MAPPING, STRATIGRAPHY, AND TECTONIC IMPLICATIONS OF LOWER PERMIAN STRATA, EASTERN WICHITA MOUNTAINS, OKLAHOMA

By

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PREFACE

The purpose of this thesis is to map, propose a revised stratigraphic section for, and comment on the tectonic implications of the Lower Permian deposits surrounding the eastern Wichita Mountains of southwestern Oklahoma. It is hoped that this thesis will raise questions and encourage investigators to scrutinize the geologic literature so that our geologic interpretations can continue to evolve.

I am deeply indebted to the many individuals that provided useful comments, ideas, and suggestions which helped in the completion of this study. Deepest appreciations are conveyed to my major advisor Dr. R. Nowell Donovan for his counsel, guidance and friendship and to my committee members Dr. Gary F. Stewart and Dr. Ibrahim Cemen for their suggestions and review of the text.

Sincere thanks are expressed to Deborah Ragland who ordered photos and provided interpretations which were vital in the preparation of this thesis.

Gratitude is expressed to Mr. and Mrs. Charlie Oliver for their hospitality, friendship and for allowing me the "run" of the Kimbell Ranch. Thanks are also expressed toward the many other landowners who granted access to their property.

I would like to thank Dr. R. Nowell Donovan, Dr. Wayne Pettyjohn and and the Oklahoma Water Resources Board for providing funding for the mapping project. This portion of the study was conducted to examine ground water recharge potentials of the Permian strata and was duplicated in a report submitted to the Water Board.

Finally I wish to give special thanks to my family and most of all my wife, Kathryn Collins Bridges for her assistance, encouragement and support.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION.................................... 1

Statement of Purpose...................... 1
Location of the Study Area................ 1
Method of Study........................... 2
Geologic Setting.......................... 2

II. PREVIOUS WORK................................... 7

III. REGIONAL STRATIGRAPHY........................... 26

Introduction.............................. 26
Wichita Mountain Igneous Complex.......... 26
Tillman Metasedimentary Group........ 26
Raggedy Mountain Gabbro Group........ 26
Carlton Rhyolite Group............... 28
Wichita Granite Group................ 28
Diabase Intrusions................... 28
Sedimentary Succession.................... 28
Timbered Hills Group................. 28
Arbuckle Group....................... 29
Simpson Group........................ 31
Viola Group.......................... 31
Pennsylvanian and Permian Rocks........... 31
Pleistocene Rocks......................... 33

IV. LOWER PERMIAN DISCRIPTIVE STRATIGRAPHY......... 35

Introduction.............................. 35
Sandstones................................ 35
Mudstones................................. 37
Conglomerates............................. 39
Granite Boulder Conglomerates........ 41
Rhyolite Porphyry Conglomerates...... 41
Limestone Conglomerates.............. 44
Gabbro-Anorthosite-Granite Conglomerates....................... 48
Calcretes................................. 49
Introduction......................... 49
Description.......................... 50
Megabreccias.............................. 55
Cave Deposits............................. 62

Chapter Page

V. STRATIGRAPHIC NOMENCLATURE..................... 69

Introduction.............................. 69
Litho-stratigraphic Investigations........ 69
Bio-straigraphic Investigations........... 72
Stratigraphic Comparison.................. 74
Revised Stratigraphy...................... 87
Wichita Formation..................... 90
Hennessey Group....................... 92
El Reno Group......................... 92

VI. TECTONIC IMPLICATIONS.......................... 94

Introduction.............................. 94
Tectonic Setting.......................... 94
Paleo-Climatic Influences on Tectonic Deposits................................ 98
Tectonics................................. 102
Tectonic Summary......................... 106
Timing.................................... 112
Tectonic Effects on Hydrocarbon Migration................................ 112

VII. SUMMARY AND CONCLUSIONS....................... 116

Suggestions for Future Investigations..... 120

REFERENCES CITED.................................... 121

LIST OF TABLES

Table Page

I. Progressive Stages of Calcrete Development in Nongravelly Sediments According to Gile, (1970)................................ 51

II. Progressive Stages of Calcrete Development in Gravelly Sediments According to Gile, (1970).. 51

III. Progressive Stages of Calcrete Development According to Steel, (1970).................. 52

IV. Development Time Required of Stages, According to Leeder, (1975)................. 53

V. Vertebrate Faunas From Southwest Oklahoma Cave sites According to Simpson, (1979)..... 64

VI. Comparison of Post Oak Conglomerate and Granite Wash Characteristics According to Gilbert, (1982).......................... 79

LIST OF FIGURES

Figure Page

1. Major Geological Provinces of Oklahoma. Study Area is Located in The Wichita Mountain Uplift (after Johnson, 1972)................. 3

2. Tectonic Map of Southwestern Oklahoma (After Powell and Others, 1980)...................... 5

3. Geological Map of the Wichita Mountains Area; Permian Conglomerates are Differentiated According to Clast Composition (after Chase, 1954)... 10

4. Stratigraphic Column of Late Pennsylvanian and Early Permian Strata of Southern Oklahoma and Texas According to Miser (1954) and Chase (1954)... 12

5. Stratigraphic Column of the Lower Permian Strata According to MacLachlan, (1967)............... 15

6. Stratigraphic Column of Lower Permian Strata According Fay, (1968)......................... 17

7. Geological Map of Wichita Mountains Area (after Havens, 1977).................................. 18

8. Stratigraphic Column of Late Pennsylvanian and Early Permian Strata of Southwestern Oklahoma According to Havens (1977).................... 19

9. Tor Weathering of Granite in the Wichita Mountains (after Gilbert, 1982)............... 23

10. Schematic Cross Section of the Meers Valley Showing Inverted Relief Across the Valley and the Approximate Position of the Boulder Beds... 24

11. Schematic Cross Section of Blue Creek Canyon During the Early Permian; Depicts The Infill of the Canyon by Coarse Clastics and the Formation of Karst Features................. 25

Figure Page

12. Stratigraphic Section of the Exposed Rocks Within the Study Area........................ 27

13. Pleistocene Conglomerates Cap this Hill and Overly Permian Strata, South Side of Highway 62, Sec. 28, T. 2 N., R. 13 W................ 34

14. Typical Arkosic Sandstone, NE 1/4, Sec. 19, T. 4 N., R. 13 W.............................. 36

15. Sandstone and Shale Sequence With Lenticular Channel Sandstones, NW 1/4, Sec. 2, T. 3 N., R. 12 W.................................... 38

16. Limestone Conglomerates Overlying a Calcrete Capped Red Mudstone........................ 40

17. Typical Exposure of Granite Clast Conglomerates With Rounded Clasts........................ 42

18. Granite Clasts Conglomerates Unconformably Overly Carlton Rhyolite, Sec. 16, T. 3 N., R. 13 W..................................... 43

19. Limestone-Rhyolite Clast Conglomerates Exposed in Blue Creek Canyon....................... 45

20. Coarse Limestone-clast Conglomerate Facies Overlain by More Typical Limestone-clast Conglomerates................................ 46

21. Typical Limestone Clast Conglomerate Unconformable Overlying Arbuckle Rocks........ 47

22. Calcrete Nodule Exhibiting Shrinkage Cracks and Slickensides................................ 54

23. Mature Permian Calcrete Profile Developed in Sandstones and Conglomerates, North Shore, Lake Lawtonka............................. 56

24. Thick Calcrete Being Excavated for Road Metal Sec. 10, T. 4 N., R. 12 W.................... 57

25. Geologic Map by Harlton (1951), Megabreccia Outcrops South of the Meers Fault are Incorrectly Interpreted as Cambro-Ordovician Arbuckle Limestone........................... 59

26. Boulder Field of Megabreccia, Resembles Disturbed Arbuckle Outcrops.................. 60

Figure Page

27. Distant View of Megabreccia Outcrop............. 61

28. Approximate Stratigraphic Position of Cave Site Vertebrates According to Simpson (1979)........ 65

29. Permian Travertine Fissure Deposits in Arbuckle Limestone, South Carnegie Site................ 66

30. Fissure Exposed in a Quarry Wall, South Carnegie Site is Infilled With Fine Clastics... 67

31. Breakdown of the Lower Permian Strata of North Texas and Correlation with the Lower Permian of Oklahoma According to Simpson (1973)........ 70

32. Correlation of the Lower Permian Strata of Northern Texas, South-Central, and Southwestern Oklahoma and the Approximate Position of the Fissure Sites According to Olson (1967)... 73

33. Revised Correlation of the Lower Permian of North Texas and Southwestern Oklahoma According to Simpson (1979).................. 75

34. Depositional Model of Lower Permian Sedimentation (From Donovan Unpublished)...... 83

35. Electric Log of the Thermo-Dyne, Corbin # 1, Showing Numerous Calcrete Horizons; Horizon # 20 is the Pontotoc "A" Calcrete From Donovan (1978)... 84

36. Revised Stratigraphic Section for the Lower Permian in the Vicinity of the Eastern Wichita Mountains............................ 91

37. Escarpment Supported by Garber Sandstone, West Lane of I-44................................ 93

38. Tectonic Curves (Solid Line) and Subsidence Curves (Dashed Line) for the Tectonic Provinces of Southern Oklahoma During the Late Pennsylvanian and Early Permian According to Arbenz (1956).................... 95

39. Tectonic Curves for Southern Oklahoma Tectonic Provinces During the Late Pennsylvanian and Early Permian According to Ham and Wilson (1967)... 96

40. Rates of Denudation for Carbonate Rocks Plotted

Figure Page

Against Precipitation, Possible Paleo-Climatic Indicators are Positioned at Top...... 101

41. Azimuth Frequency Diagram (top) and Histogram (bottom) Representing the Orientations of 50 Megabreccia Clasts in the Meers Valley......... 104

42. Schematic Model Illustrating a Condensed Sequence Along the Northern Wichita Block and Southern Anadarko Basin....................... 107

43. Relief of the Limestone Block Became Sufficient to Initiate Building of Small Limestone Alluvial Fans Southward into the Meers Valley.. 108

44. Rejuevenated and Reversed Movement along the Meers Fault Uplifted the Limestone Block, Earthquakes Probably Caused Large Boulders of Limestone to Tumble into the Meers Valley...... 110

45. A Final Episode of Relief Related Conglomerates were Deposited Southward into the Meers Valley... 111

46. Bitumens Filling Vugs and Fractures in a Calcrete Nodule.............................. 114

PLATE

Plate

1. Lower Permian Geologic Map....................In Pocket

CHAPTER I

INTRODUCTION

Statement of Purpose

This thesis describes the aerial extent, stratigraphy and tectonic implications of the Lower Permian rocks in the vicinity of the eastern Wichita Mountains, southwest Oklahoma. "Lower Permian" rocks of this study are generally considered to be Wolfcampian and Leonardian in age. This study is part of ongoing research in the Wichita Mountains area under the direction of Dr. R. Nowell Donovan, Oklahoma State University, Dr. Charles M. Gilbert, Texas A & M University and the Oklahoma Geologic Survey.

Field work in the study area revealed the necessity for a new geologic map and clarification of the stratigraphic nomenclature. In addition, field work provided further insite into the tectonic history recorded in the Lower Permian strata.

Location of the Study Area

The study area includes Permian strata surrounding the eastern Wichita Mountains and Slick (Limestone) Hills of southwestern Oklahoma. The study area lies within

Townships 1-6 North and Ranges 11-16 West of Caddo, Kiowa, and Comanche Counties (Figure 1).

Method of Study

Work for this thesis was conducted in three stages. The first stage involved a thorough compilation of the available literature and the examination of aerial photographs and topographic maps. These were helpful in locating some of the Permian outcrops and delineating geologic contacts.

The second stage consisted of field work which began in the summer of 1984 and continued intermittently through the spring of 1985. Field work consisted of reconaissance mapping, locating and describing outcrops, measuring sections, collecting rock samples and making additional field observations. The final stage of this investigation consisted of an overall analysis of the collected data.

Due to the immense size of the mapping area and the relatively poor exposures of outcrops, detailed geologic mapping is difficult: most contacts are indefinite.

Geologic Setting

Lower Permian strata are exposed at the surface overlying older Paleozoic rocks of the eastern Wichita Mountains and Slick Hills. Strata were laid down in alluvial fan, braided stream and floodplain environments in a semiarid climate (Donovan, 1978). These rocks were

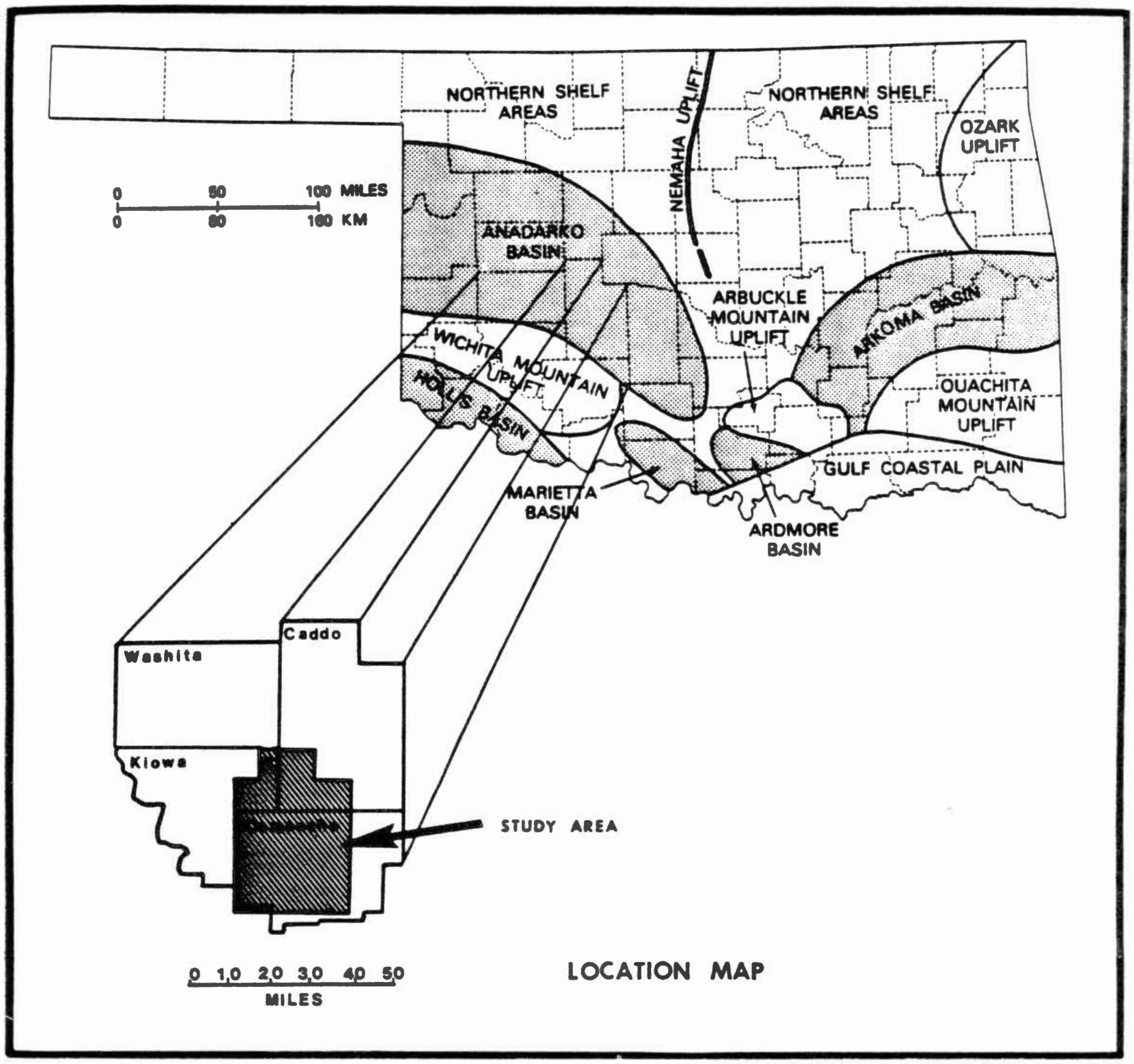


Figure 1. Major Geological Provinces of Oklahoma. Study Area is Located in the Wichita Mountain Uplift (after Johnson, 1972)

deposited on the Pennsylvanian structural provinces known as the Wichita-Amarillo Uplift, the Anadarko Basin and Hollis-Hardeman Basin (Figure 2). Cambrian through Ordovician rocks exposed in this region represent part of a regional depocenter which has been termed the Southern Oklahoma aulacogen (Hoffman et al., 1974).

The Southern Oklahoma aulacogen, described by Hoffman et al. (1974), Webster (1980), and Brewer (1982), began to form with the intrusion and extrusion of Middle Cambrian igneous and volcanic rocks into older igneous and metasedimentary rocks along a pre-existing crustal weakness, in an extensional setting. The continental crust failed to split, becoming an aulacogen (ie., a failed rift arm) marked by a slow downwarping of the crust. The trough infilled with approximately 6000 feet of predominantly shallow water marine carbonates in late Cambrian to early Ordovician time. These rocks are known as the Arbuckle and Timbered Hills Groups. Subsidence rates began to wane from the Middle Ordovician into the Silurian, as recorded by the alternation of deep and shallow water facies in the Simpson through Hunton Groups. Predominantly deep water sediments of Late Silurian through Mississippian provided a further and final contribution to the aulacogen. This was followed by a complex series of deformations developed by the closure of the continental crust in the southern Oklahoma area. According to Webster (1980), destruction of the aulacogen occurred in two main episodes; the "Wichita"

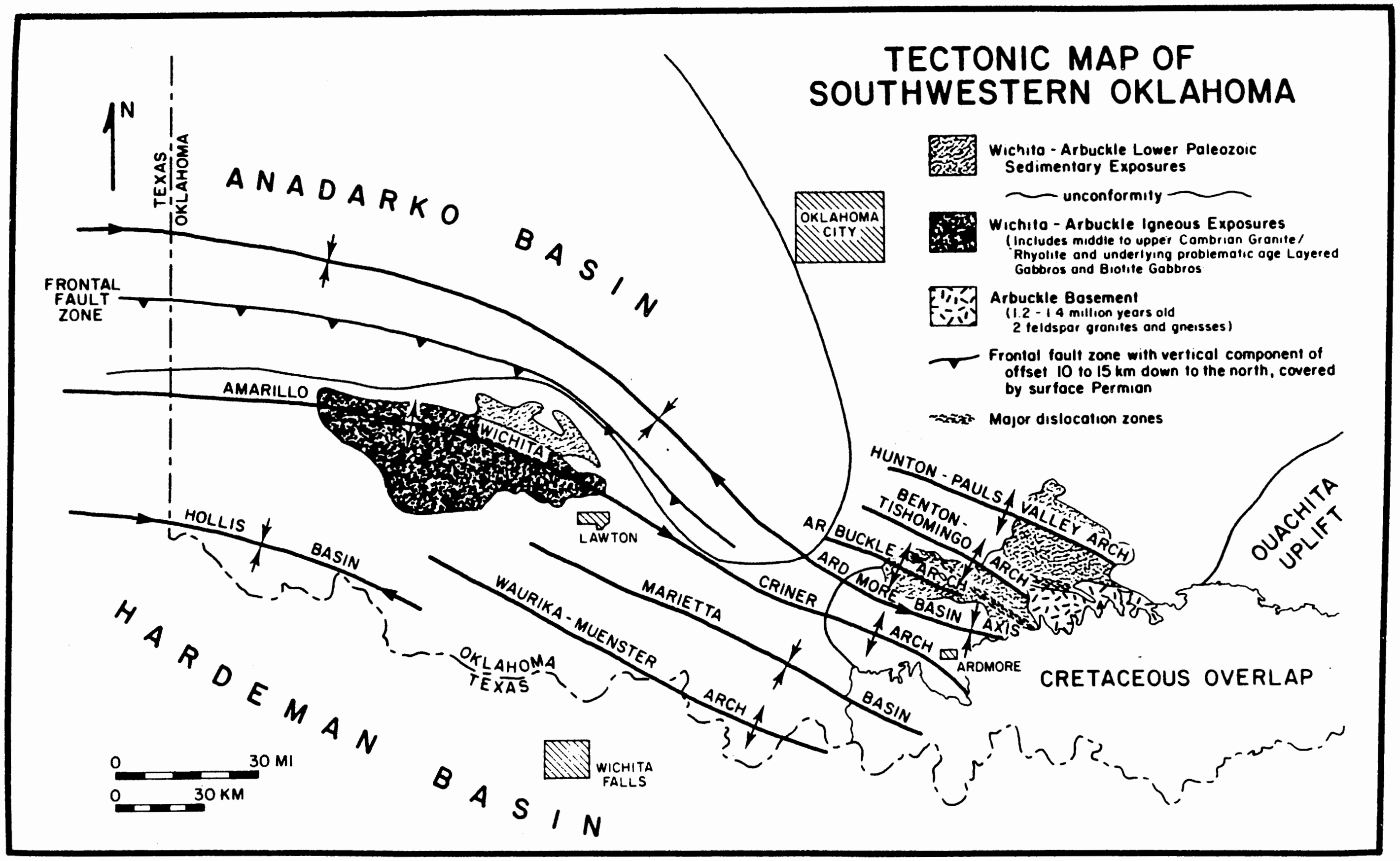


Figure 2. Tectonic Map of Southwestern Oklahoma (after Powell and Others, 1980)

orogeny (Morrowan-Desmoinesian) and the "Arbuckle" orogeny (Virgilian). The "Wichita" episode was characterized by uplift of the Wichita block along a series of subparallel high angle reverse faults causing the formation of the present day structural provinces (Webster, 1980). The "Arbuckle" orogeny was characterized by a combination of thrusting and left-lateral wrenching (oblique) movements (Brewer, 1982). The final periods of deformation were recorded in the Upper Pennsylvanian and Lower Permian rocks. The Permian rocks record the culmination of tectonic events. Fault related conglomerates and breccias grade upward into fluvial, flood plain, and closed basin shallow water playa sediments.

CHAPTER II

PREVIOUS WORK

Many surveys of the Wichita Mountains area were conducted prior to the 1900´s. Although their work is not discussed here, such authors as Shumard, Comstock, Cummins, Hill and Vaughan deserve credit for their pioneering work.

One of the first in depth geologic studies of the Wichita Mountains area was conducted by Foster Bain in May of 1889. Bain described "red beds" of earlier than Permian age as the Geronimo Series. These rocks were described as shales interbedded with conglomerates composed of two inch rounded granite, rhyolite and limestone pebbles having a calcareous matrix. "Red beds" were described as sandstones and shales existing mainly in the prairies. No environment of deposition was offered for either the Geronimo Series or the "red beds" in Bain´s report.

