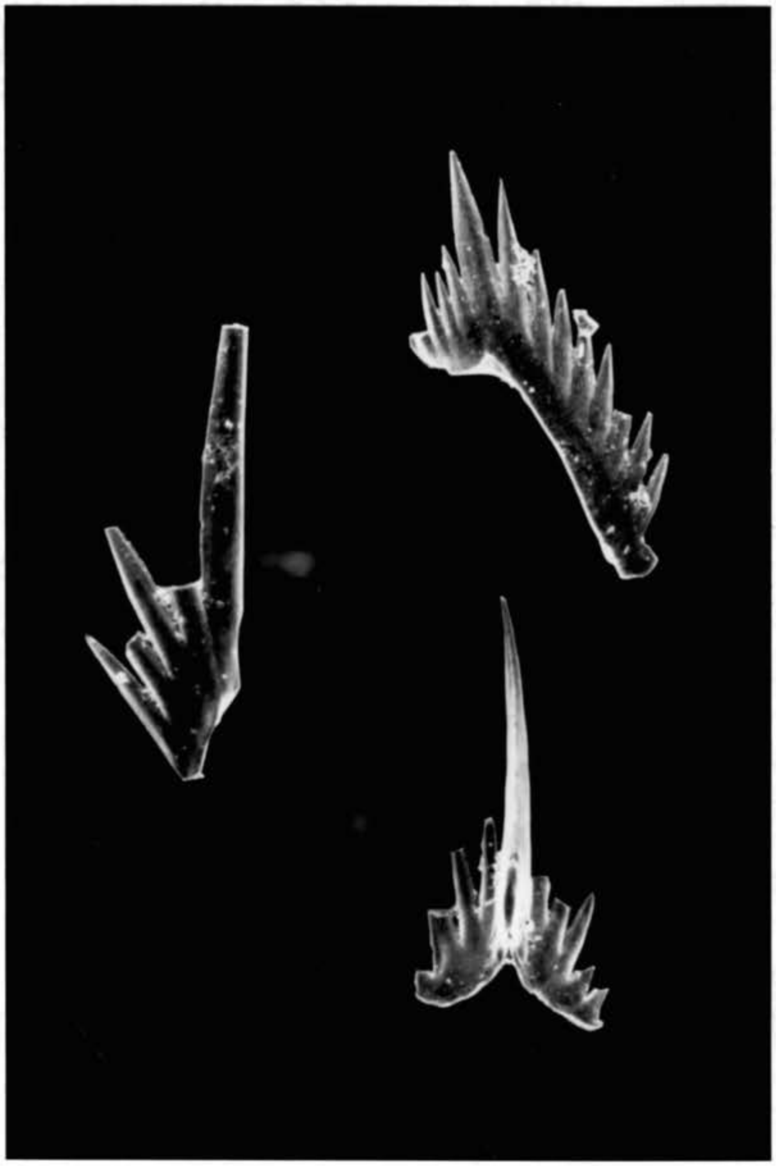


Figure 19. Xaniognathus abstractus

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VITA 2

Clark Edwin Wilkinson Jr.

Candidate for the Degree of

Master of Science

Thesis: BIOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE CUTOFF FORMATION, (PERMIAN) IN LAST CHANCE CANYON, EDDY COUNTY, NEW MEXICO

Major Field: Geology

Biographical:

Personal Data: Born in Tahlequah, Oklahoma, October 21, 1963, the son of C. Edwin, and Carolyn Wilkinson. Married, March 18, 1989 to Jacqueline Gronwald.