Taff (1904) noticed locally derived conglomerates outcropping near the mountains and hills. He interpreted them as shore line deposits of the Permian sea laid down chiefly by wave action and deposited contemporaneously with the "red beds", composed of red clays and grits. He also noted that these conglomerates may be mistaken for more recent Pleistocene (?) conglomerates which also occur locally.

Hoffman (1930) contended that the red coloration begins in the upper Pennsylvanian strata and grades upward into Permian rocks. He believed that the sources of the sediment were the ancient mountain ranges of southern Oklahoma, which provided thick sequences of sandstones, sandy clays and shales. Environments of deposition were believed to be shallow marine with possible delta and river deposits.

Hoffman labeled all the conglomerates as gravels and interpreted them as being Pleistocene in age based on similarities of known Pleistocene gravels located near Frederick, Oklahoma. These gravels were described as rounded to semirounded granite pebbles and boulders. Rounding of the clasts was believed to be due to extensive water transport. Hoffman postulated that the gravels once existed at elevations above 1800 feet and that they were probably sufficient to fill in the valleys and depressions, completely eliminating the old drainage patterns.

Merritt and Ham (1941) described small local deposits of reddish conglomeratic rocks containing rounded pebbles of anorthosite. These rocks were characteristically composed of zeolites and opal with varying amounts of calcite and dolomite. They were interpreted as Precambrian in age and named the Tepee Creek Formation.

Based on detailed field observations, Mayes (1947) reinterpreted the Tepee Creek Formation and concluded that it was of Late Pennsylvanian or Early Permian age, ie., younger than the Wichita red beds of the surrounding plains. He believed the origin of the zeolites to be from the diagenetic reaction between local anorthosite rocks and saline waters. The later opal he believed to be a replacement of the zeolites. He thought that calcite and dolomite were direct precipitates from sea water with the source of the carbonate being the decomposition of the anorthosite.

Miser´s geologic map of Oklahoma (1954) presented a system of stratigraphic nomenclature. This nomenclature was provided by Chase (1954) and is explained in the following review of the latter´s work.

Chase (1954) conducted a detailed investigation of Permian conglomerates around the Wichita Mountains. He described and mapped locally derived conglomerates on both the north and south sides of the mountains, named them the "Post Oak Conglomerate" and declared them to be a member of the Wichita Formation (Figure 3). Conglomerates were divided into four genetic facies: i) granite boulder conglomerates, ii) rhyolite porphyry conglomerates, iii) limestone conglomerates, and iv) granite-gabbro conglomerates with zeolite-opal cement.

Granite boulder conglomerate were described by Chase as consisting of well rounded boulders and cobbles ranging in diameter form 6 to 18 inches, interbedded with cross-bedded lenses of finer arkosic conglomerates, sandstones

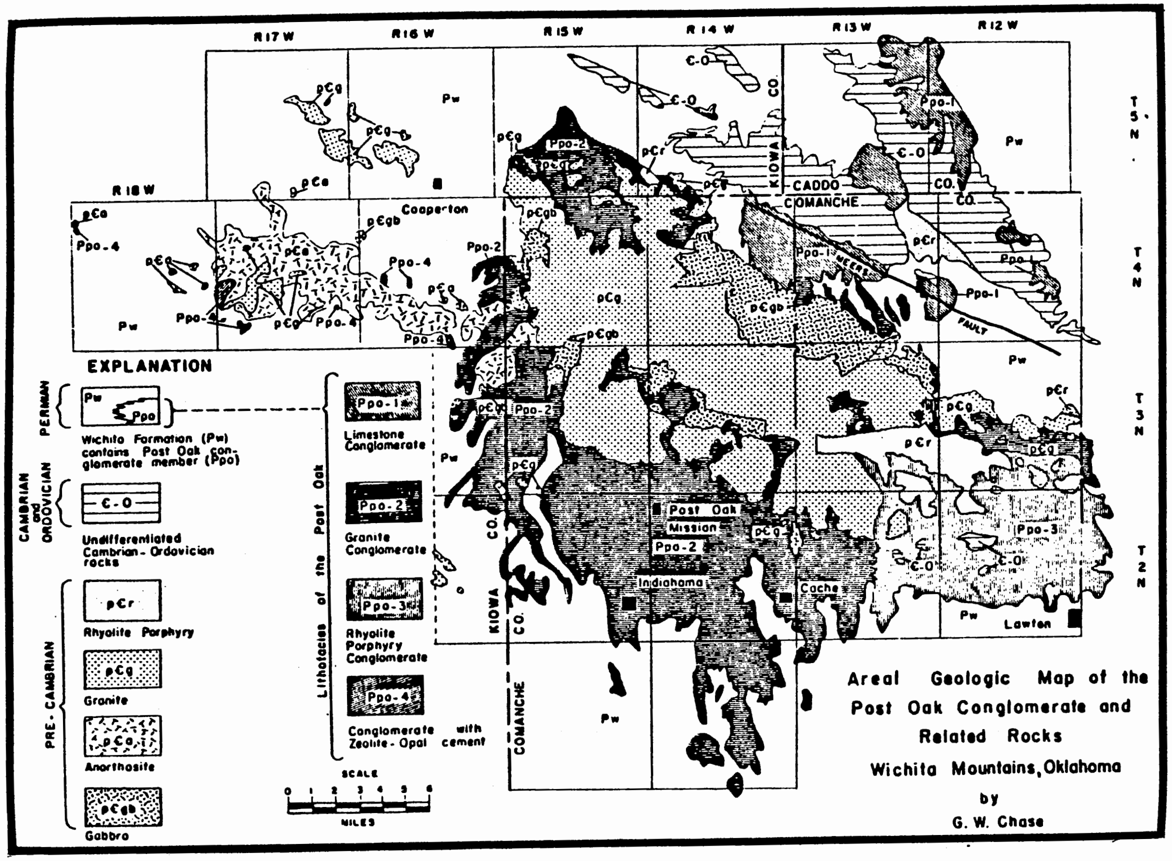


Figure 3. Geological Map of the Wichita Mountains Area; Permian Conglomerates are Differentiated According to Clast Composition (after Chase, 1954)

and shales. Cements of limonite, calcite and clay were recognized. This facies was considered to grade distally into finer materials and continue into the subsurface for a distance up to 20-30 miles.

Chase reported that dominantly rhyolite porphyry conglomerates graded lithologically into mixtures of dominantly granite and limestone conglomerates.

Limestone conglomerates composed of Cambro-Ordovician derived clasts were described along the flanks of Arbuckle limestone outcrops. Conglomerates composed of clasts from 6 to 24 inches generally occur with some boulders having a diameter of up to 3 feet. These conglomerates were described as changing abruptly into limestone sand and "limestone flour" mixed with clays and shales (Chase, 1954).

Chase´ conglomerates with zeolite-opal cements were the same rocks described previously by Merritt and Ham (1942) and Mayes (1947).

Chase interpreted the conglomerates and arkoses as near shore deposits, marking the last significant orogenic movements prior to the area being covered by the Permian sea. He believed the conglomerates of the Wichita Formation to be equivalent to the Wellington Formation, possibly ranging from the upper part of the Pontotoc Group to the lowest part of the Garber Sandstone (Figure 4).

Ham, Merritt, and Frederickson (1957) followed Chase´s stratigraphic nomenclature, but believed that the Post Oak

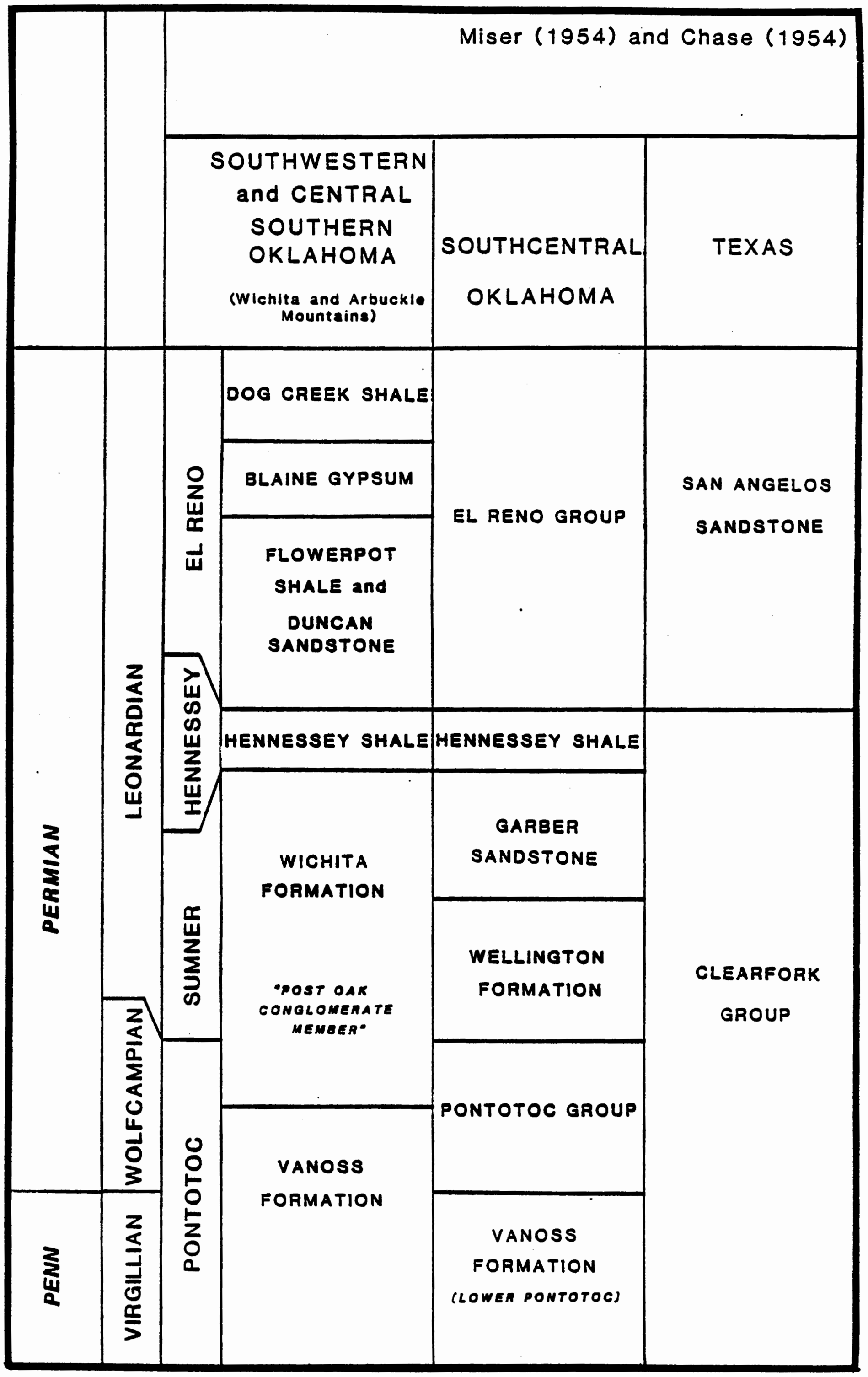


Figure 4. Stratigraphic Column of Late Pennsylvanian and Early Permian Strata of Southern Oklahoma and Texas According to Miser (1954) and Chase (1954)

Member should be revised to include conglomerates and arkoses in the overlying Hennessey Formation in the vicinity of Quartz Mountain, near Lugert. They also noticed solution-widened joints, in Arbuckle limestone, filled with red clay and containing bones of Permian reptiles. They believed this filling was from Permian sediments that once covered the hills and cited supporting evidence for this hypothesis as being the exposure of lower hills presently being exhumed by erosion from beneath a conglomerate cover.

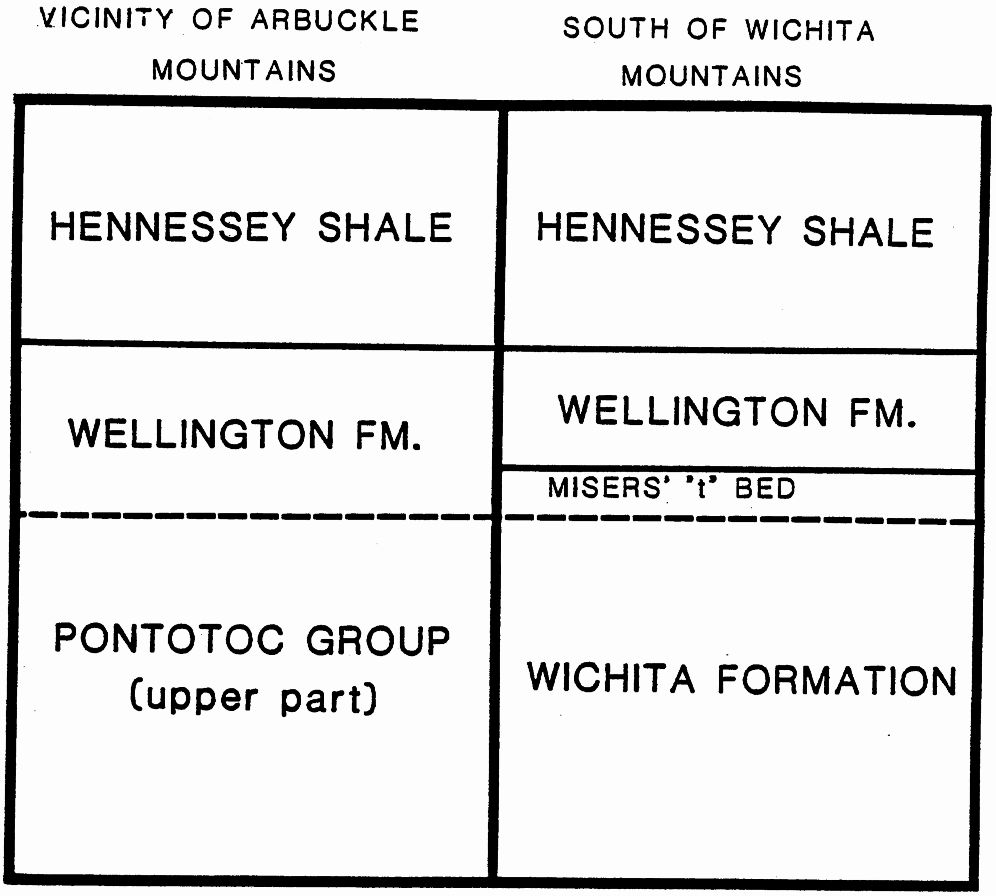
Olson (1967) conducted a study on terrestrial vertebrates in the Lower Permian rocks of southwestern Oklahoma. He attempted to use vertebrate faunal assemblages as chronostratigraphic indicators within previously mapped lithologic units and to correlate these units with the North Texas stratigraphic section. Lithologic units were based on the divisions set forth by the geologic map of Oklahoma (Miser, 1954).

Olson mentioned the difficulty in locating suitable outcrops both for fossil collecting and for stratigraphic studies. He also noticed that the lenticular nature and discontinuity of beds complicated correlation. He stated that the Lower Permian strata of southwestern Oklahoma more closely resembled the Lower Permian of North Texas than the Lower Permian rocks of central Oklahoma. Olson did not attempt to define the Wolfcampian-Leonardian boundary. He instead used Wichita and Clear Fork Groups as major units in his stratigraphic investigation. Based on vertebrate paleontologic evidence Olson believed that the lithostratigraphic units trancended time boundaries. Rocks in the study area of similar lithologic character to rocks in north central Oklahoma were depicted as being older than the their apparent lithologic equivalents.

In a paleotectonic investigation of the Permian system in southwest Oklahoma, MacLachlan (1967) included a revision of Miser´s (1954) stratigraphic nomenclature. MacLachlan believed that the Post Oak Conglomerate was equivalent to the Lower Wellington Formation and the Upper Wichita Formation. This differed from Miser´s classification in that MacLachlan believed that the Wellington Formation was separate from and overlies the Wichita Formation (Figure 5).

MacLachlan noticed the obscurity of the Pennsylvanian-Permian boundary and cited continuous deposition of like lithologies as a major contributor to the problem. Conglomerates were postulated by MacLachlan as having resulted from the intense orogenic movement of the Wichita Mountains, which had begun earlier in the Paleozoic and ended with the beginning of Leonardian time.

Fay (1968) proposed a redefinition of Lower Permian stratigraphy in southwestern Oklahoma. Fay suggested dropping of the term "Wichita Formation" or "Group" from the stratigraphic nomenclature, based on field evidence indicating that all formations mappable in southwest



VICINITY OF ARBUCKLE MOUNTAINS	SOUTH OF WICHITA MOUNTAINS
HENNESSEY SHALE	HENNESSEY SHALE
WELLINGTON FM.	WELLINGTON FM. MISERS' 't' BED
PONTOTOC GROUP (upper part)	WICHITA FORMATION

Figure 5. Stratigraphic Column of the Lower Permian Strata According to MacLachlan, (1967)

Oklahoma are younger in age than the Wellington Formation and the Garber Sandstone (Wichita equivalents according to Miser, 1954). In turn the Formation names of "Claypool", and "Addington" were substituted. Fay described the Cedar Hills Member as the Hennessey Group equivalent in the study area (Figure 6).

Havens, (1977) in a hydrologic study of the Lawton Quadrangle, compiled and published a revised geologic map of southwest Oklahoma (Figure 7). He established the Wellington Formation as the base of the Permian system and the Oscar group as the top of the Pennsylvanian. The Post Oak Conglomerate was considered equivalent to the Hennessey Group and Garber Sandstone (Figure 8).

Kwang (1978) in a petrographic and geochemical analysis of Lower Permian calcretes in southwestern Oklahoma suggested an alluvial piedmont-fan depositional environment for the Post Oak Conglomerate and a fluvial and flood plain model of deposition for the Garber Sandstone and Hennessey Shale. A semiarid climate was interpreted, evidenced by gypsum relicts, barite, and calcretes. Kwang inferred, based on slow accretionary rates for calcretes, that long periods of sediment exposure existed during the Early Permian and that sediment accumulation was slow and episodic. Kwang´s stratigraphic nomenclature was adopted from Havens, (1977) without modification.

Simpson, (1979) attempted to assign a more valid stratigraphic position to the Lower Permian vertebrate

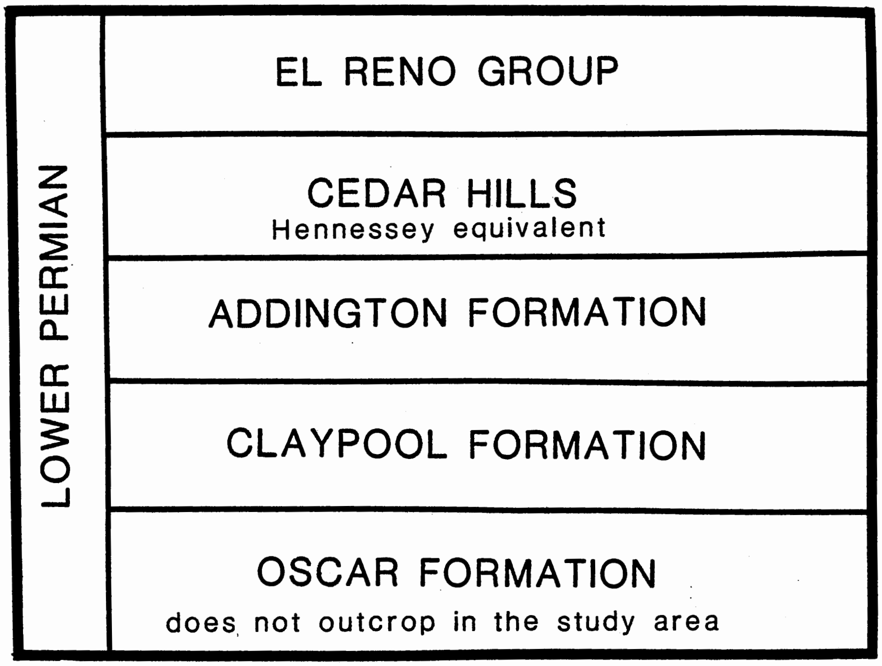


Figure 6. Stratigraphic Column of Lower Permian Strata According Fay, (1968)

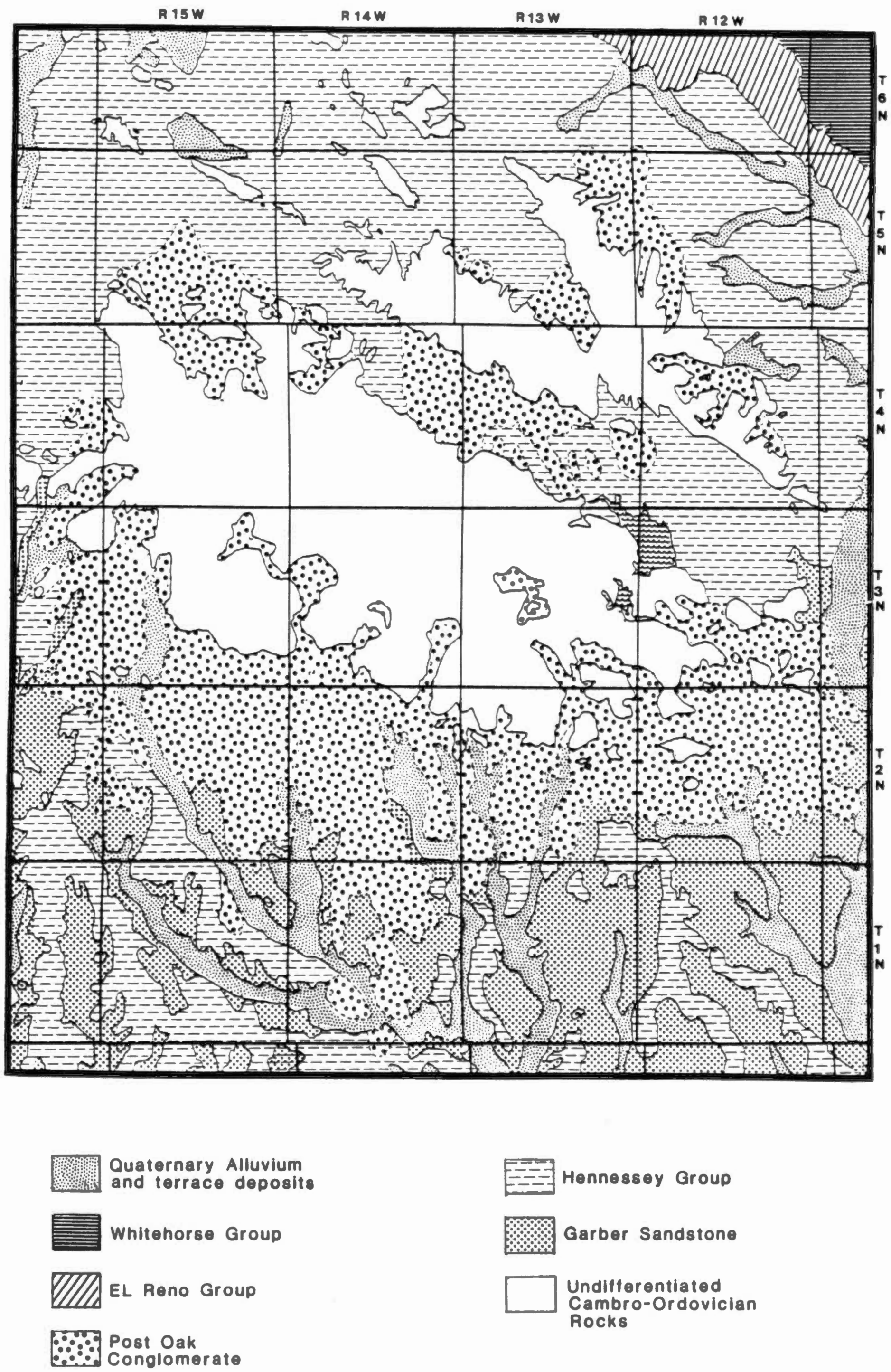


Figure 7. Geological Map of Wichita Mountains Area (after Havens, 1977)