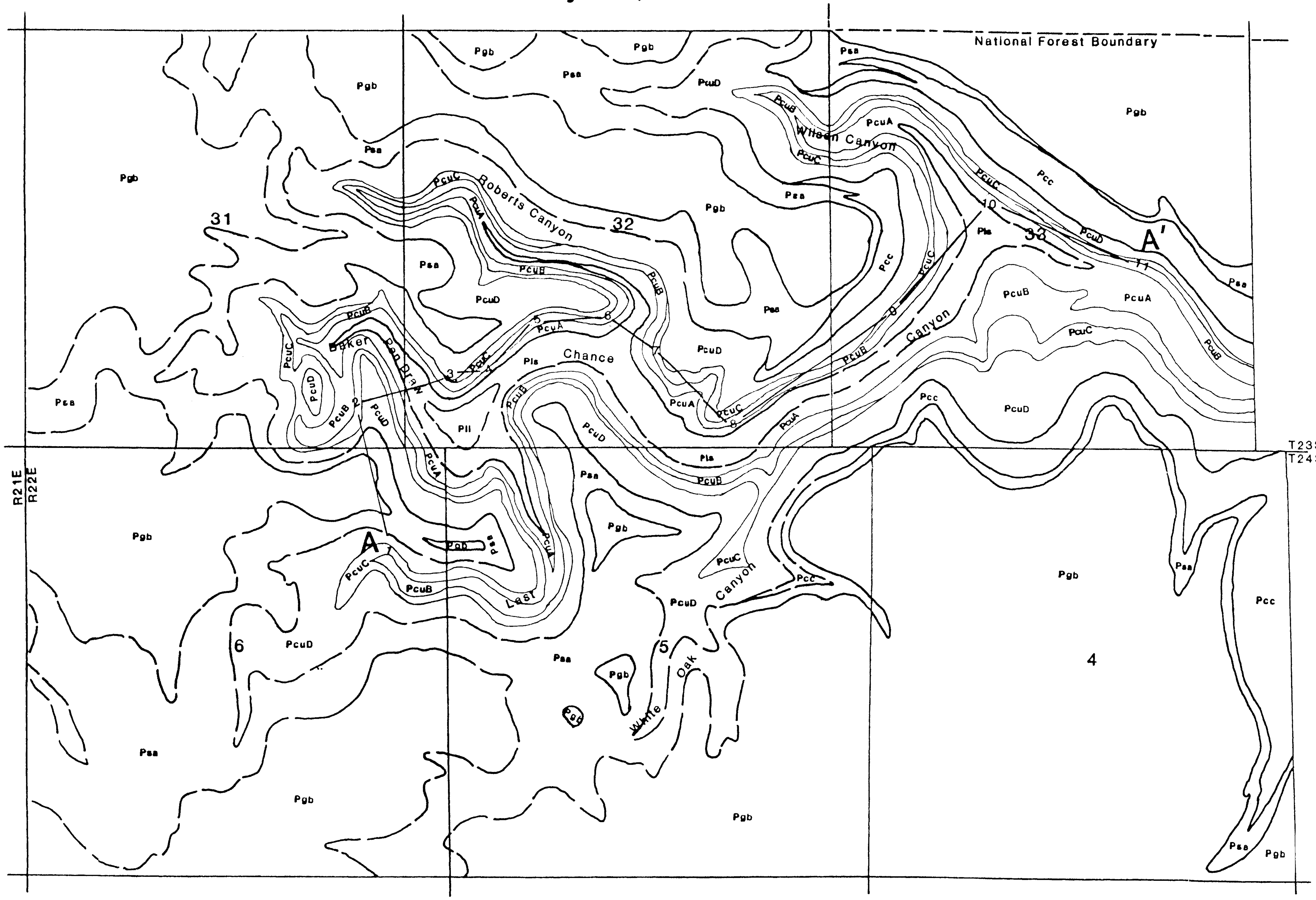
Education: Graduated from Thomas A. Edison High School, Tulsa, Oklahoma in May, 1981; received Bachelor of Science in Geology from Oklahoma State University in December, 1985; completed requirements for the Master of Science degree at Oklahoma State University in May, 1989.

Professional Experience: Teaching Assistant, T. Boone Pickens School of Geology, Oklahoma State University, May, 1987, to May, 1989.

Reconnaisance Geologic Map of Last Chance Canyon

Sections 31, 32, and 33, T23S, R22E and 4, 5, and 6, T24S, R22E

Eddy Co., New Mexico



Key

- Pgb Grayburg Formation
- Psa San Andres Limestone
- Pcc Cherry Canyon Sandstone
- PcuA Cutoff Formation, unit A
- PcuB Cutoff Formation, unit B
- PcuC Cutoff Formation, unit C
- PcuD Cutoff Formation, unit D
- Pls Unidentified Sandstone
- Pll Unidentified Limestone