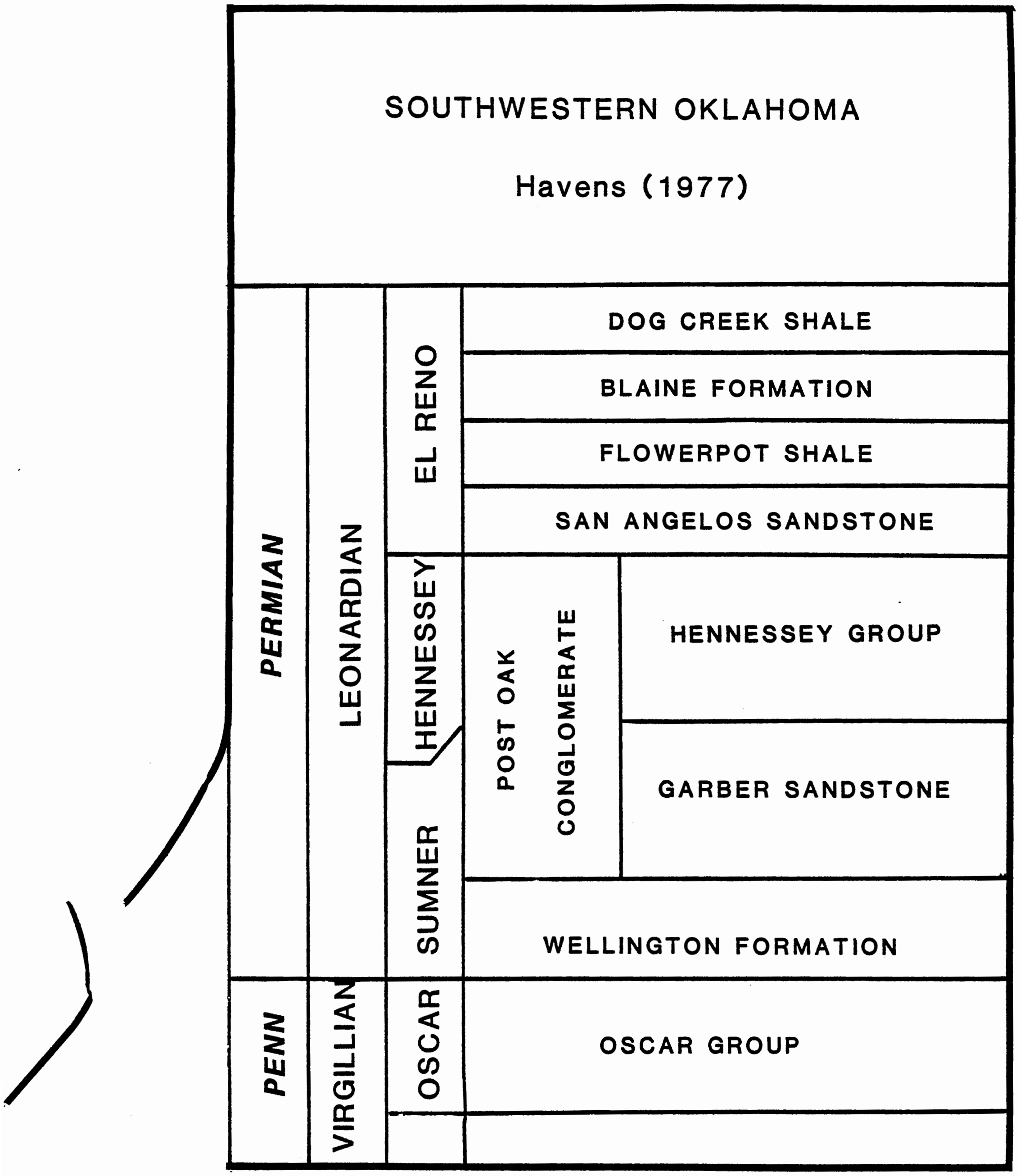


Figure 8. Stratigraphic Column of Late Pennsylvanian and Early Permian Strata of Southwestern Oklahoma According to Havens (1977)

sites of Southern Oklahoma on the basis of Fay´s (1968) and Havens´ (1977) systems of stratigraphic nomenclature. He believed that since the Permian of southern Oklahoma had been accurately mapped, referring to Havens (1977), that the vertebrate fossil sites described by Olson and others could be placed in their proper stratigraphic context. Simpson hypothesized that the arid environmental conditions which existed in north Texas at the end of Wichita time were responsible for the elimination of many Wichita vertebrates. Conditions were, however; regarded as being favorable around the Wichita Mountains, thus sustaining many of these genera through the Late Leonardian.

Papers by Al-Shaieb et al. (1976, 1977a, 1977b, 1978, 1980, 1982) are the most detailed published works on the Lower Permian strata in southwestern Oklahoma. Studies consisted mainly of sedimentologic, petrographic, and diagenetic analysis of rocks, conducted primarily on the south side of the Wichita Mountains. Because much of the clastics mapped by Chase as Post Oak Conglomerate were described by Al-Shaieb et al. as sandstones and mudstones, the name "Post Oak Formation" was preferred.

The "Post Oak Formation" of Al-Shaieb et al. was described as texturally immature channel sandstones and conglomerates interbedded with red siltstones and shales, exhibiting immature paleosols (calcretes) in fine and coarse grained lithologies. Channel deposits were described as multi-storied close to the mountains and discrete farther to the south; discrete channels being separated by finer grained rocks. Well rounded granite cobbles and boulders in conglomerates were considered to have resulted from in-situ spheroidal weathering of granite, rather than by transportation. Alluvial fan, braided stream, and alluvial plain depositional environments were interpreted on the basis of paleocurrents and textures. Calcretes and dessication cracks were regarded as indicators of episodic sedimentation and semi arid climate.

Discrepancies were noticed by Al-Shaieb et al. in Chase´s geologic map. Surficial unconsolidated granite boulders were mapped and interpreted by Chase as granite "Post Oak Conglomerate"; whereas, field observations made by Al-Shaieb et al. indicated a possible Pleistocene age. Discrepancies in Chase´s map were thought to be minor and no alterations were proposed.

Both Chase´s (1954) and Havens´ (1977) classifications of stratigraphic nomenclature were used by Al-Shaieb et al.; however, in the later publications Havens´ classification was preferred.

Gilbert (1979, 1982) recognized a Permian exhumed, tor type granite topography, which resulted from the weathering of regularly spaced horizontal and vertical fractures in the granite. Gilbert pointed out that weathering predominated over erosion to produce spheroidally rounded clasts which were later stripped away and deposited as Post Oak Conglomerate. He hypothesized that erosion of the clasts might have been caused by uplift or an increase in rainfall (Figure 9).

Gilbert suggested a easterly source for many of the shales. He also pointed out what he believed were dissimilarities in characteristics between the subsurface "granite wash" and the surface Post Oak Conglomerate signifying seperate tectonic styles for each.

Donovan (1982, 1984), classified most of the limestone conglomeratic detritus shed from the Slick Hills as having resulted from post tectonic denudation of the uplifted limestone. However, boulder breccia beds coupled with the enormous extent of typical limestone conglomerates in the Meers Valley suggested syntectonic deposition, possibly caused by localized uplift of the Slick Hills. Strongly inverted relief across the Meers Valley was cited as evidence for this uplift (Figure 10). In addition to describing the Permian rocks in Blue Creek Canyon, Donovan also noticed karst features which he considered to be Permian in age (Figure 11).

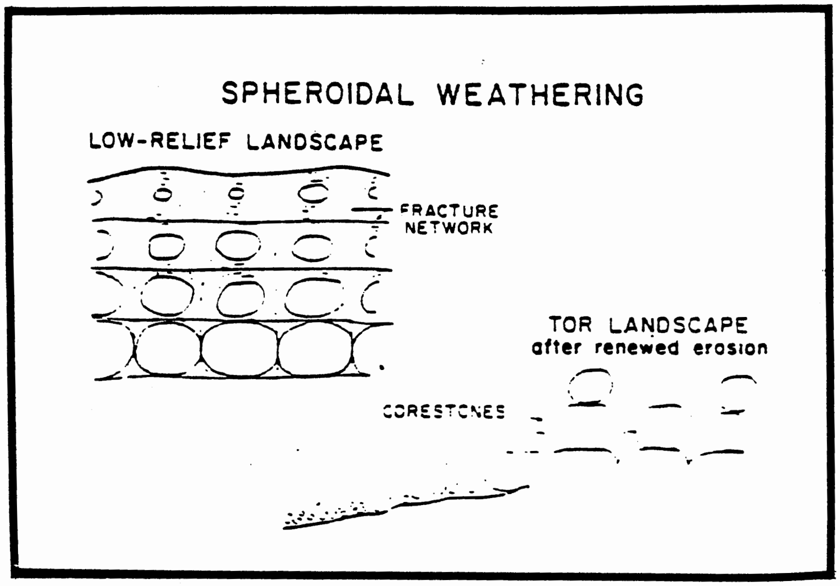


Figure 9. Tor Weathering of Granite in the Wichita Mountains (after Gilbert, 1982)

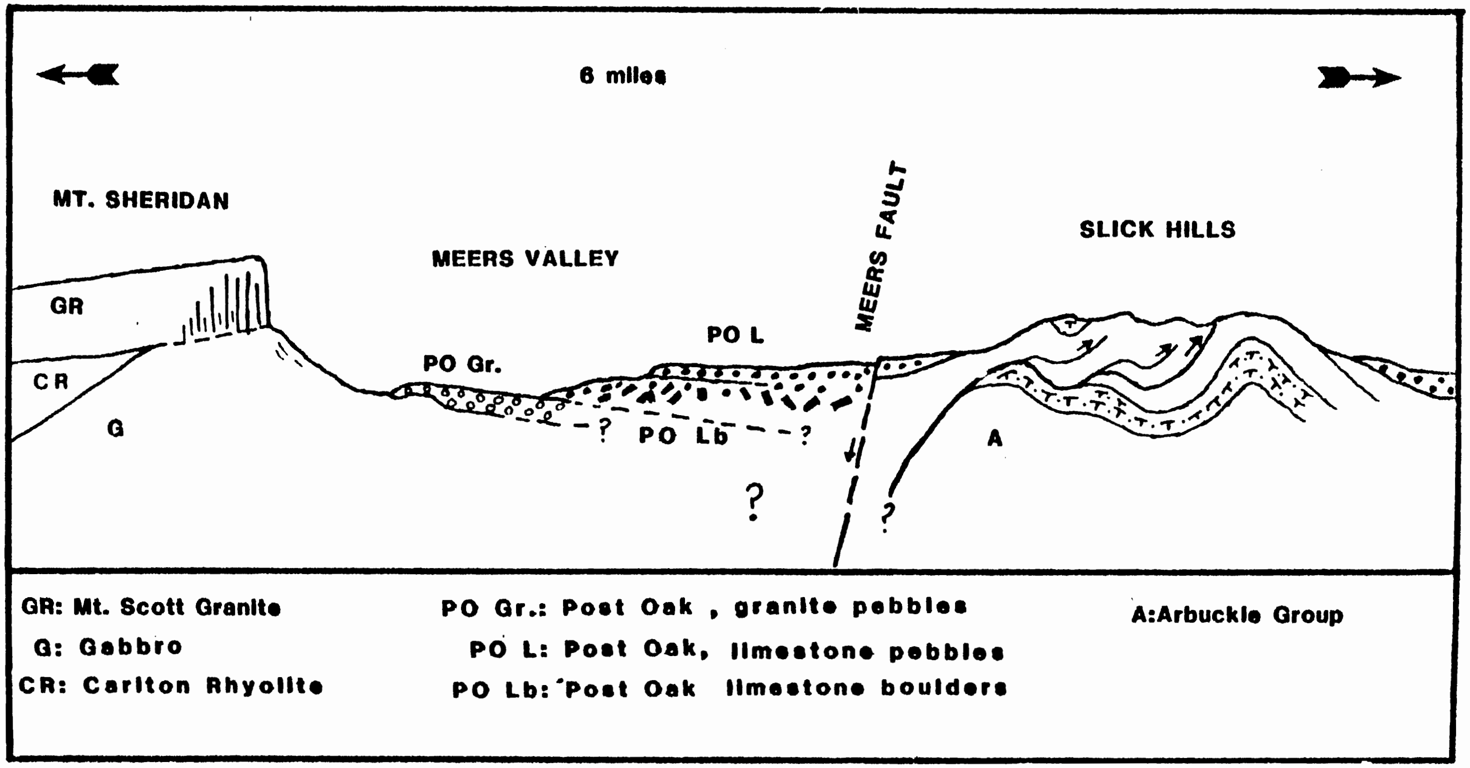


Figure 10. Schematic Cross Section of the Meers Valley Showing Inverted Relief Across the Valley and the Approximate Position of the Boulder Beds

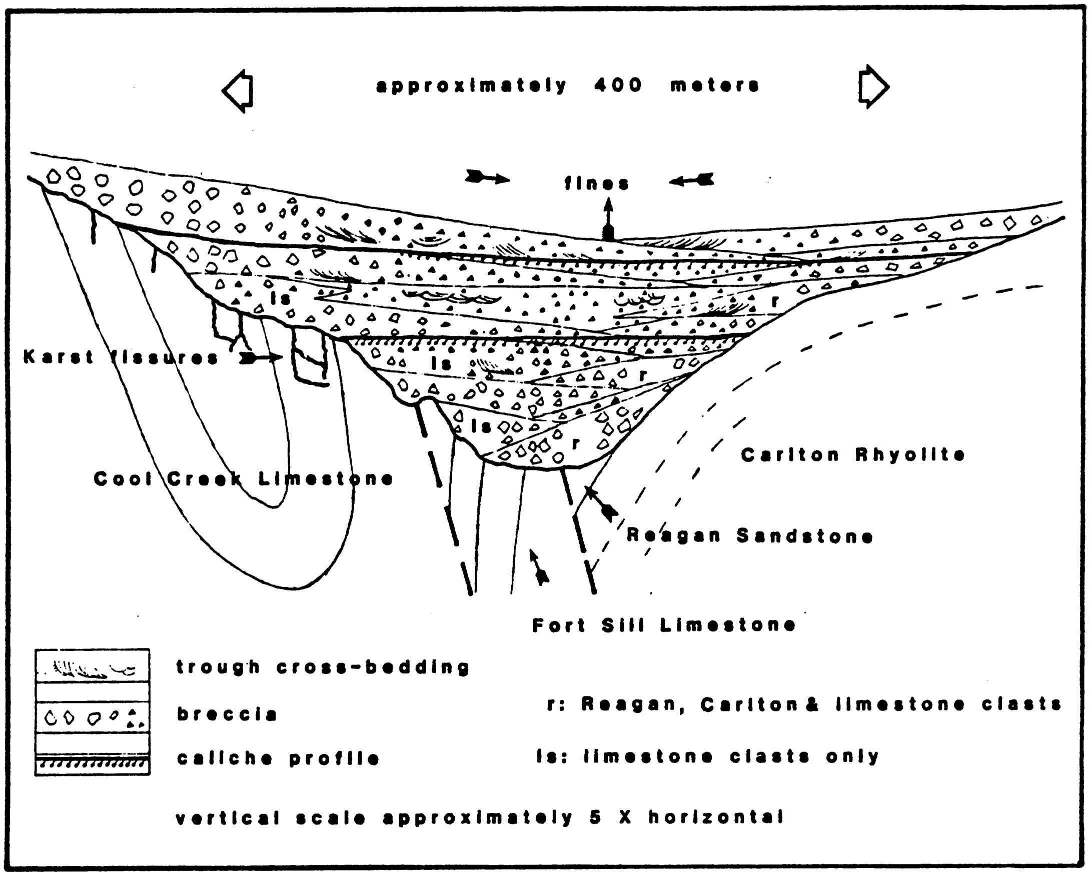


Figure 11. Schematic Cross Section of Blue Creek Canyon During the Early Permian; Depicts the Infill of the Canyon by Coarse Clastics and the Formation of Karst Features

CHAPTER III

REGIONAL STRATIGRAPHY

Introduction

The following is a stratigraphic summary of the exposed Cambrian through Recent rocks in the study area. Importance is placed on Cambrian and Ordovician strata which supplied most of the detrital material in the Lower Permian rocks (Figure 12).

Wichita Mountain Igneous Complex

Tillman Metasedimentary Group

The Tillman Metasedimentary Group of Pre-cambrian ? age is thought to be represented by zenoliths of meta-quartzite and meta-graywacke incorporated in rocks of the Raggedy Mountain Gabbro Group and the Wichita Granite Group. There is no field evidence to establish the exact stratigraphic position of this group (Gilbert, 1982).

Raggedy Mountain Gabbro Group

The Raggedy Mountain Gabbro group is broken down into two formations, the Glen Mountain Layered Complex and the Roosevelt Gabbros. Late Pre-cambrian to Early Cambrian

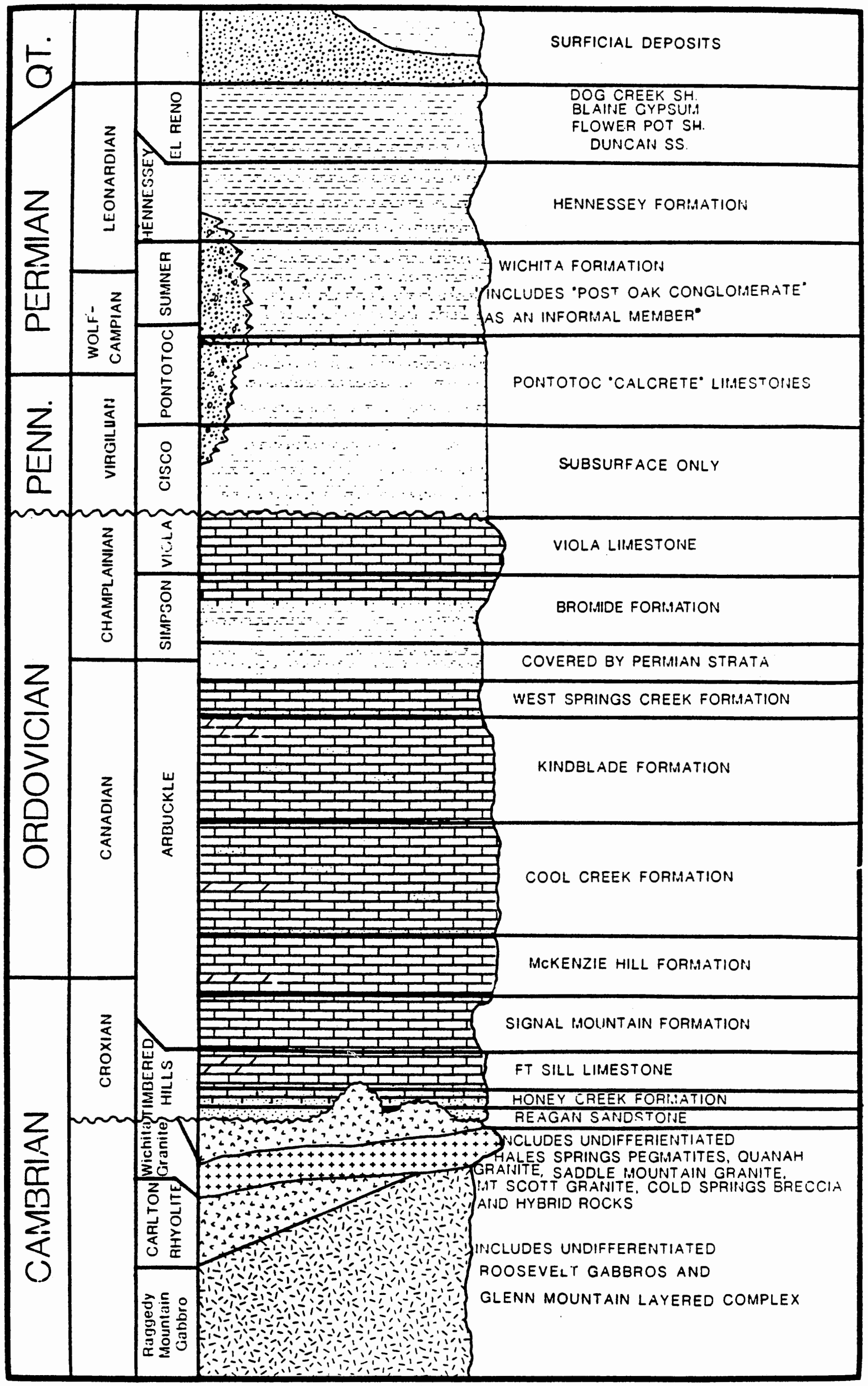


Figure 12. Stratigraphic Section of the Exposed Rocks Within the Study Area

anorthositic gabbros, gabbro, and troctolite characterize the Glen Mountain Layered Complex. Late Cambrian medium to fine grained, hornblende-biotite gabbros comprise the Roosevelt Gabbros (Gilbert, 1982).

Carlton Rhyolite Group

The Middle Cambrian Carlton Rhyolite Group is described as rhyolitic lava flows interbedded with tuffs and agglomerates (Donovan, 1982).

Wichita Granite Group

Representatives of the Wichita Granite Group in the study area include the Mount Scott Granite, Saddle Mountain Granite, Medicine Park Granite, Cache Granite, and the Quanah Granite. They consist predominantly of medium to fine grained, alkali feldspar granites (Gilbert, 1982).

Diabase Intrusions

Middle Cambrian fine grained diabasic intrusions occur predominately in dike form, cutting all other igneous rocks in the study area. They do not appear to cut the Reagan Sandstone, the lowestmost sedimentary unit (Donovan, 1982).

Sedimentary Succession

Timbered Hills Group

The Upper Cambrian Timbered Hills Group unconformably overlies the Carlton Rhyolite Group. The basal Reagan

Sandstone represents a trangression of quartzose sandstone with varying amounts of glauconite over a basal facies of conglomerate. A transitional boundary exists between the quartz rich Reagan Sandstone and the coarse bioclastic carbonate sandstone of the Honey Creek Formation (Donovan, 1982).

Arbuckle Group

Overlying the Timbered Hills Group is the Cambro-Ordovician Arbuckle Group. The lower portion of this Group consists of several carbonate formations. Upper Cambrian representatives are the Fort Sill Formation, Royer Dolomite, and the Signal Mountain Formation.

The Fort Sill Formation is characteristically a thinly bedded, micritic limestone with silty, shaly, and oolitic horizons represented in sections (Chase et al., 1956). Three members were designated by Nelmes (1958) and Brookby (1969) of which the upper massive bedded member serves as a distinctive marker horizon in the field (McConnell, 1983).

The Signal Mountain Formation overlies the Fort Sill Formation except in two localities where the distinctive rugged-weathering brown Royer Dolomite is present (Chase et al. 1956). The Signal Mountain Formation is often a valley former consisting of brown to gray thinly bedded limestone with numerous zones of intraformational conglomerates.

Members of the Upper Arbuckle Group in ascending order include the McKenzie Hill, Cool Creek, Kindblade, and West

Spring Creek Formations.

The McKenzie Hill Formation consists predominantly of interbedded limestones one to two feet thick. The Formation is differentiated from the underlying Signal Mountain Formation by its nodular chert horizons, massive bedding and robust weathering.

The Cool Creek Formation is characterized by a variety of recognizable lithologies: intraformational conglomerates, oolitic sandstones, algal boundstones and calcilutites (Donovan, 1982). A sandy limestone formally named the Thatcher Creek Member marks the base and is an excellent marker bed for mapping purposes (Ragland and Donovan, 1985).

Massive bedded algal limestones coupled with the distinguishing fossils Archaeoscyphia and Ceratopea help to define the obscure boundary between the Cool Creek formation and the Kindblade Formation. Lithologically the Formations are similar (Chase et at., 1956).

The West Spring Creek Formation is not fully exposed in the eastern Wichita Mountain area. The Formation is poorly exposed and difficult to distinguish from the underlying Kindblade Formation. According to Barthelman (1968) thin laminated limestones containing beds of quartz sandstone mark the contact between the Kindblade Formation and the West Spring Creek Formation.

The greatest part of the Upper Arbuckle Group is composed of various types of limestone, however in the upper parts of this Group distinctive brown dolomites make up a large percentage of the rock.

Simpson Group

A large portion of the Simpson Group, of Middle Ordovician age, lacks outcrop representation in the study area. The unrepresented section includes the Oil Creek, Mclish, and Tulip Creek Formations. Most of the Bromide Formation is covered by Permian strata of the Wichita Formation. One hundred and eight feet of upper Bromide Formation is exposed on the south flank of three small hills located in the northwest portion of the study area

Viola Group

Unconformably overlying the Simpson Group in the study area is a resistant organic rich, cherty limestone informally referred to as the Viola Limestone. This limestone occurs as a cap rock in four rounded hills in the northwestern portion of the study area.

The Viola Group is the youngest rock of the Cambro-Ordovician section to be overlain unconformably by Permian strata in outcrop.

Pennsylvanian and Permian Rocks

Undifferentiated Pennsylvanian and Permian strata are described here only briefly, these rocks are described further in Chapter IV.

Upper Pennsylvanian and Lower Permian rocks overlie Lower Pennsylvanian rocks in the subsurface (Harlton, 1963). Illustrating the major unconformity which exists locally within the Pennsylvanian section. Upper Pennsylvanian and Permian strata represent a section referred to by many authors as "red beds". Although most use the term "red beds" to refer only to Permian rocks, it has been observed by many that a period of continuous deposition of like lithologies occurred from Upper Pennsylvanian into the Lower Permian time. This period of continuous deposition combined with a lack of paleontologic data has made the placing of the Pennsylvanian-Permian contact a subject of dispute and confusion among authors and workers.

Rocks belonging to the above systems are generally composed of shales, sandstones, limestones, dolomite, and conglomerates. Rocks in the upper section contain abundant evaporites. Carbonate rocks are more common lower in the section. Color ranges from varying shades of red, purple, brown, gray, tan, and green. Color has been used by some workers as a lithologic indicator but it has been observed that color is completely independent of lithologic and time boundaries.

Several different systems of stratigraphic nomenclature have been proposed for these rocks. This nomenclature is discussed in Chapter V.

Rocks of Upper Permian age are exposed in the north and northeast section of the study area. These rocks are recognized as the El Reno and the Whitehorse Groups and consist mainly of shales, sandstones, carbonates and evaporites (Miser, 1954). These Upper Permian "red beds" are not discussed further in this thesis.

Pleistocene Rocks

The uppermost strata identified in the study area are composed of Tertiary? and Quaternary deposits. The author believes the oldest of these deposits are approximately Pliocene-Pleistocene equivalents, although no exact ages have been determined for these rocks. They will hereinafter be referred to the Pleistocene, these deposits are significant in that they have previously been interpreted by some authors as Permian. These strata consists predominantly of dull orange conglomerates, sandstones, calcretes, and poorly indurated mudrocks. These rocks often contain reworked clasts of the underlying Lower Permian strata. In many outcrops differentiating these rocks from Lower Permian rocks is difficult. This is attributed because the Lower Permian and the Pleistocene rocks are compositionally similar and were likely deposited in similar environments (Figure 13).

Figure 13. Pleistocene Conglomerates Cap this Hill and Overly Permian Strata, South Side of Highway 62, Sec. 28, T. 2 N., R. 13 W.

CHAPTER IV

LOWER PERMIAN DESCRIPTIVE STRATIGRAPHY

Introduction

The study area of this thesis contains a wide variety of lithologies. This chapter describes the types and character of strata that comprise the Lower Permian section.

Sandstones

Lower Permian sandstones vary widely in composition due mainly to the variety of available source rocks in the vicinity of the study area.

Sandstones south of the igneous Wichita Mountains are mainly composed of detritus which resulted from the weathering of the exposed Permian Wichita Mountains. They are classified as poorly sorted arkoses and subarkoses (Figure 14). Detrital carbonate clasts are rare south of the mountains. Sandstones are generally poorly indurated, containing cements of hematite, limonite, clays and rarely calcium carbonate. Barite is the least common cement and is found mainly in nodular radiating concretions. Sandstones vary in color ranging from shades of brown, red, orange, maroon, green, and gray.

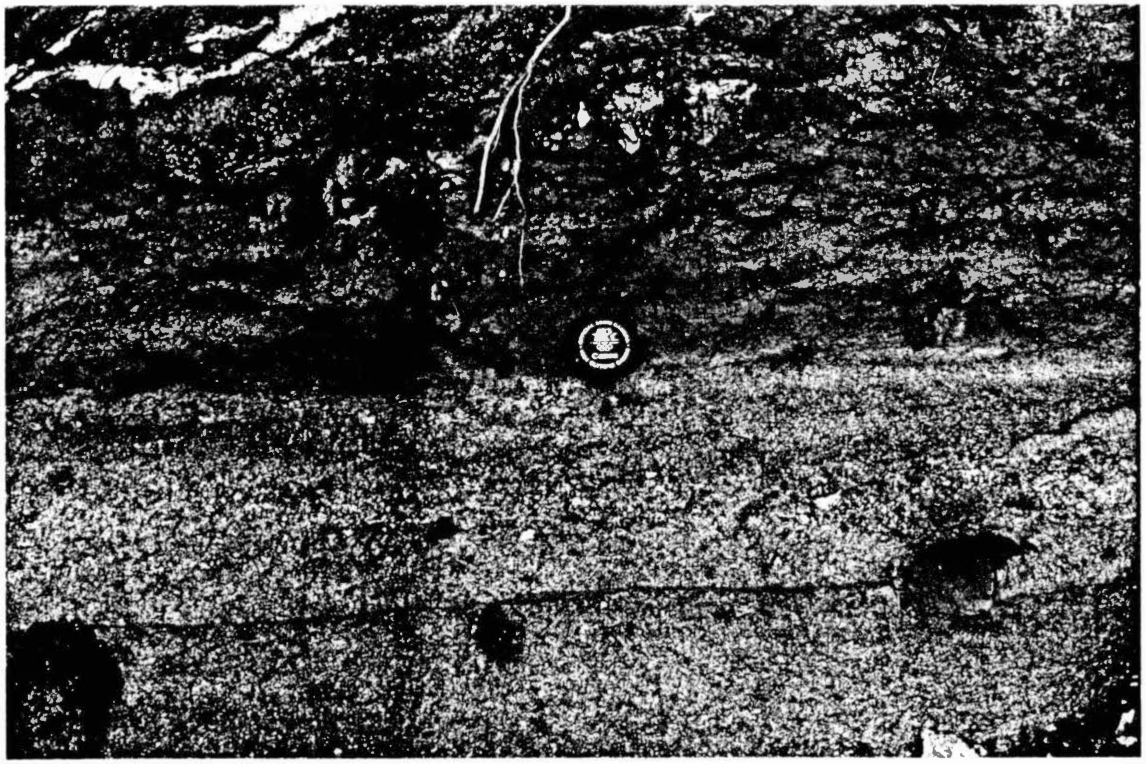


Figure 14. Typical Arkosic Sandstone, NE 1/4, Sec. 19, T. 4 N., R. 13 W.

North of the igneous Wichita Mountains in the Meers Valley, sandstones are similar but are predominately cemented by calcium carbonate cement and may contain lenses of heavy minerals such as magnetite and illmanite (Collins, 1985).

North of Slick Hills some of the sandstones contain a high percentage of limestone clasts. Many are reworked intraformational calcrete fragments rather than Cambro-Ordovician carbonates detritus. However the latter supply much of the detritus for conglomerates in the vicinity. Color of sandstones is generally lighter north of the Slick Hills than elsewhere and is often tan, buff to gray. Cements are characteristically carbonate although cements of limonite, hematite and clays are also present.

Sandstones throughout the study area exhibit few sedimentary structures, but sometimes contain medium scale trough crossbedding, horizontal laminations, and lenses (Figure 15). Clay clasts are common as well as channel lags composed commonly of granite clasts. Sandstones are sometimes impregnated with asphalt and may appear to be black to brown.

Mudstones

Mudstone as a descriptive term is used in place of shale and siltstone in this thesis because most rocks in this category are composed of poorly indurated intermixed sand, silt and clay sized particles, lacking in fissility.

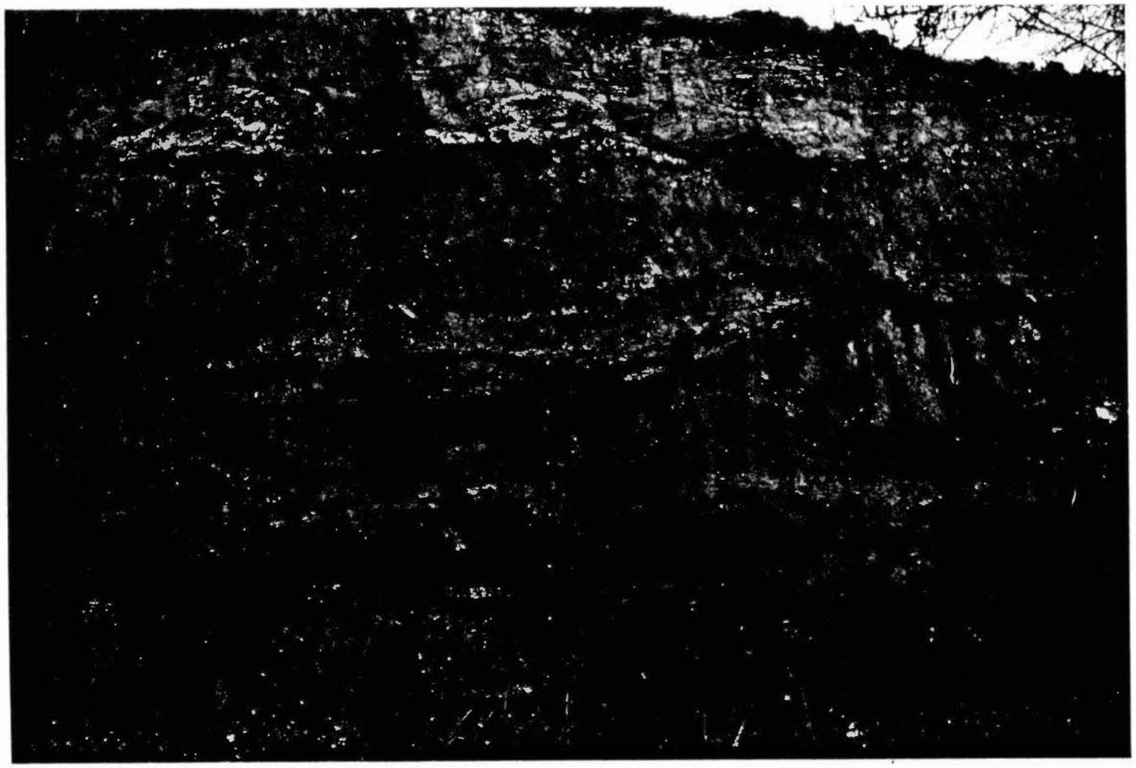


Figure 15. Sandstone and Shale Sequence With Lenticular Channel Sandstones, NW 1/4, Sec. 2, T. 3 N., R. 12 W.

Mudstones are interbedded with sandstones and conglomerates and are estimated to make up the largest percentage of rock type in the study area. Mudstones have weathered to form extensive plains and are best exposed along streams or other such cuts with sufficient caprock to preserve their outcrop. Mudstones vary widely in color with maroon and green predominating. Mudstones often act as host rocks for calcrete, barite and carbonaceous concretions (Figure 16).

Conglomerates

The definition of conglomerate pertaining to this thesis is that rock which contains at least 30-50 percent pebble or larger sized clasts in proportion to other constituents.

Conglomerates were divided by Chase (1954) into four main types i) granite boulder conglomerate, ii) rhyolite porphyry conglomerate, iii) limestone conglomerate, and iv) granite-gabbro conglomerate cemented with zeolite and opal cement. Chase also noticed the intermixing of some forms of these conglomerates. Field work has revealed that type iv should also include conglomerates composed of granite-anorthosite clasts cemented by calcite. Type iii should be modified to include large boulder breccia beds which are termed "megabreccia" (Donovan, Bridges, Collins 1985), but will be discussed separately in this thesis.

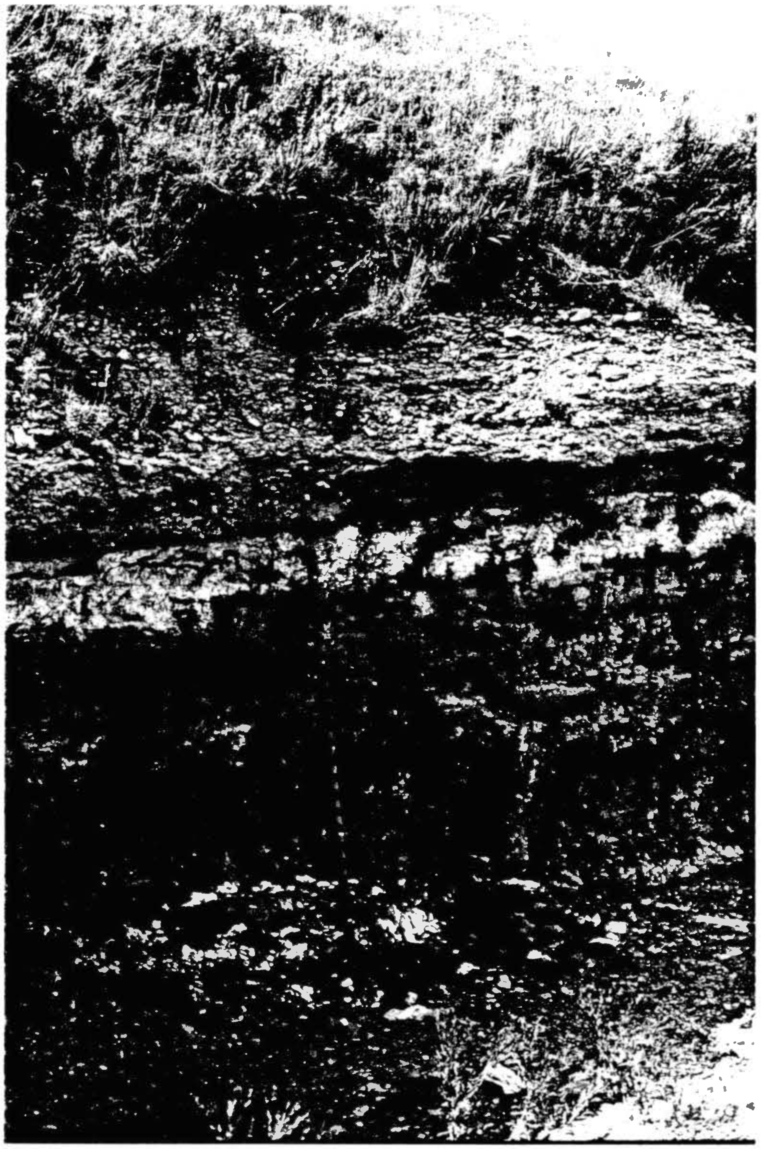


Figure 16. Limestone Conglomerates Overlying a Calcrete Capped Red Mudstone

Granite Boulder Conglomerates

Granite boulder conglomerates are generally composed of sub-rounded to well rounded granite clasts embedded in a matrix of arkosic sandstones and clays; mixtures of the two are common. Clasts vary in size and are commonly 2-10 inches in diameter (Figure 17). Conglomerates are often poorly stratified and exhibit few sedimentary structures. The largest clast observed in the study was approximately 3 feet in diameter, although judging by the size of granite core stones presently exposed on outcrops, clast sizes over 10 feet could exist. Outcrops are generally poor with the clasts often being weathered to grus. Color of the conglomerates varies from shades of yellow, red, and brown. Outcrops of granite boulder conglomerate are well exposed north and east of Meers Sec. 28, T. 4 N., R. 13 W, on the Wichita Wildlife Refuge Sec. 16, T. 3 N., R. 13 W, (Figure 18) and Sec. 30, T. 3 N., R. 14 W. Much of the natural outcrop of granite conglomerate occurs on Fort Sill Military Reservation which is restricted to public access. Parent rock types other than Wichita Granite Group were not determined for the granite clasts.

Rhyolite Porphyry Conglomerates

The distribution of rhyolite conglomerates were not observed as being as extensive as mapped by Chase. Conglomerates of this type generally contain a high

Figure 17. Typical Exposure of Granite Clast Conglomerates With Rounded Clasts

Figure 18. Granite Clasts Conglomerates Unconformably Overly Carlton Rhyolite, Sec. 16, T. 3 N., R. 13 W.

percentage of limestone and granite clasts. Al Shaieb et al. (1977) noted this and believed the designation of rhyolite conglomerate as a separate facies was unwarranted. Conglomerates of this type are best exposed in Blue Creek Canyon Sec. 11 T. 4 N., R. 13 W. (Figure 19) and on Fort Sill at Quarry Hill Sec. 8 T. 2 N., R. 11 W.. Parent rock for rhyolite conglomerates is apparently the Carlton Rhyolite which outcrops in the vicinity.

Limestone Conglomerates

Limestone conglomerates are generally well exposed along the flanks of the Cambro-Ordovician limestone hills. Clasts sizes are variable, with clasts of 1 inch to 20 inches being common (Figures 20 and 21). Clasts are usually angular to rounded, well sorted and well cemented. Conglomerates are usually well stratified and exhibit few sedimentary structures. Bedding forms include sheet beds, lenses, and channels. Cements are predominately fibrous and micritic calcite with minor amounts of pyrite, hematite, barite and clay. Calcretes are common in these rocks and are responsible for the micritic cements. Unusually large angular limestone clasts occur as deposits within the limestone conglomerates. These deposits are referred to as megabreccias and will be discussed separately.

Figure 19. Limestone-Rhyolite Clast Conglomerates Exposed in Blue Creek Canyon

Figure 20. Coarse Limestone-clast Conglomerate Facies Overlain by More Typical Limestone-clast Conglomerates

Figure 21. Typical Limestone Clast Conglomerate Unconformably Overlying Arbuckle Rocks

Gabbro-Anorthosite-Granite Conglomerates

Gabbro-anorthosite-granite conglomerates, originally called the Tepee Creek Formation by Merrit and Ham (1941) and Mayes (1947) were reexamined by Chase (1954). Chase dropped the name Tepee Creek Formation and included these rocks into the Post Oak Conglomerate which he designated as a member of the Wichita Formation. These rocks are considered unusual because they sometimes contain cements of opal and zeolites. Calcite is also present as a cement. Although most of this rock type does not lie within the study area at least two outcrops of this type of conglomerate were observed within this area. One outcrop occurs in Sec 34, T. 4 N., R. 16 W. and Sec 3, T. 3 N., R. 16 W.. This exposure displays a dark red gabbro-granite-anorthosite conglomerate containing clasts generally less than one inch in diameter suspended in a fine grained groundmass. Another outcrop that was not mentioned by any of the previous authors is located at the south east corner of Sec. 23, T. 4 N., R. 15 W.. This rock is a gray gabbro-anorthosite conglomeratic sandstone cemented with calcite. Clasts vary from sand size to several inches in diameter. The occurrence of this rock type is of interest because no outcrops of gabbro or anorthosite have been identified locally.

Calcretes

Introduction

Calcretes are authigenic accumulations of principally calcium carbonate, which form mainly through the processes of pedogenesis (Leeder, 1975). Calcretes are known by various other names such as caliche and cornstones (Reeves, 1970). Ancient accumulations of this type rock are often classified as fossil soils or paleosols. Studies of calcretes have been conducted worldwide on different aged rocks. Steel (1974) examined Permian calcretes in the New Red Sandstone of western Scotland. Allen, (1974a), (1974b) and Leeder, (1973) investigated Silurian-Devonian calcretes in the Old Red Sandstones of Brittian. Triassic-Jurassic calcretes were described by Hubert, (1977) in Connecticut. Pliocene through Recent calcretes have been studied in the high plains of the western United States by many investigator such as: Gile and Hawley (1966), Price (1925), and Reeves (1970).