Formation Contact

Inferred Formation Contact

Cutoff Unit Contact

Scale

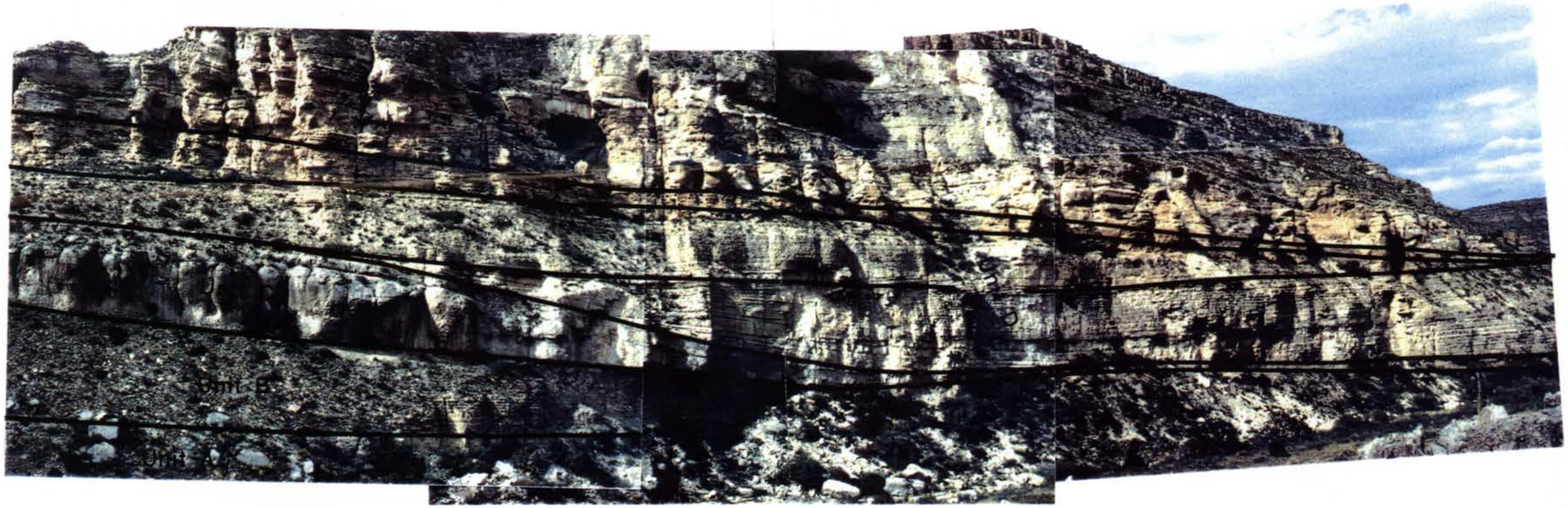
1/4 Mile

500 Meters

North

Plate 2

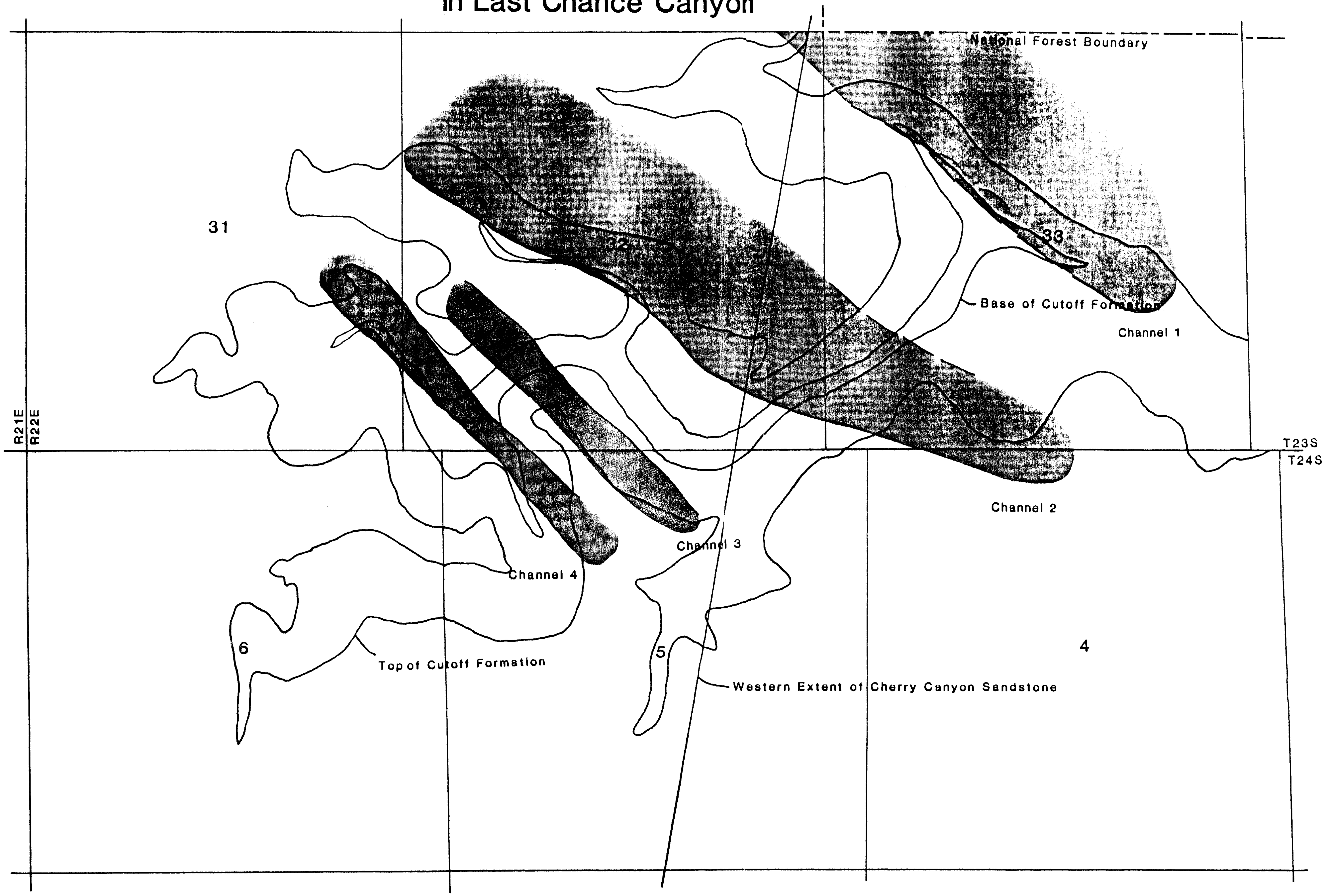
Panorama of the West Wall of Last Chance Canyon Between Wilson and Roberts Canyons