Calcretes normally develop on flood basins, alluvial fans, and alluvial plains, where precipition rates vary from approximately 4 to 24 inches annually (Leeder, 1975). Other factors determining calcrete formation include temperature, geomorphic stability (sedimentation and erosion rates), and carbonate supply (Leeder, 1975). Early workers believed the sources of calcium carbonate resulted from capillary action caused by evaporation.

Calcium carbonate rich waters were believed to have been drawn to the surface where evaporation took place and precipitated calcretes. More recent workers believe that calcium carbonate is brought in by carbonate rich aeolian dust and carried into the soil by downward percolation of meteoric waters (Leeder, 1975). Calcretes have been used by many authors as paleoenvironmental indicators signifying semiarid to arid climates and ephemeral deposition.

Reeves classified calcretes as young, mature, late mature, and old age. Gile, Steel, and Leeder described similar stages of calcrete development as represented in tables I,II, III, IV.

Description

Permian calcretes of southern Oklahoma have been identified by Al Shaieb et al. (1977), Stone (1977), Donovan (1978), Kwang (1978), and Collins (1985).

Calcretes occur in a variety of rock types in the study area. Mudstones, sandstones, and conglomerates host calcretes. Calcrete morphologies exhibit typical characteristics with breccias, fractured clasts, nodules,laminations, psuedo-pisolites, concretions, septaria, slickensides, and rhizoconcretions being common (Figure 22). An excellent description of these morphologies is provided by Reeves, (1970). Calcretes are often white in color, but colors are often similar to the host rock. Although calcretes are found throughout the

TABLE I

PROGRESSIVE STAGES OF CALCRETE DEVELOPMENT IN NONGRAVELLY SEDIMENTS ACCORDING TO GILE, (1970)

Stage 1 - Scattered grain coatings or carbonate filaments.

Stage 2 - Carbonate nodules separated by low carbonate material.

Stage 3 - Carbonate impregnated throughout and plugged in last part of this stage.

Stage 4 - Indurated laminar horizon, consisting primarily of carbonate, formed on top of plugged horizon.

TABLE II

PROGRESSIVE STAGES OF CALCRETE DEVELOPMENT IN GRAVELLY SEDIMENTS ACCORDING TO GILE, (1970)

Stage 1 - Horizons have thin, partial or complete carbonate coatings on pebbles.

Stage 2 - Thicker carbonate coatings and some filaments in interstices between coatings.

Stage 3 - Horizons have carbonate virtually *throughout, the horizon becomes plugged with carbonate in last part of the stage.

Stage 4 - Laminar horizon has formed on top of plugged horizon.

TABLE III

PROGRESSIVE STAGES OF CALCRETE DEVELOPMENT ACCORDING TO STEEL, (1970)

Stage 1 - Small (1 to 6 cm in diameter), irregularly shaped nodules composing less than 10% of rock.

Stage 2 - Nodules are up to 10 cm in diameter of vertically elongate and up to 15 cm long. Nodules occupy less than 50% of rock in upper part of profile, downgrading to stage 1.

Stage 3 - Carbonate appears as nodules, vertical pipes or horizontal sheets. Carbonate occupies more than 50 % of rock but clastic sediment can still be clearly seen within carbonate framework. There is a downward gradation into stage 2.

Stage 4 - Calcrete exists as beds within which only rare patches of clastic sediment are seen. There is a downward gradation to stage 3.

Stage 4a- Characterized by distinct horizons of laminar, brecciated or pisolitic carbonate, usually as a capping to stage 4. In some cases carbonate is partially silicified or thin beds of carbonate alternate with thin beds of chert.

TABLE IV

DEVELOPMENT TIME REQUIRED OF STAGES, ACCORDING TO LEEDER, (1975)

Stage 1: minimum - 1000 years, maximum - 4500 years

Stage 2: minimum - 3500 years, maximum - 7000 years

Stage 3: minimum - 6000 years, maximum - 10,000 years

Stage 4: minimum - 10,000 years

Figure 22. Calcrete Nodule Exhibiting Shrinkage Cracks and Slickensides

study area they are best exposed in the Meers Valley along the north shore of Lake Lawtonka Sec. 36, T. 4 N., R. 13 W. (Figure 23). A discussion of the calcretes in the Meers Valley is included in a thesis by Collins, (1985). Calcretes south of the Wichita Mountains are described by Kwang, (1978). Permian calcretes are found around a Viola-Bromide Hill in Sec. 21, T.6 N., R. 15 W. and occur around several other limestone hills in the northwest portion of the study area, but there is some question to the exact age of the calcretes. The author believes at least some of these calcrete outcrops are Pleistocene in age.

Calcretes have been mined in several locations in the study area for use as road metal (Figure 24).

Megabreccias

Megabreccias are defined as large angular blocks composed of Cambro-Ordovician limestones and dolomites. Dimensions are commonly two to ten feet in length along exposed sides. Donovan (1984) was the first to describe these megabreccias as a boulder breccias facies of limestone clast Post Oak Conglomerate. The term megabreccia was applied by Donovan et al. (1985) to these large blocks which occur in the Meers Valley and is now applied to all such occurrences. Megabreccias are a facies of the limestone conglomerates, as noticed by Donovan, but because of their great clast size and probable tectonic significance it is appropriate that they be treated and

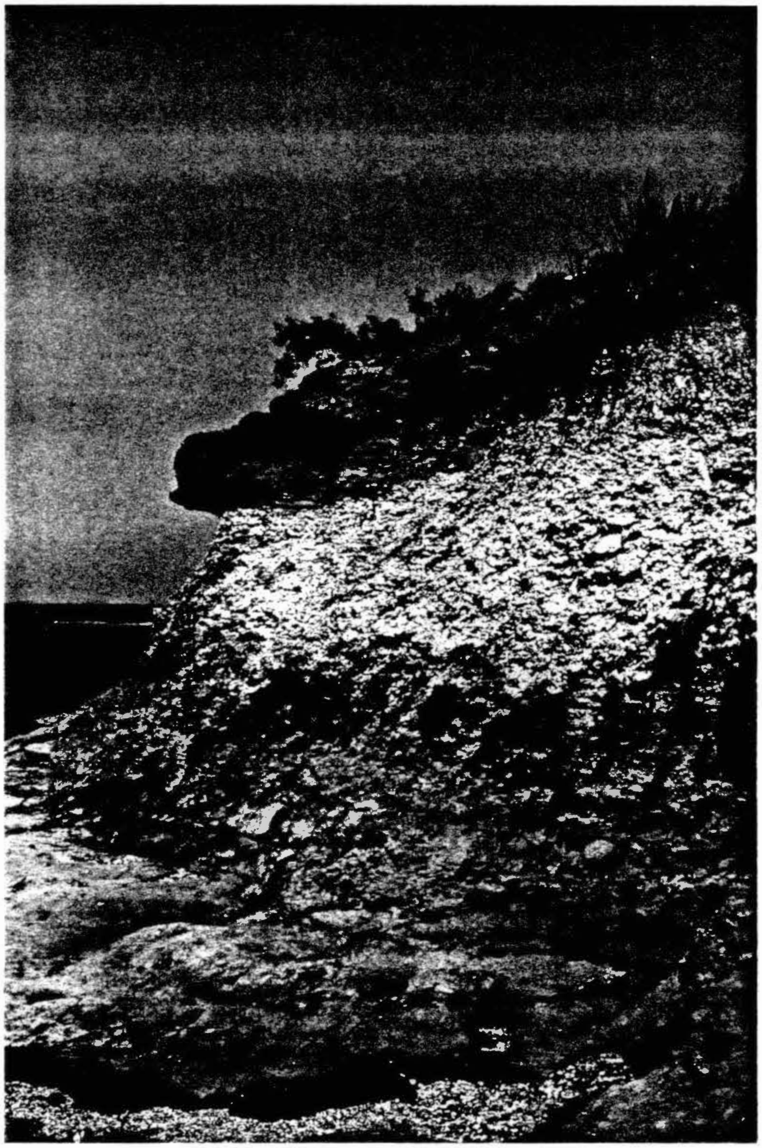


Figure 23. Mature Permian Calcrete Developed in Sandstones and Conglomerates, North Shore, Lake Lawtonka

Figure 24. Thick Calcrete Being Excavated for Road Metal
Sec. 10, T. 4 N., R. 12 W.

described separately.

Harlton (1951) mapped outcrops of Kindblade Limestone in the Meers Valley south of the Meers Fault (Figure 25). It is these outcrops of disoriented blocks of limestone that have been interpreted in this thesis as megabreccias.

The Geologic Map of Oklahoma (Miser, 1954) shows a large area south of the Meers fault incorrectly mapped as Arbuckle Limestone. This area is correctly mapped as Post Oak Conglomerate, containing megabreccia outcrops (Plate 1). It is easily understood how these megabreccias could be interpreted as disturbed Cambro-Ordovician outcrops. Megabreccia outcrops often contain blocks as large as 30 feet in length and superficially resemble extremely deformed Cambro-Ordovician outcrops in the Slick Hills north of the Meers fault (Figure 26 and 27). Stratigraphic relationships in the Meers Valley clearly show that the megabreccias are contained within the limestone clast conglomerate although their position is variable. Megabreccias are known to occur in three locations in the study area, the Meers Valley T. 4 N., R. 13 & 14 W., Blue Creek Canyon Sec. 21, T. 4 N., R. 13 W. and Sec. 35, T. 5 N., R. 13 W., and southeast of an unnamed limestone hill in Sec. 26, T. 6 N., R. 14 W.. Megabreccias in the Meers Valley are mainly composed of clasts derived from Upper Arbuckle limestones and dolomites, predominantly from the Kindblade Formation. Blocks of dolomitized breccias are also common in the Meers Valley. Elsewhere blocks appear

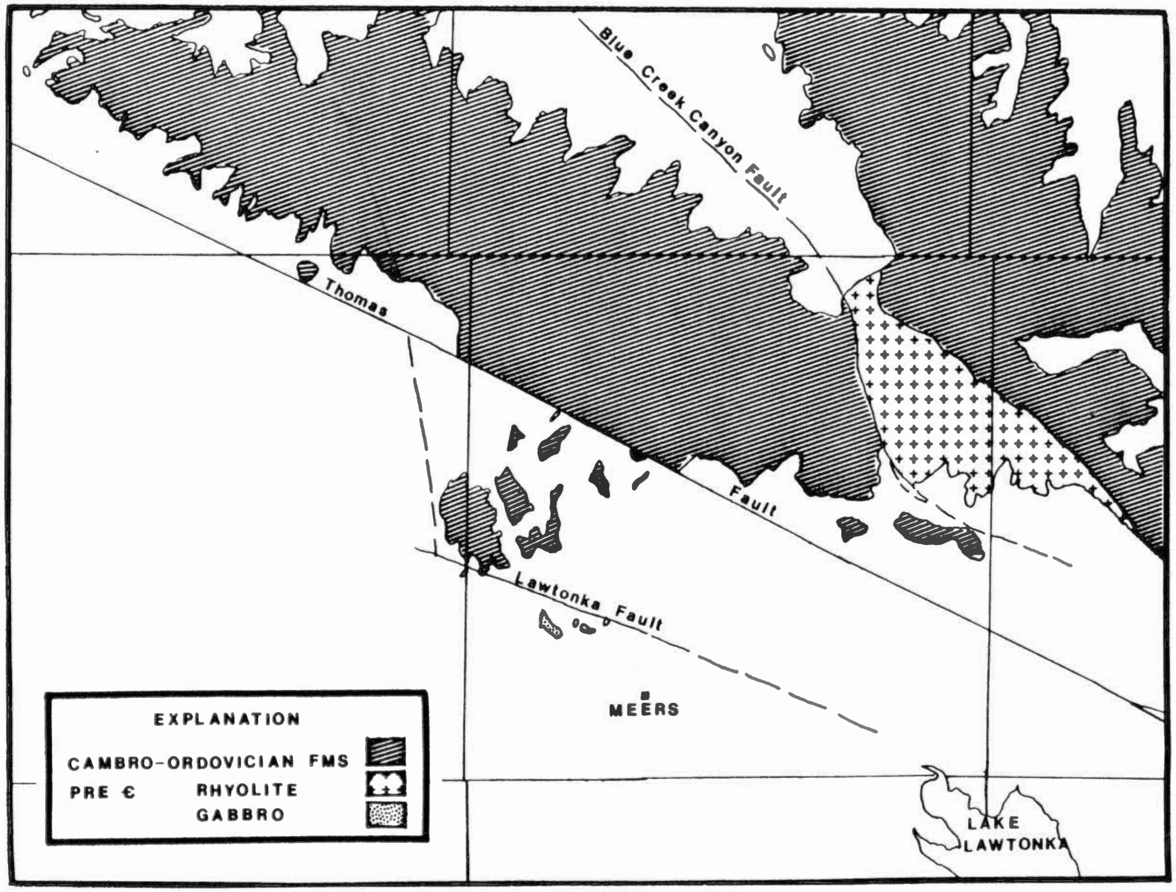


Figure 25. Geologic Map by Harlton (1951), Megabreccia Outcrops South of the Meers Fault are Incorrectly Interpreted as Cambro-Ordovician Arbuckle Limestone

Figure 26. Boulder Field of Megabreccia, Resembles Disturbed Arbuckle Outcrops

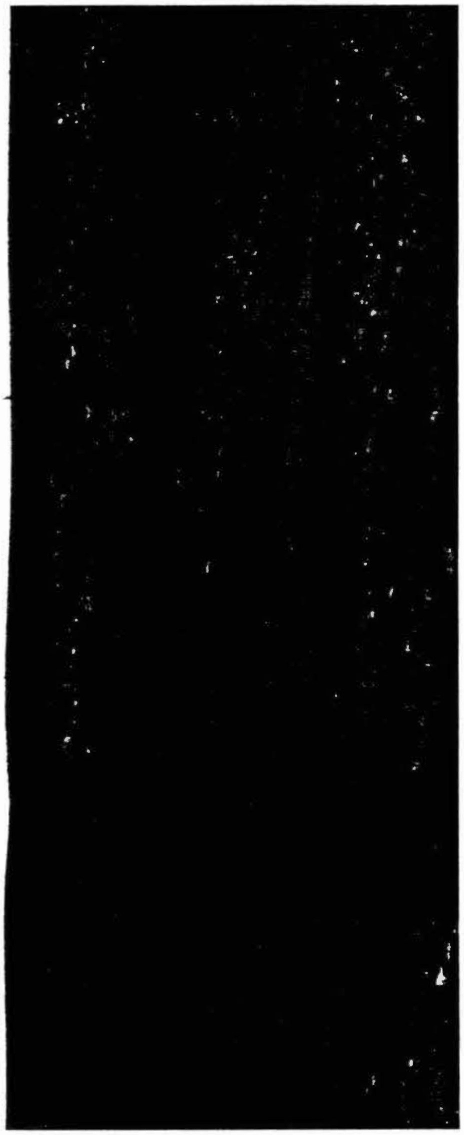


Figure 27. Distant View of Megabreccia Outcrop

to have been derived from the Ft. Sill Limestone.

Cave Deposits

Permian karst features within the study area have been identified and described previously by Ham, Merritt, and Frederickson (1957), Olson (1967), and Donovan (1982). These karst features consist of solution-widened joints or fissures that occur within hills of Arbuckle Limestone. In a road cut along State Highway 19 about 5 miles northwest of Blue Creek Canyon Sec. 23, T. 5 N., R. 13 W. Donovan (1982) identified two types of fissures, detritus filled and open caves. Detritus filled fissures were believed to have once been opened to the surface while unfilled caves were probably not directly in contact to the surface. Detrital constituents were described as limestone fragments cemented in reddened micrite. Donovan believed that these fissure formed directly beneath the unconformity between the Arbuckle limestones and the Permian land surface.

Ham, Merritt, and Frederickson (1957) described similar fissures containing bones of Permian reptiles in a limestone quarry near Porter Hill. They believed the fissures were infilled by Permian sediments that once covered the limestone hills.

Olson (1967) used the names "Richards Spur" or "Fort Sill" to define the site described by Ham, Merritt, and Frederickson. He described the fissures as being infilled with clays and coarser constituents including coarse conglomerates as well as Permian vertebrate fossils.

In an abandoned quarry about 11 miles south of Carnegie, Olson described a previously unreported fissure site (South Carnegie Site). The reported location of this site was inaccurate and should be corrected to NE 1/4 Sec. 26, T. 6 N., R. 14 W. Poorly preserved vertebrate bones were described as coming from two fissures in the Arbuckle limestone. Olson believed that both the Richards Spur and South Carnegie sites were formed at the same time and by similar processes.

Simpson (1979) compiled a list of the vertebrate faunas from Richards Spur and South Carnegie (Table V). He was uncertain about the exact stratigraphic position of these sites but estimated that they probably corresponded to the Upper Garber Formation (Figure 28).

Inspection of the South Carnegie site revealed quite a diverse suite of rocks within the fissures. Nearly vertical fissures formed along variably trending solution widened joints within Upper Arbuckle rocks. Fissure walls are often coated with travertine (Figure 29). Horizontally interlaminated clays and travertines exhibiting desication cracks and soft sediment deformation features were found in some of the fissures (Figure 30). Other deposits include dripstones, cave pearls, crossbedded siltstone, sandstones, conglomerates, and breccias containing phosphatic vertebrate bone fragments. Colors of the cave rocks vary

TABLE V

VERTEBRATE FAUNAS FROM SOUTWEST OKLAHOMA CAVE SITES ACCORDING TO SIMPSON, (1979)

		Richards Spur	South Carnegie
REPTILIA	*Basicranodon fortsilensis*	x	x
	Captorhinus aguti	x	
	Colobomycter pholeter	x	
	Delorhynchus priscus	x	
	Labidosaurus hamatus	x	
	Thrausmosaurus serratidens	x	
AMPHIBIA	*Cacops* sp.	z	
	Cardiocephalus sternbergi	x	
	C. peabodyi	z	
	Dissorophidae indet.	x	
	Doleserpeton annectens	x	
	Eryopidae indet.	z	
	Euryodus primus	x	
	Llistrofus pricei	z	
	Phlegethontia sp.	x	
	Tersomius sp.	x	
	Trematops sp.	z	
PISCES	Undifferentiated xenacanths	x	

x = previously known
z = newly discovered

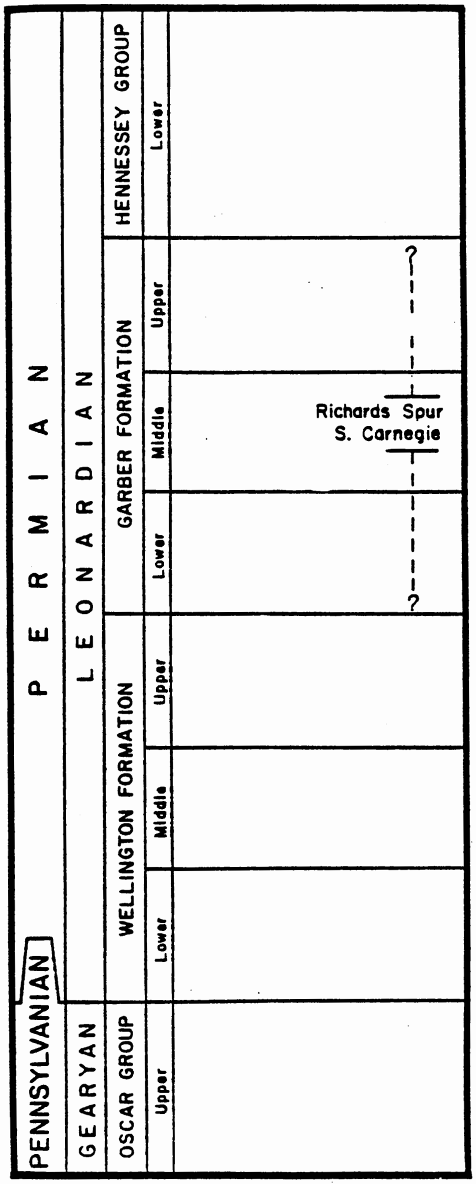


Figure 28. Approximate Stratigraphic Position of Cave Site Vertebrates According to Simpson (1979)

Figure 29. Permian Travertine Fissure Deposit in Arbuckle Limestone, South Carnegie Site

Figure 30. Fissure Exposed in a Quarry Wall, South Carnegie Site is Infilled With Fine Clastics

and are often shades of orange, brown, and green. Pyrite and hydrocarbons have been incorporated within these rocks.

Fissure fills sites have been discovered in other limestone quarries within the study area, however they were not found to contain vertebrate fossils.

Assuming the most widely accepted theories of cave formation, it is highly unlikely that these fissures formed recently within the exposed hills that now contain them. A more believable explanation is that advanced by Ham, Merritt, and Frederickson (1957) and Donovan (1982), who have proposed that these hills were once covered by Permian sediments and have now been exhumed. Evidence supporting this theory is the present uncovering of buried hills by erosion of Permian strata and the resemblance of some fissure rocks to other Lower Permian strata within the study area.

CHAPTER V

STRATIGRAPHIC NOMENCLATURE

Introduction

This chapter discusses and compares existing Lower Permian stratigraphic nomenclature for the study area. Because stratigraphic nomenclature varies greatly from one author to another, an attempt has been made in this thesis to clarify the stratigraphy and to present a revised stratigraphic section. The following stratigraphic investigations are divided into predominately litho-stratigraphic and bio-stratigraphic investigations.

Litho-stratigraphic Investigations

Cummins (1889) divided the Lower Permian of north Texas into the Wichita and Clear Fork Formations. These formational names were applied to the Permian section of southwestern Oklahoma by Gould (1926). The Wichita and Clear Fork beds of Texas were later given Group status and broken down into separate formations. The names generally agreed upon appear in Figure 31 (Simpson,1973). The Wichita-Clear Fork section surrounding the Wichita Mountains in Oklahoma was not mapped and subdivided into separate units until the work of Fay, (1968) and Havens,

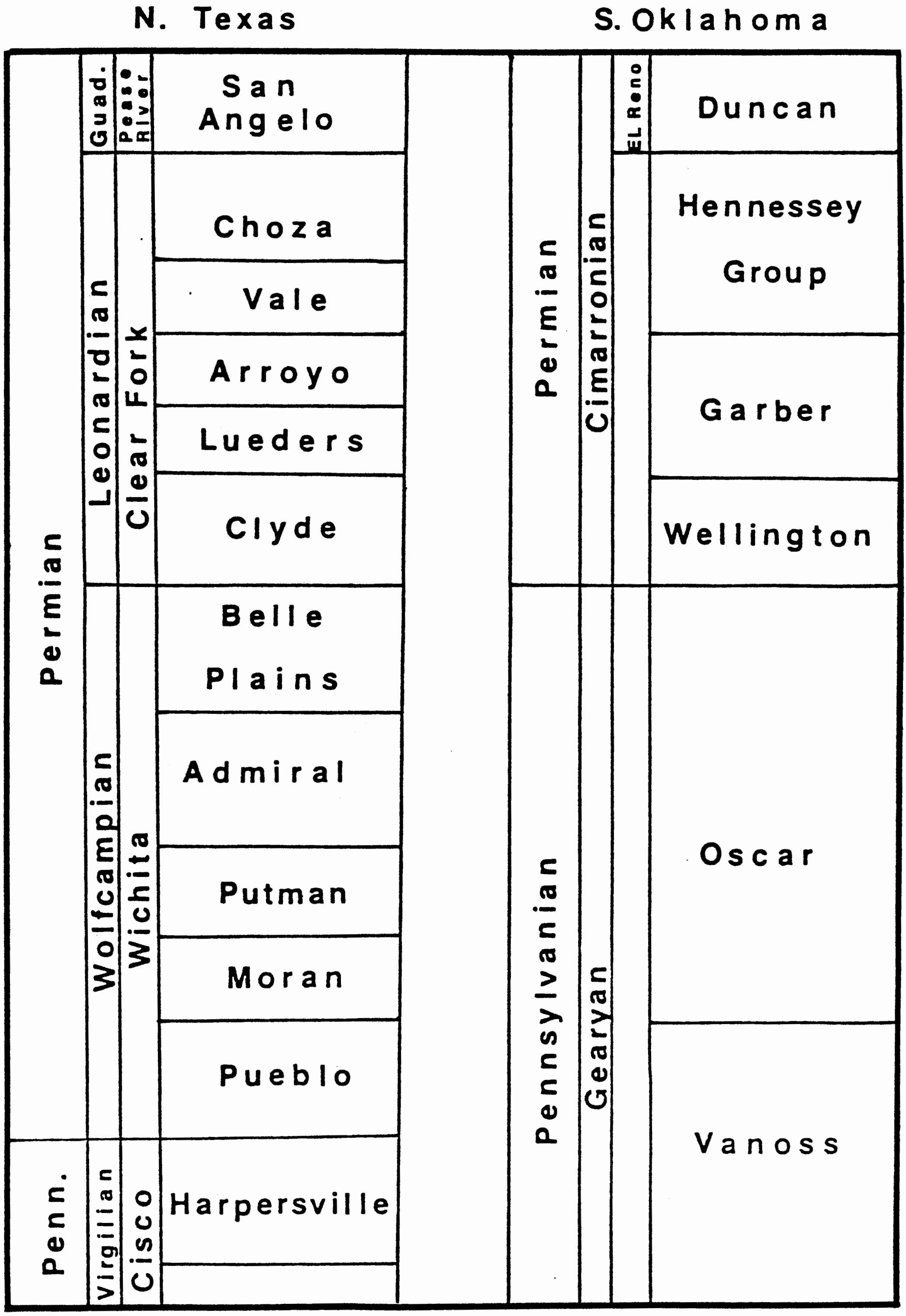


Figure 31. Breakdown of the Lower Permian Strata of North Texas and Correlation with the Lower Permian of Oklahoma According to Simpson (1973)

(1977). Formation names from north-central and south-central Oklahoma however were applied to rocks around the Wichitas.

The geologic map of Oklahoma (Miser, 1954) referred to the Lower Permian in the vicinity of the Wichitas as the Wichita Formation. Miser (1954) and Chase (1954) (Figure 4) believed that the Wichita Formation is equivalent to the Upper Pontotoc Group, the Wellington Formation, and the Garber Sandstone (in ascending order). The Post Oak Conglomerate, was designated as a member and assigned to the Lower Wichita Formation. The Hennessey Shale of Oklahoma was designated as the equivalent to the Clear Fork of Texas. Ham, Merritt, and Frederickson (1957) believed that the Post Oak Conglomerate should be revised to include conglomerates in the western Wichita Mountains which were believed to be Hennessey equivalents.

MacLachlan (1967) (Figure 5) modified Miser´s stratigraphic section by designating the Wellington Formation as a separate unit that overlies the Wichita Formation. The Garber Sandstone was either eliminated from the section or included into the Wichita Formation. It is not made apparent in MacLachlan´s report why these revisions were made.

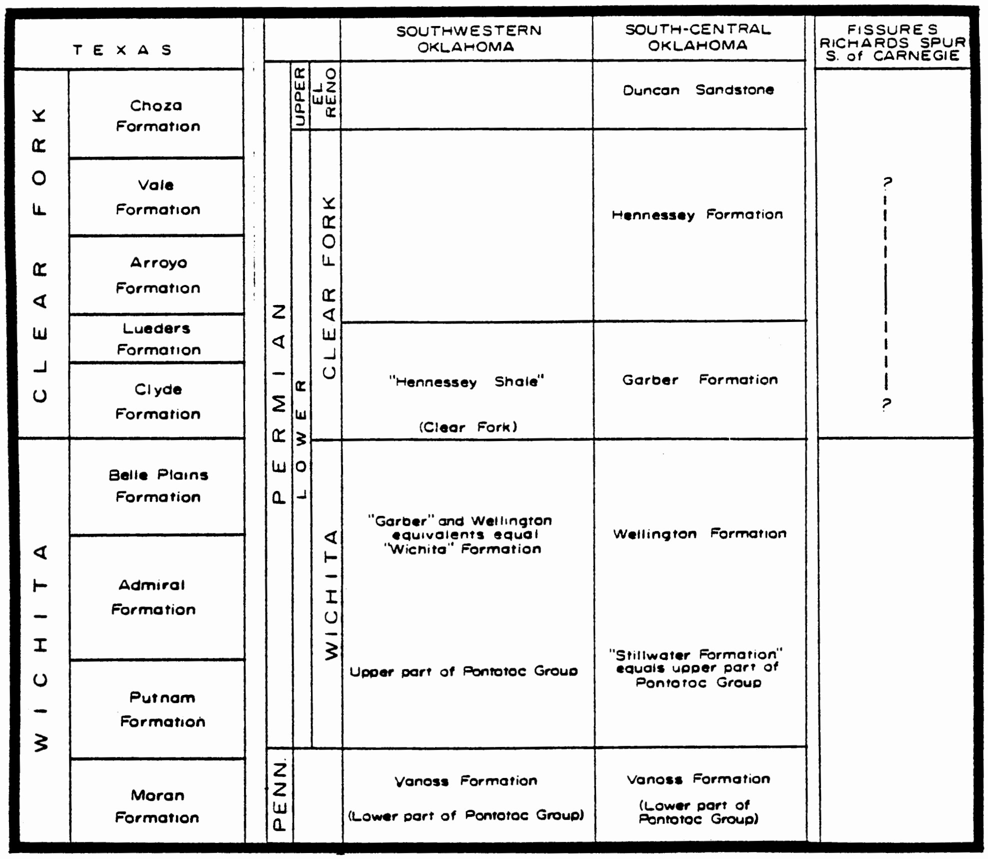
Havens´ (1977) compiled map of the Lawton quadrangle subdivided the Lower Permian (Figure 7). Havens´ information for these subdivisions for the Lower Permian strata was derived from work conducted by R. O. Fay of the

Oklahoma Geologic Survey. Havens designated the Post Oak Conglomerate a separate formation and correlated it with the Hennessey Group and the Garber Sandstone. The latter section was held to overly the the Wellington Formation and underlie the El Reno Group (Figure 8).

Bio-stratigraphic Investigations

Olson (1967) conducted a study of Early Permian vertebrates in Oklahoma and attempted to assign ages to the strata as classified by Miser (1954). Fragmented vertebrate fossils were studied, described, and correlated to vertebrate studies conducted in north Texas (Figure 32). Most of Olson´s vertebrate sites lie outside this thesis study area but two sites, Richards Spur (Ft. Sill) and the South Carnegie sites lie within the study area. Olson believed, that both these sites were possibly Arroyo in age and correlated approximately with the Hennessey of Southwestern Oklahoma (Figure 32).

Simpson´s (1973) correlation of the Lower Permian of North Texas and Oklahoma proposed that the Wellington Formation of Oklahoma directly correlated with the Clyde Formation of Texas (Figure 31). This correlation was based on stratigraphy and mapping by Fay in Oklahoma and A. S. Romer in Texas in which beds could be traced across the Red River (Simpson, 1973). Differences existed in the interpretation of the Pennsylvanian-Permian boundary and series names were inconsistent between the two states.



TEXAS					SOUTHWESTERN OKLAHOMA	SOUTH-CENTRAL OKLAHOMA	FISSURES RICHARDS SPUR S. of CARNEGIE
CLEAR FORK	Choza Formation	PERMIAN	UPPER	EL RENO		Duncan Sandstone	
	Vale Formation		LOWER	CLEAR FORK		Hennessey Formation	? ?
	Arroyo Formation						
	Lueders Formation				"Hennessey Shale" (Clear Fork)	Garber Formation	
	Clyde Formation						
WICHITA	Belle Plains Formation			WICHITA	"Garber" and Wellington equivalents equal "Wichita" Formation	Wellington Formation	
	Admiral Formation						
	Putnam Formation				Upper part of Pontotoc Group	"Stillwater Formation" equals upper part of Pontotoc Group	
	Moran Formation	PENN			Vanoss Formation (Lower part of Pontotoc Group)	Vanoss Formation (Lower part of Pontotoc Group)	

Figure 32. Correlation of the Lower Permian Strata of Northern Texas, South-Central, and Southwestern Oklahoma and the Approximate Position of the Fissure Sites According to Olson (1967)

Oklahoma used the Gearyan stage for the Upper Pennsylvanian and the Cimarronian stage for the Lower Permian, whereas Texas used Virgilian for the Upper Pennsylvanian stage and Wolfcampian and Leonardian for the Lower Permian Stages.

Simpson (1979) used Havens´ geologic map to assign stratigraphic positions to the Lower Permian vertebrate sites. A revision to his (1973) Lower Permian Texas-Oklahoma correlation was proposed based on an extended field study by Fay. The Wellington Formation of Oklahoma was now correlated with the Belle Plains Formations of Texas (Figure 33). Simpson was unsure of the exact stratigraphic position of the the Richards Spur (Fort Sill) and South Carnegie vertebrates sites, but believed that they were Arroyo in age corresponding to the Upper Garber Formation (Table V) and (Figure 33). Simpson proposed that the topographically positive Wichita Mountains acted as a haven during harsh climates causing certain vertebrate genera to be sustained for a longer period in southern Oklahoma than in northern Texas.

Stratigraphic Comparison

The previous Pennsylvanian-Permian stratigraphic studies of southwestern Oklahoma clearly exhibit distinct differences. These differences make it difficult to decide which system of stratigraphic nomenclature is most correct. Some investigators might be inclined to use the most recent stratigraphy in the belief that it is the most correct.

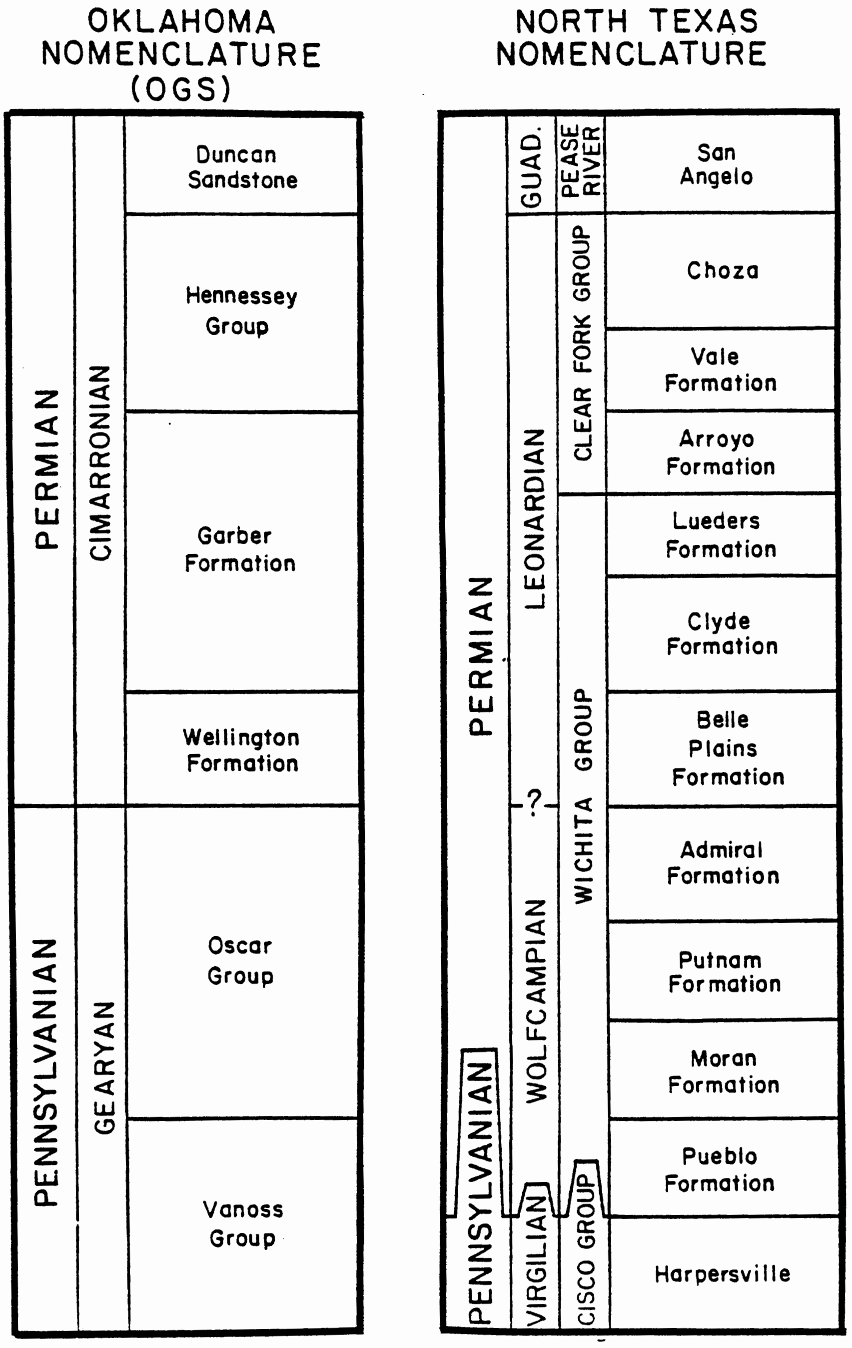


Figure 33. Revised Correlation of the Lower Permian of North Texas and Southwestern Oklahoma According to Simpson (1979)

Others might tend to use the most widely accepted nomenclature in the belief that consistency is best. A problem of which stratigraphic framework to use exists at least partly due to the complexity of this southwestern Oklahoma section.

Two main versions of stratigraphic sections can be extracted from the literature: those which follow the stratigraphic system of Miser (1954) and Chase (1954) (Figure 4) and those that use the stratigraphic system of Havens (1977) (Figure 8). Other investigators either used these proposed sections or slightly modified versions. Because of the time involved in determining stratigraphic relationships in the field, many investigators probably chose to use one of the previously published sections without concerning themselves with the variations in the previous works. In some cases both stratigraphic systems were used, thus adding to the confusion. Although the differences are quite obvious when the stratigraphic sections are compared side by side, very little field evidence has been provided by these workers to support these stratigraphic subdivisions.

Field evidence was collected for this study in order that an exact stratigraphic section be produced for the study area. However, it became apparent after reviewing this information that not enough geologic data has been accumulated to produce this exact section. This was primarily because of poor exposures and incomplete sections. A tentative section, has been produced and defended. Before this revised section is presented; an examination of how and why the existing stratigraphic sections differ so widely is necessary.

One unit that these stratigraphers have disagreed about is the position of the Post Oak Conglomerate of Chase (1954). Miser (1954) and Chase (1954) believed that the Post Oak Conglomerate was equivalent to the Upper Pontotoc Group and the Garber Sandstone. Neither of these formations had been satisfactorily delineated across the study area by later workers. Havens (1977) believed that the Post Oak Conglomerate was only equivalent to the Hennessey Group and the Garber Sandstone (Figure 8). It is presumed, based on Havens´ references list that this information came from the Oklahoma Geologic Survey or more specifically R. O. Fay (1968) and unpublished work.

Conceptual problems exist in treating this group of conglomerates as a separate mappable unit correlative to certain formations in the area. It has been well documented that along the northern Wichita Mountain front conglomerates exist in the subsurface from the Lower Pennsylvanian up through the Lower Permian. The conglomerates have been informally termed the "Granite Wash". These conglomerates are episodic in nature, difficult to correlate, and are often interbedded with various other lithologies. Therefore, they have not been treated as separate units. The conglomerates of the subsurface and those mapped and described on the surface are related. Therefore it is suggested that they should not be treated as separate formal units but as informal units that are equivalent to different formations depending on location and tectonic and erosional histories.

These surface conglomerates have been included as part of the informal "Granite Wash" by some authors. In contradiction other authors tend to try and separate the surface conglomerates from the subsurface conglomerates. One such attempt was made by Gilbert (1982) (Table VI). Some of the differences listed in this table have not been confirmed in the present study. Evidence suggesting that these conglomerates are related is as follows: i) there is no discernible break between the Upper Pennsylvanian and the Lower Permian conglomerates; ii) evidence presented in this thesis suggests that some surface conglomerates are related to faulting (as are some subsurface conglomerates); iii) clast size and rounding in the conglomerates is extremely variable and ranges from angular to rounded, and finally; iv) a distinct but gradual climatic and depositional environment change from an overall humid climate in a marine or near marine setting to an overall semi-arid climate in a non-marine setting is recorded in the Pennsylvanian-Permian section and partly responsible for many characteristic differences. Consequently, while it is possible to distinguish some upper (ie. Permian) conglomerates from some lower (ie Pennsylvanian) ones, this

TABLE VI

COMPARISON OF POST OAK CONGLOMERATE AND GRANITE WASH CHARACTERISTICS ACCORDING TO GILBERT, (1982)

	Post Oak	Granite Wash
a.	surface and near surface	subsurface
b.	Permian	dominantly Pennsylvanian and some Permian
c.	reflects local source: no significant transport	reflects more regional source, noticeable transport
d.	not directly related to faults	related to uplifted blocks and faults; higher relief sources
e.	clast size 10-100cm; rounded and spherical igneous clasts	variable clast size with angular igneous clasts
f.	non-marine	much non-marine but with marine interuptions

distinction cannot always be made and certainly in no way coincides with the recent erosional surface (which is an arbitrary dividing line).

A further conceptual point concerns the evident fact that the conglomerates are a response to large acting tectonic stress and furthermore are located at or about the "hinge" between the Wichita uplift and the surrounding basement suggests that it is most unlikely that they were all deposited on a crust that was behaving homogenously. In fact it is clear from the work of Collins (1985) and Donovan et al. (1985) that the conglomerates in the Meers Valley were deposited in a small depocenter which was subsiding much more slowly than the adjacent Anadarko basin. The Meers deposits represent a "starved" sequence in which very low rates of sediment entrapment occurred. Consequently hiati must be frequent, clearly complicating local correlation.

It is appropriate to consider the Post Oak Conglomerate as several facies of coarse clastics that resulted from the uplift and erosion of the Wichita Mountains. It is however inappropriate to use such a term only for surface exposures and not for subsuface occurrences. Also it is difficult to represent on a geologic map conglomerates which are often interbedded with sometimes large amounts of other lithologies such as sandstones and shales. Furthermore a geologic map which suggests correlation of surface outcrops is misleading and confusing because multiple conglomerate horizons are represented. There is however some merit to a map showing aerial distribution of these conglomerates as long as one keeps in mind it´s deficiencies. It is also evident from field observation that correlation of individual conglomerate horizons with formations distal to the Wichitas is difficult if not impossible to justify due to the nature of the deposits (discontinuous and lenticular), the limited outcrops and subsurface data available and because episodic, tectonically-controlled, multistoried coarse clastics are poor chronostratigraphic indicators. Lithostratigraphic horizons of coarse clastics have not been traced into the subsurface or for appreciable distances at the surface.

Chases´ (1954) geologic map shows a large area south of the Wichita Mountains mapped as Post Oak Conglomerate. Examination of this area revealed that most of the mapped strata was not conglomerate but rather sandstones and shales. Channel lag conglomerates do occur in this strata but not in sufficient amounts to term the entire section as conglomerate. Al-Shaieb et al. (1980) observed this discrepancy, causing them to prefer the term "Post Oak Formation" instead of "Conglomerate". This informal modification of the stratigraphic terminology only tended to add to the confusion.

Geologic markers are not completely absent in the coarse clastic facies. Calcretes (which represent periods of non-deposition and soil development) may record chronstratigraphic correlatable horizons. It is very important that the depositional model be fully understood before any such correlation is attempted (Figure 34). Calcretes may be elevationally equivalent but not time equivalent. For example a calcrete could be forming on part of a floodplain or abandoned channel while other portions are receiving at least enough deposition to prevent soil formation. The processes could later be reversed producing an apparent time equivalent marker.

Calcretes that have proven to be reliable markers in the subsurface include the Pontotoc "A", "B", "C", and "D" limestones which are located in the northern portion of the study area (Figure 35).