Channel 2

Scale 15 meters

Location of Channels in Unit C of the Cutoff Formation In Last Chance Canyon



Shaded Areas Show Location of Channels

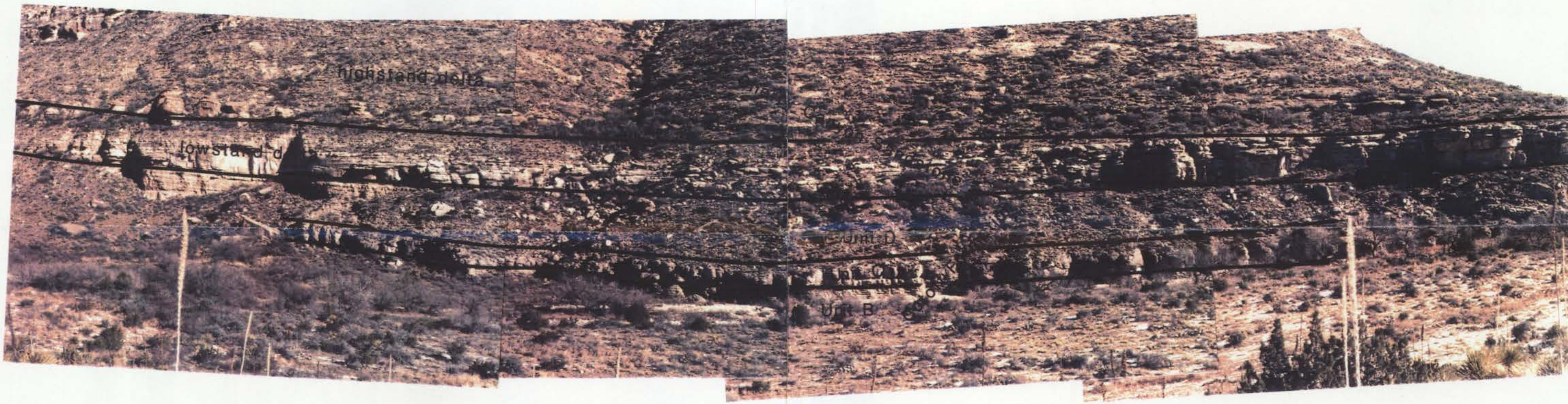
North

Scale

1/4 Mile

500 Meters

Panorama of the North Wall of Last Chance Canyon Between Wilson and Sittingbull Canyons



Scale 15 meters