The Wichita Formation of Miser (1954) and Chase (1954), which contains the Post Oak Conglomerate as a member, is another problem not in agreement between authors. Miser and Chase did not or were not able to break down a large section of the Lower Permiam strata surrounding the Wichita Mountains. Formations equivalent to those used in other localities in Oklahoma and Texas were not differentiated. Instead they used the Wichita Formation to represent this undivided strata. The Wichita Formation was believed to be equivalent to the upper part of the Pontotoc Group, the Wellington Formation and the Garber Sandstone. On the geologic Map of Oklahoma a "t" bed was included in certain places and believed to be the

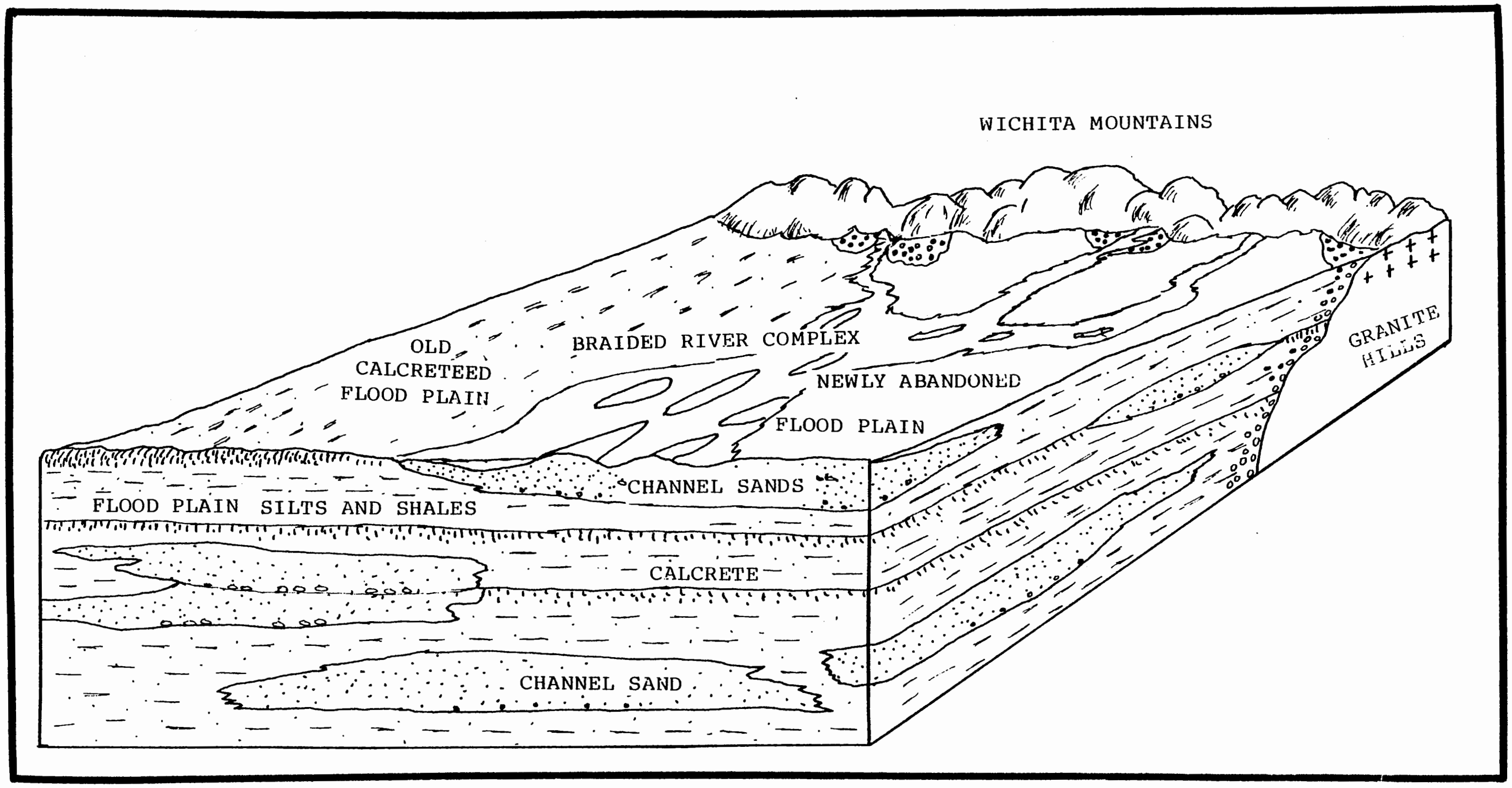


Figure 34. Depositional Model of Lower Permian Sedimentation (From Donovan Unpublished)

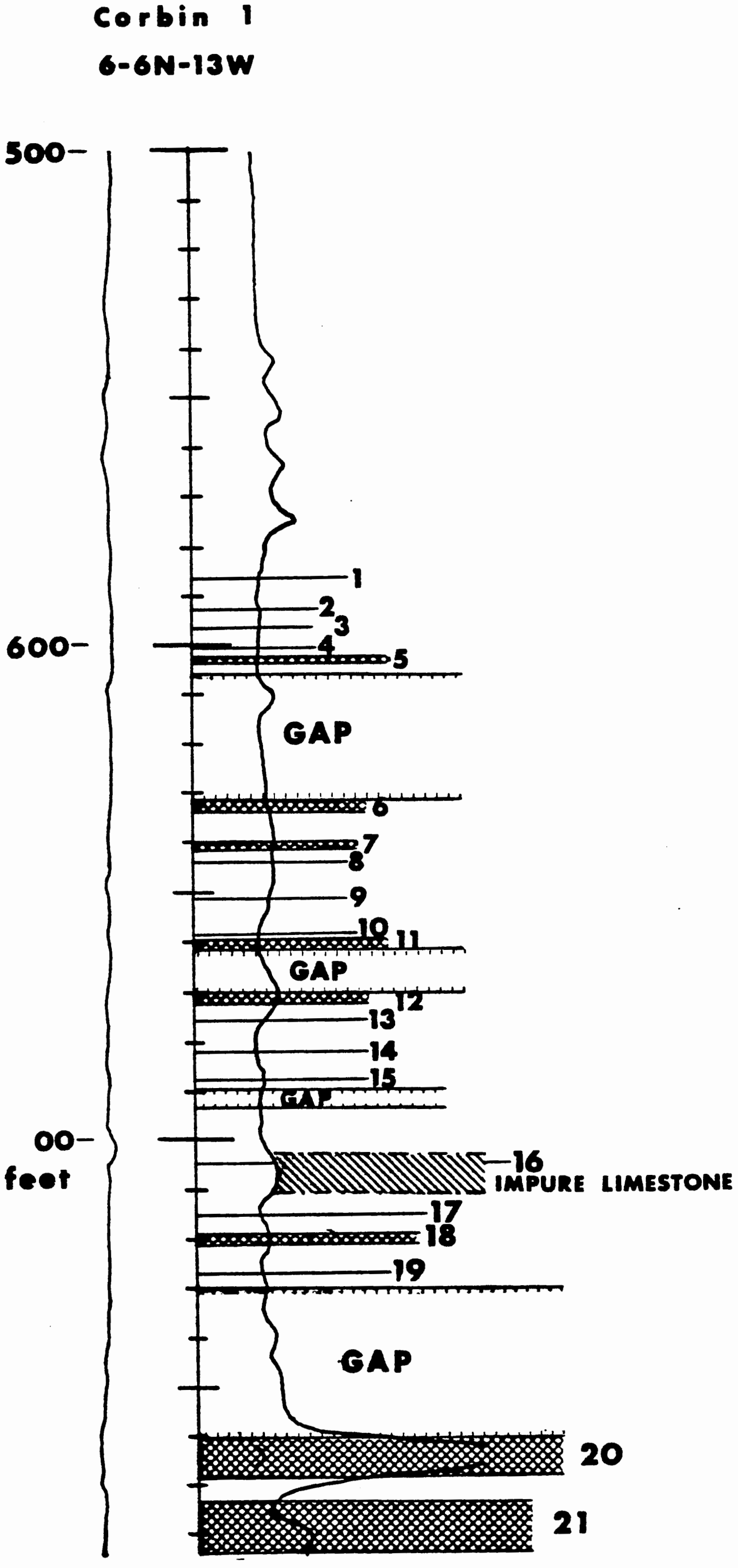


Figure 35. Electric Log of the Thermo-Dyne, Corbin # 1, Showing Numerous Calcrete Horizons; Horizon # 20 is the Pontotoc "A" Calcrete From Donovan (1978)

Asphaltum Sandstone (an asphalt impregnated sandstone) of Bunn (1930) (equivalent to the base of the Garber Sandstone).

Havens (1977) geologic map eliminated the Wichita Formation and delineated the Hennessey Group, the Garber Sandstone, the Wellington Formation and the Pennsylvanian Oscar Formation in its place. The latter two formations do not outcrop in the study area. At first glance the breakdown of the Wichita Formation might seem appropriate, however distinct differences exist in the placement of geologic contacts between the Hennessey Group of Havens and the Hennessey Shale of Miser. This difference is quite significant in that it allows for two distinct interpretations of the stratigraphic position, thickness and extent of the Hennessey strata. These differences are most likely caused by the similarities between the Hennessey and the other Permian formations, poor definition of the Hennessey strata, and the lateral lithologic change within this strata.

The Garber Sandstone as mapped by Havens (1977) and Miser's (1954) "t" bed (equivalent to the basal Garber Sandstone) are not in agreement as to their locations on the two geologic maps. This might again be explained by different stratigraphic definitions of the Garber and/or its equivalent by the workers. However it seems from the definitions provided by the two investigators that both had in mind a similar descriptive unit with an asphaltic sandstone at the base. One possible explanations for this disagreement might be that more than one asphaltic sandstone unit exists in the study area. Adding to this confusion is a publication by Bunn (1930) which states emphatically that the Asphaltum Sandstone and the Ryan Sandstone are equivalent. However, Havens treats the Asphaltum Sandstone as the base of the Garber and the Ryan Sandstone as a separate unit marking the base of the Wellington Formation.

Other asphaltic sandstones have been observed in the study area and considering the number and geometry of the Permian sandstones coupled with the complexity of oil migration, it seems highly unlikely that i) only one or two sandstones would be asphaltic and ii) that they would be continuous enough to correlate over appreciable distances.

It is not known if the Wellington Formation as mapped by Havens (1977) and Miser (1954) is in agreement. Havens´ map shows no outcrop of Wellington strata within the study area and Miser does not differentiate Wellington or equivalent strata within the study area. Chase (1954) identified the location of what he believed was the Wellington Formation and describes it as purplish red shales containing concretions of barite and calcium carbonate. The location of this section was given as Sec. 18, T. 1 N., R. 13 W. Strata fitting Chases´ description was believed to be traceable all along the south side of the Wichita Mountains.

Strata similar in description to that of Chase (1954) has been identified in this study south of the Wichita Mountains, however time restrictions along with discontinuous and inaccessible outcrops prevented detailed mapping of these rock units.

Other authors have presented different stratigraphic sections within the study area. Fay´s (1968) proposal (see page 14, paragraph 4, and Figure 6) was not accepted; however his map (along with revised unpublished versions) became a major reference for the Lower Permian contacts on Havens´ (1977) geologic map.

MacLachlan´s (1967) stratigraphic section (Figure 5) shows discrepancies between it and the explanation in his text. The Garber Formation is described in the text, but is excluded from the stratigraphic section. MacLachlan´s section has not been perpetuated in the recent literature.

Revised Stratigraphy

As mentioned previously in this text an exact stratigraphic section could not be constructed based on the information collected for this thesis. The author has depended on the previous work available for the study area.

After sifting through many geologic investigations that cover regions outside the study area it became obvious that this investigation was greatly dependent on geologic field work and descriptions that have been conducted some distance from the study area. All of the formation names and original descriptions applying here originated outside of the study area (with the exception of the "Post Oak Conglomerate"). This was probably because the Permian rocks around the Wichita Mountains were some of the last to be described and mapped in Oklahoma.

In the natural progression of geologic investigation, information is continually accumulated and more in depth studies are conducted in order to better define an area. As a result many geologic units are broken down into more refined units. This is possible only when enough data has been collected. Still there are areas that have been examined for decades that are left virtually undivided, because of complex stratigraphy and insufficient geologic data. The Lower Permian strata surrounding the Wichita Mountains has followed such a natural progression. "Red Beds" were termed Wichita-Clear Fork beds and later divided into the Wichita Formation and the Hennessey Shale by Miser (1954) and Chase (1954). When the geologic map of Oklahoma was produced in 1954 not enough geologic data had apparently been produced to divide these units further. Since that time an effort by Fay (1968) and Havens (1977) has been made to further define these units. As brought forth previously in this text distinct differences exist between the studies of Miser and Chase and that of Havens. If evidence was discovered by Havens to warrant changes in Miser´s and Chase´s geology, documentation of this evidence should have been provided along with the published map.

Havens´ geologic map of the Lawton Quadrangle is however a compiled map and it might be assumed that no original field work was conducted. Much if not all of the geology for Havens´ map was taken directly from the referenced sources. For example the contacts for Post Oak Conglomerate on Havens map are taken either from Chase´s 1954 map or the geologic map of Oklahoma. It it likely that Havens´ map represents a combination of two interpretations of the Lower Permian, one by Fay and the other by Chase. If such is the case this map can not be considered reliable as far as the Lower Permian rocks are concerned because both interpretations varied considerably. Because evidence for Havens´ Garber and Hennessey contacts was not provided and because these contacts could not be verified in this study it is assumed that much of this map is inaccurate. Chase´s (1954) and Miser´s (1954) studies provide evidence to support their geology. Errors in Chase´s and Miser´s map do exist and have been identified in this study. They include Pleistocene conglomerates that have been mistaken for Permian and sections of predominately sandstones and shales have been misclassified as conglomerates.

Paucity of collected field data caused by the complexity of the stratigraphy, the discontinuity and poor character of outcrops coupled with the conflicting previous geological interpretations, plus the lack of acceptable rock dating techniques, has made it impossible to differentiate separate formations on the geologic map. For the previous reasons and because similarities exist between the observations made for this thesis and the work of Miser and Chase it was decided to construct the revised stratigraphic section based on their work (Figure 36).

Wichita Formation

The Wichita Formation of this thesis is believed to be equivalent to the Upper Pontotoc Group the Garber Sandstone and the Wellington Formation. The lower part of this unit may, probable does contain the Pennsylvanian-Permian contact. The Permian portion of this unit is believed to partly Wolfcampian and partly Leonardian in age. Conglomerates, sandstones, siltstones, limestones (calcrete), and mudstones that vary in color from shades of red, maroon, gray, green, and white comprise most of the formation. Some of the equivalent can be recognized within this unit. Some of the calcretes in the study area are thought to represent the Upper portion of the Pontotoc Group. One calcrete that surrounds a Viola-bromide hill in the Sec. 20 T. 6 N., R. 15 W. is thought to correlate to the Pontotoc "A" limestone of the South Carnegie Oil Field (Figure 35). The Wellington Formation is thought to be represented by dark red and maroon sandstones and mudstones containing calcrete concretions and barite nodules. Strata of this type was observed throughout the southern portion of the study area. The Garber Sandstone consists of a conglomeratic sandstone that supports an escarpment along

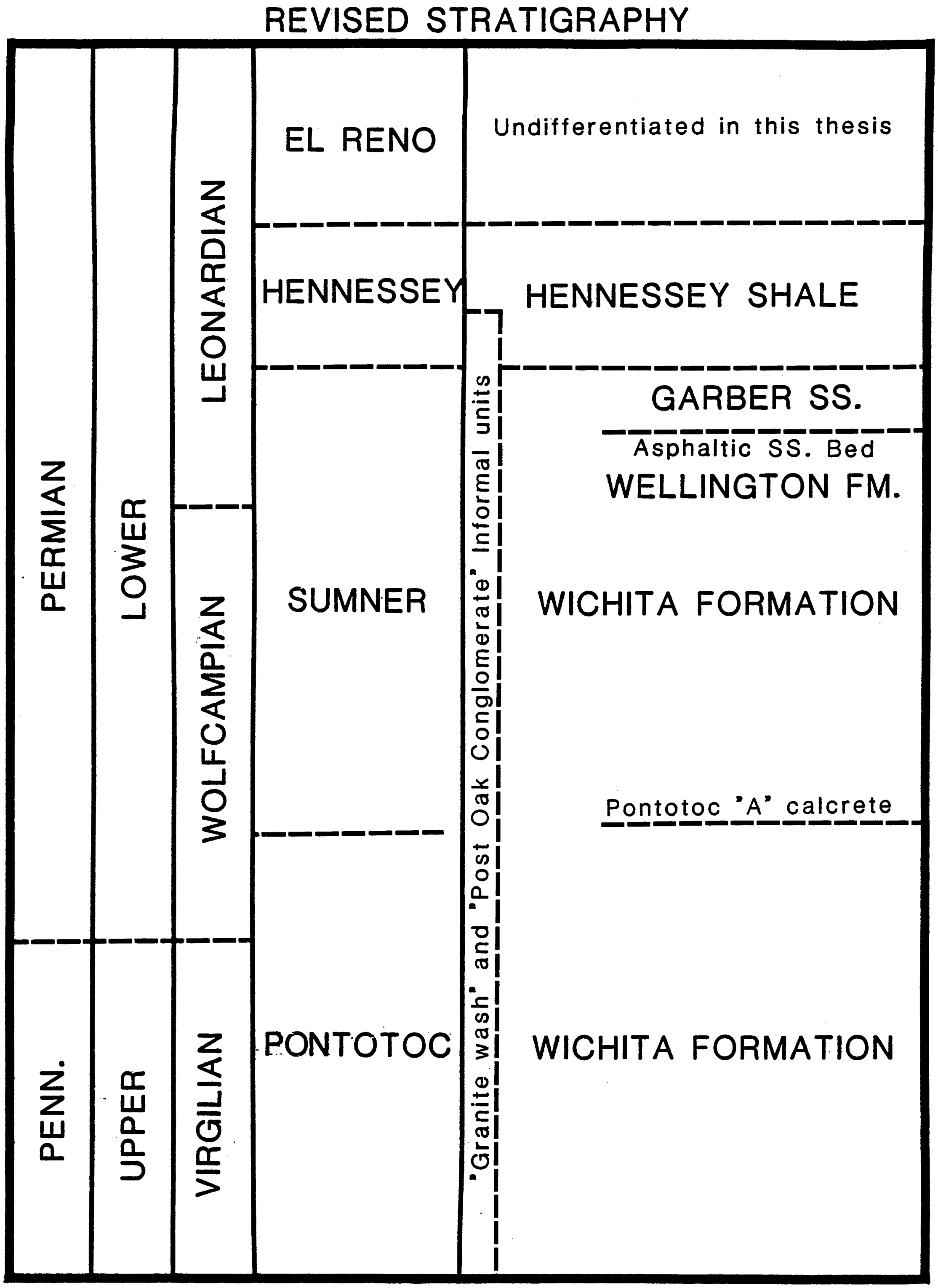


Figure 36. Revised Stratigraphic Section for the Lower Permian in the Vicinity of the Eastern Wichita Mountains

The H. E. Bailey Turnpike Sec. 9, T. 3 N., R. 11 W. (Figure 37). This unit strikes northwest through Porter Hill and continues into the grass-covered plains were it becomes difficult to distinguish.

The Post Oak Conglomerate is designated as an informal member of the Wichita Formation. The greatest part of this formation is believed to be equivalent to the lower portion of the Wichita Formation and extends almost into the Garber equivalent section. However, some conglomerates may be equivalent to strata higher in the section.

Hennessey Group

The Hennessey Group is represented mainly by reddish and green sandstones and shales. The contact with the Wichita Formation is obscure and could not be picked accurately throughout the study area. For this reason Miser´s contact will be dashed in on the geologic map.

El Reno Group

Overlying the Hennessey Group is the El Reno Group a series of predominantly sandstones and shale which outcrops in the northern and northeastern portion of the study area. This Group was not examined in this study but, the base is approximated on the geologic map (Plate 1).

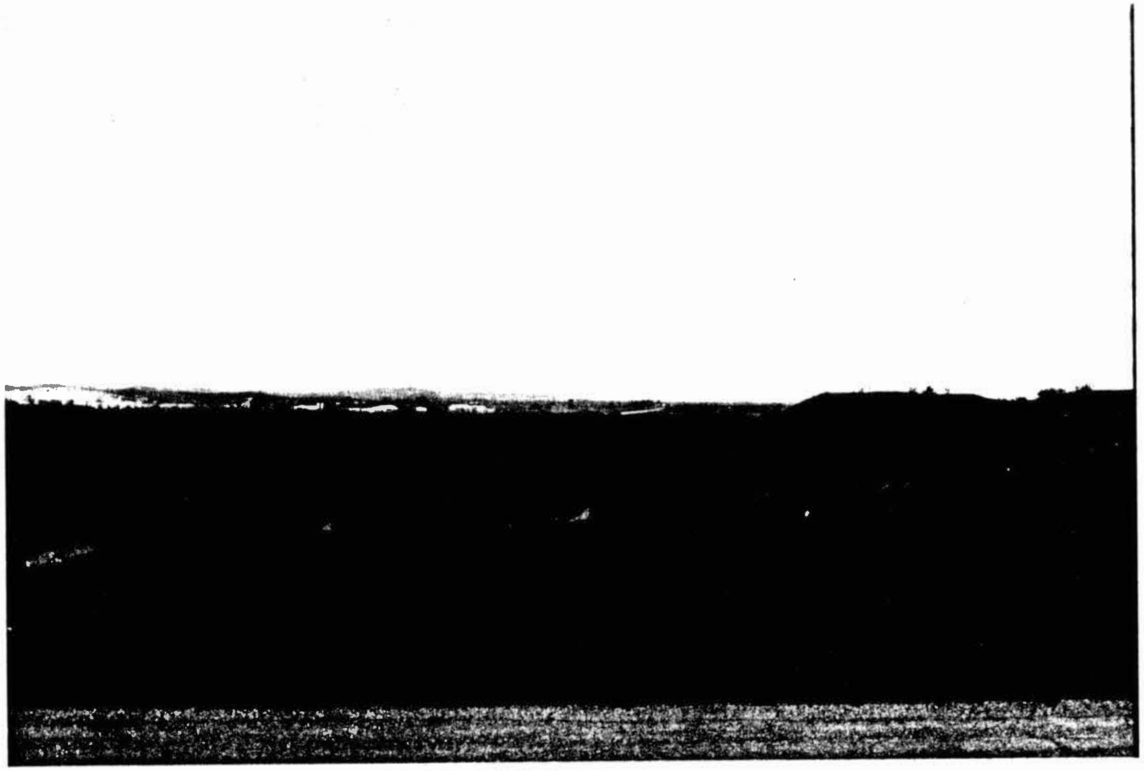


Figure 37. Escarpment Supported by Garber Sandstone, West Lane of I-44

CHAPTER VI

TECTONIC IMPLICATIONS

Introduction

The following chapter discusses the tectonic setting, history, and various other aspects as derived from the Lower Permian section.

Tectonic Setting

Many investigators have commented on the tectonics in the vicinity of southwestern Oklahoma. Although their work has concentrated on pre-Permian tectonics, some have briefly suggested that the Upper Pennsylvanian and Lower Permian section represents the last significant tectonics that resulted from the building of the Wichita Mountains. These final tectonic events of the "Arbuckle" orogeny of Webster (1980) and Brewer (1982), were interpreted as combinations of thrusting and left lateral wrenching in a transpressional structural setting by Donovan (1985).

Ham and Wilson (1967) and Arbenz (1956) constructed tectonic curves for the various tectonic provinces in Oklahoma (Figures 38 and 39). Structural and stratigraphic evidence including conglomerates were used to identify orogenic pulses.

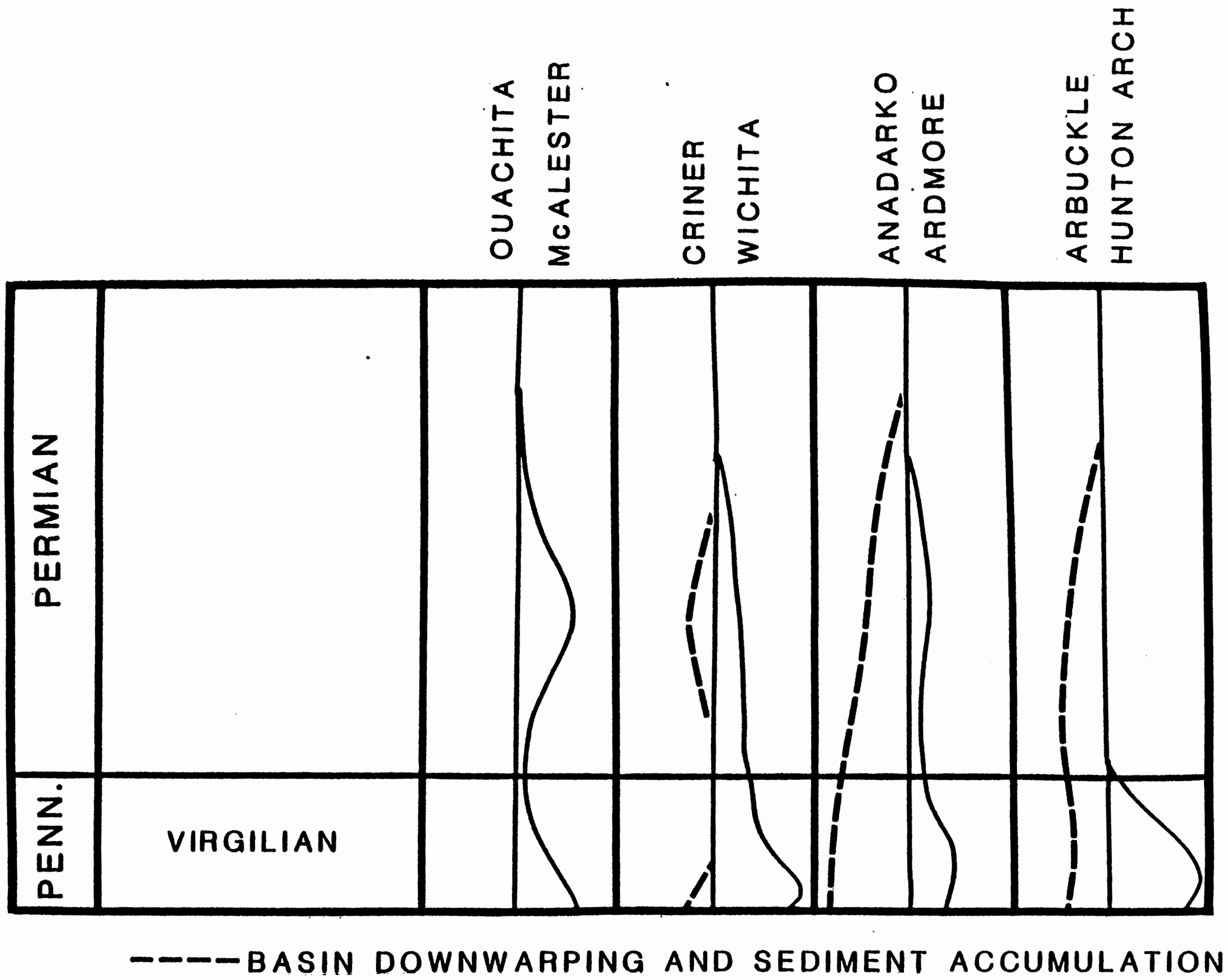


Figure 38. Tectonic Curves (Solid Line) and Subsidence Curves (Dashed Line) for the Tectonic Provinces of Southern Oklahoma During the Late Pennsylvanian and Early Permian According to Arbenz (1956)

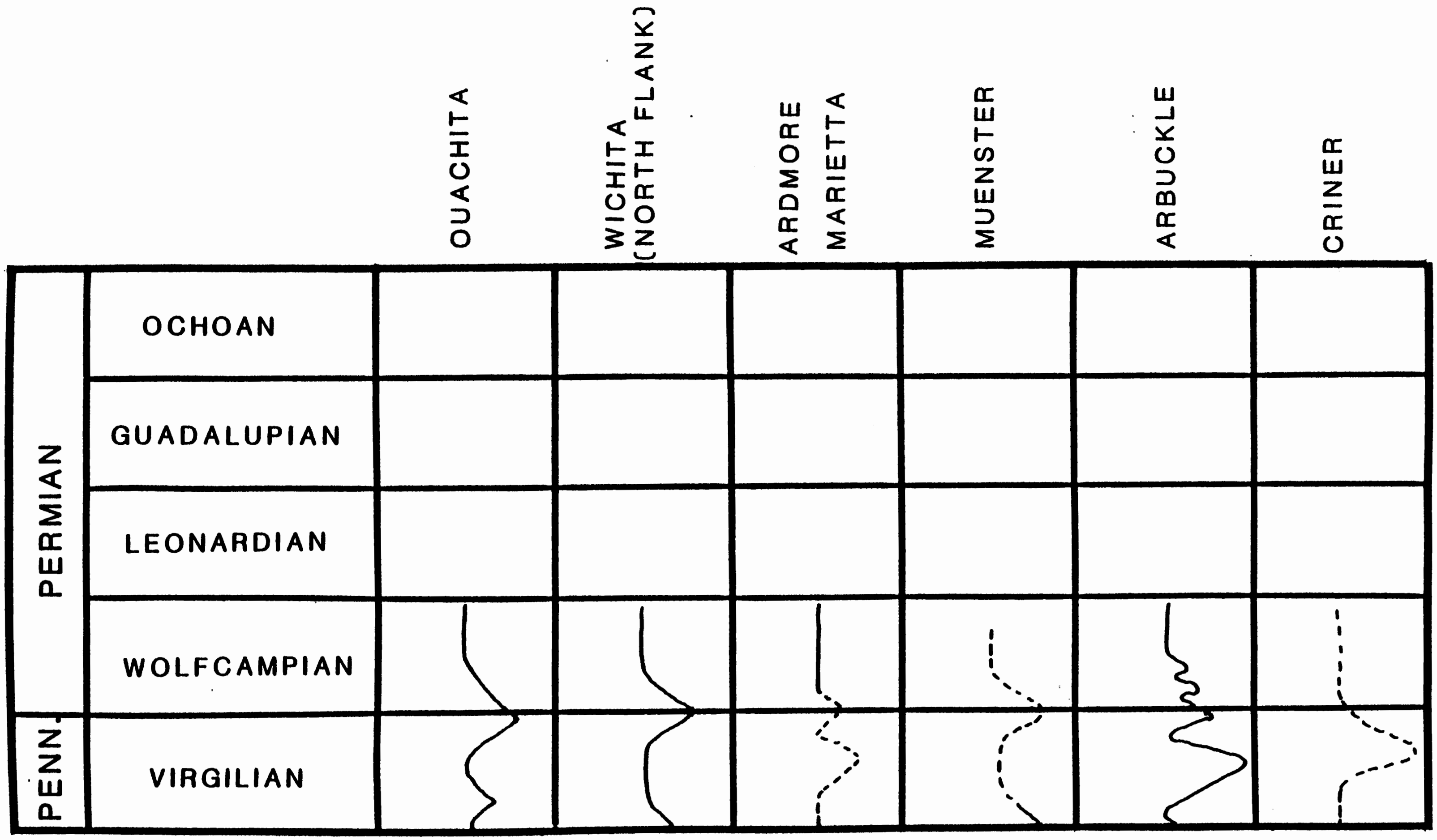


Figure 39. Tectonic Curves for Southern Oklahoma Tectonic Provinces During the Late Pennsylvanian and Early Permian According to Ham and Wilson (1967)

Arbenz´s (1956) study indicated that he was uncertain about the occurrence of Early Permian tectonics, along with subsidence, in the Criner-Wichita province, but that he believed that significant subsidence coupled with some slight tectonic activity had taken place during the same time in the Anadarko-Ardmore Basins. Elsewhere in Oklahoma, Arbenz proposed that subsidence occurred in the Arbuckle-Hunton Arch Province during the Early Permian, but that all significant tectonic pulses had probably ended in the earliest of Permian time. Arbenz inferred, but was unsure if Permian tectonic activity had occurred in the Ouachita-McAlester Province.

Like Arbenz, Ham and Wilson (1967) were also uncertain about the Permian tectonic history of the Ouachita Mountains. They indicated that orogenic activity had occurred from the Late Pennsylvanian, into the Early Permian along the north flank of the Wichita Mountains, Ardmore-Marietta Basins, Muenster Arch, and the Arbuckle Mountains. Tectonic activity was considered to have occurred slightly earlier in Criner Hills. The Arbuckle region was the only province believed to have experienced significant tectonic activity into Wolfcampian time.

In this thesis most inferences on tectonic activity are based on the identification of conglomerates and "megabreccias" in the strata surrounding the Wichita Mountains. It is believed that the deposition of these conglomerates and "megabreccias" resulted from the collapse and erosion of the Early Permian topography, which formed largely because of localized renewed movements along pre-existing faults. In contrast strata exhibiting calcretes and finer clastics are believed to represent periods of non-depostion and/or non-orogenic activity.

Paleo-Climatic Influences on Tectonic Deposits

In addition to renewed tectonics, deposition of the conglomerates and "megabreccias" was greatly influenced by the climatic conditions which existed during the Early Permian.

Many investigators have determined that the paleo-climate of the Early Permian was at least periodically semi-arid. They identified the Early Permian sedimentary environments as terrestrial, alluvial fan, fluvial, and alluvial plain environments (Al-Shaieb et al., 1977; Stone, 1977; Kwang, 1978; Donovan, 1978; Collins, 1985). Evidence (based on fossil, sedimentalogic, and petrographic data) supporting these ideas is as follows:

i) the occurrence of calcretes
ii) dessication features
iii) compositionally immature rocks
iv) extreme lateral and vertical variations in strata
v) lenticular and wedge shaped beds
vi) oxidized strata "red beds"
vii) the presence of evaporites
viii) the occurrence of vertebrate fossils

ix) the absence of marine fossils.

In contrast Gilbert (1979) believed that a more humid climate existed during the Early Permian. He identified a tor type topography in the granites of the Wichita Mountains which he believed was Lower Permian in age. This topography was believed to have resulted from the deep weathering of the fractured granites, suggesting temporary stable conditions and a humid climate. Gilbert surmised that the rounding of the cobbles and boulders in the granite facies of the Post Oak Conglomerate was due mostly to spheroidal weathering of the granite bedrock, followed by a period of tectonic activity, and erosion which stripped away and deposited the rounded granite clasts.

In the preceding paragraphs evidence has been presented to indicate that two different climates existed during the Early Permian. After careful study it is believed that these two climates did exist but that they were not necessarily restricted to Early Permian time. This evidence likely supports that the climate gradually changed, from humid to semi-arid during Late Pennsylvanian through Early Permian times.

Field work has revealed that granite clast conglomerates are the oldest exposed strata in the study area. These granite conglomerates directly underlie the limestone conglomerates and "megabreccias" in the Meers Valley. Granite conglomerate outcrops exposed throughout the study area exhibit evidence of extreme weathering and are devoid of calcretes, possibly indicating deposition in a humid climate. In contrast, the overlying limestone conglomerates often contain numerous calcrete horizons, indicating that a periodic semi-arid climate existed during their deposition. Other evidence that supports a Late Pennsylvanian humid climate is presented by Edwards (1959). He reported that Upper Pennsylvanian "Granite Wash" was sometimes influenced by marine conditions, evidenced by interbedded fusulinid limestones and by subaerial deposition in a humid climate, as evidenced by thin coal beds within the Upper Pennsylvanain strata.

It can not be presumed, because of this evidence, that the granite conglomerates are Pennsylvanian in age. Humid, deep weathering, conditions possibly persisted throughout the Late Pennsylvanian, followed by Permian uplift that accelerated erosion, prompting deposition of the highly weathered granitic materials. The residual tor topography would thus be exposed during Permian time but would actually reflect Pennsylvanian weathering. Changes in climate from humid to semi-arid would likely have affected the weathering rates of the exposed rocks. Figure 40 illustrates the effects changes in precipitation might have had on denudation rates for the exposed Cambrian and Ordovician carbonate rocks. Humid weathering conditions during Late Pennsylvanian time could have prevented the Cambro-Ordovician limestones from attaining significant topographic expression, possibly explaining why only

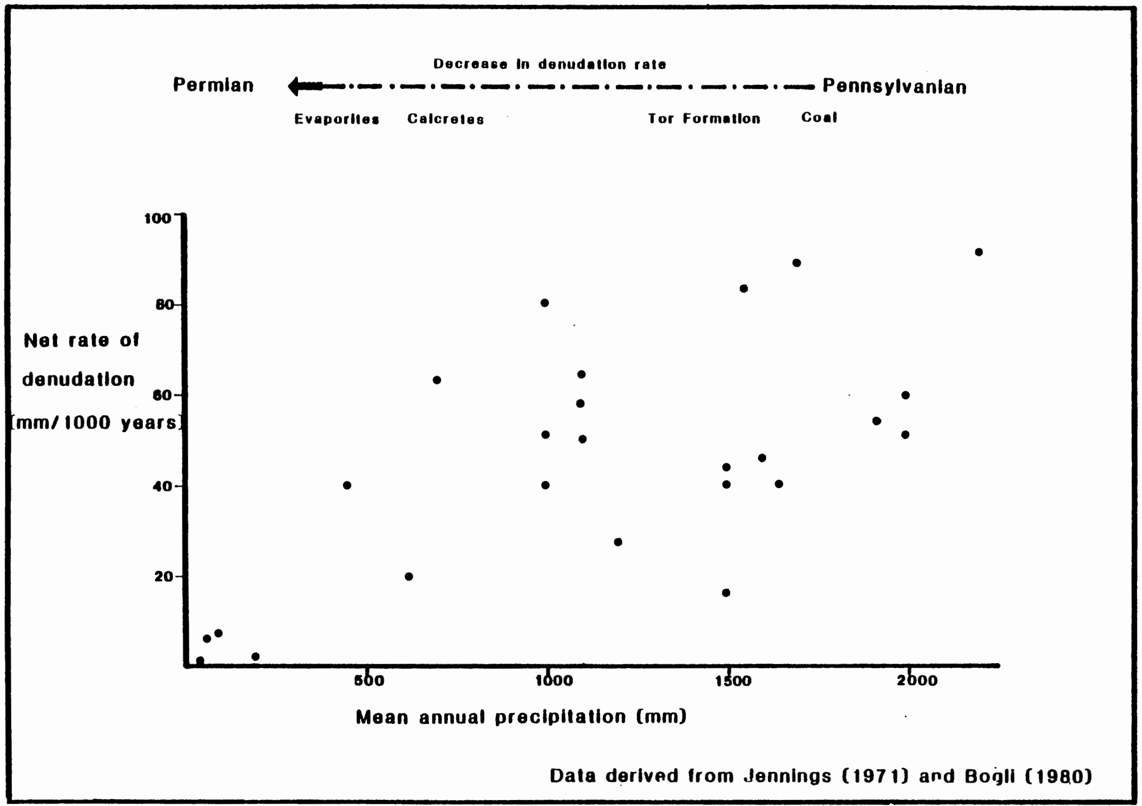


Figure 40. Rates of Denudation for Carbonate Rocks Plotted Against Precipitation, Possible Paleo-Climatic Indicators are Positioned at Top

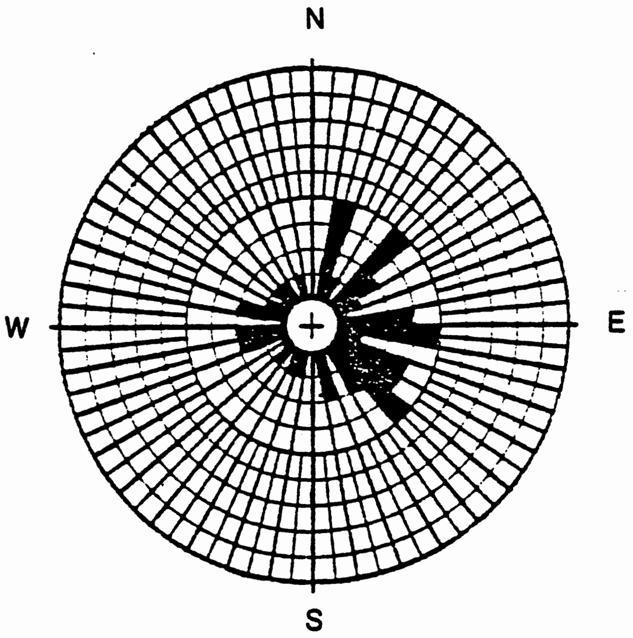
granite clast conglomerates and not granite-limestone clasts conglomerates occur in the oldest rocks in the Meers Valley. These humid conditions might have also been responsible for the formation of some karst features in the Cambro-Ordovician rocks.

Tectonics

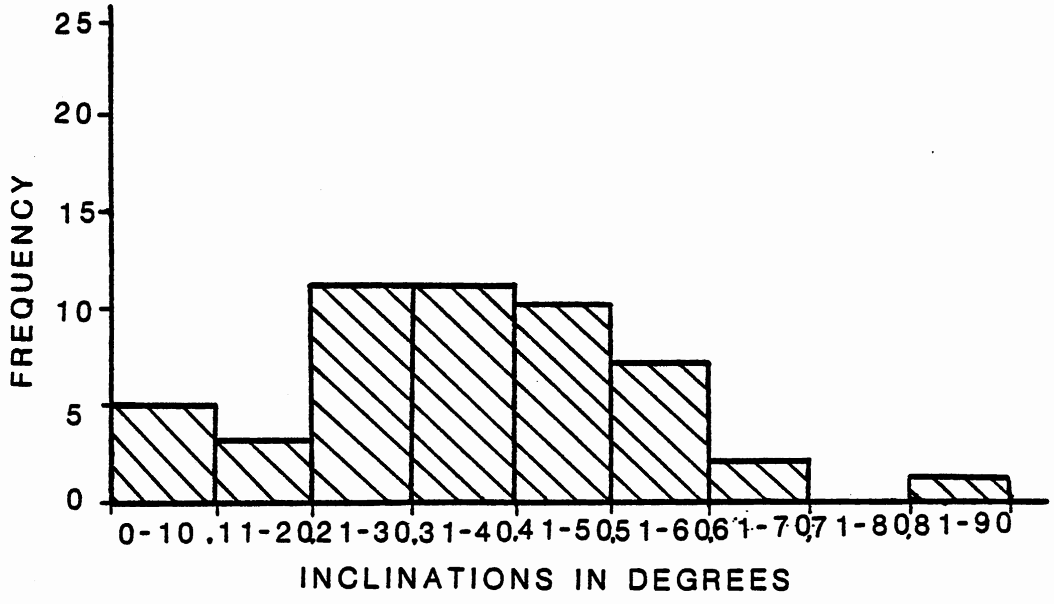
Donovan (1984) suggested that localized Permian reactivation of the pre-Permian Meers Fault, caused the limestone block, north of the Meers fault, to be upthrown, shedding enormous boulder breccias (megabreccias) and conglomerates into the Meers Valley. This uplift was a reversal of the pre-Permian throw and was believed to have been caused by the relaxation of pre-existing regional stresses. The existence of "megabreccias" and conglomerates, plus the inverted relief across the Meers Valley was cited as evidence for this fault reversal. Other evidence that may support Donovan´s theory is the latest (Quaternary) movement of the Meers Fault which exhibits a similar uplift of the limestone block. Also significant is geomorphic evidence indicating left lateral movement on the Post Permian Meers Fault (Donovan et al.,1982). Fractures and sheared limestone clasts in Blue Creek Canyon conglomerates indicate that the Blue Creek Canyon Fault also probably experienced at least some Permian or post Permian reactivation.

Donovan, Bridges, and Collins (1985) suggested that at least two miles of left lateral displacement might have taken place along the Meers Fault in Permian Times. This theory was proposed because "megabreccias" south of the Meers Fault do not appear to have been derived from Arbuckle outcrops immediately north of the fault. The simplest reconstruction indicates that the megabreccias parent rock is probably several miles to the northwest. Multiple episodes of "megabreccia" deposition may have occurred however, the differentiation of these deposits into seperate events was not possible. Several mechanisms of transport were hypothesized for the "megabreccias" by Donovan, Bridges and, Collins (1985); rockfall, landslip, boulder train, air cushion supported transport.

Orientations were taken on individual mega-clasts in the Meers Valley in hopes of deciphering the depositional and tectonic history of these deposits. Attempts were made to record strike and dips from the individual megabreccia blocks. Unfortunately, most of the limestone boulders lacked upward indicators so it was decided instead to take readings on bedding plane surfaces (without regard to true orientation) of randomly selected blocks. It was hoped that a predominate orientation could be identified. Figure 41 represents the data based on fifty measurements. The data does not indicate a random distribution, however it is believed that no definite conclusions can be reached for either the mechanics or directions of transport for the megabreccias. It is also not certain how the directions



AZIMUTH FREQUENCY DIAGRAM



HISTOGRAM

Figure 41. Azimuth Frequency Diagram (top) and Histogram (bottom) Representing the Orientations of 50 Megabreccia Clasts in the Meers Valley

and degrees of inclination of this data might be interpreted.

Likely equivalents to the granite clast conglomerates in the Meers Valley are the granite conglomerates that are found adjacent to the igneous outcrops on the south side of the Wichita Mountains. Granite conglomerates apparently do not contain "megabreccias" and may have been less affected by the Lower Permian tectonics. Most of the crustal weaknesses where fault rejuvenation might have taken place are located along the north flank of the Wichita Mountains and thus, granite conglomerates in the southern portion of the Wichitas were probably less affected by fault rejuvenation. Another possible explanation is that all the granite conglomerates were deposited prior to the renewed tectonics that effected the limestone block north of the Meers Valley.

In addition to localized tectonics, gradual regional tectonic controls acted within the study area. The determination of these regional controls is based on thicknesses and distribution of the Lower Permian section and from map analysis of the (1954) geologic map of Oklahoma.

Collins (1985) indicated that the Lower Permian section in Meers Valley represented a condensed sequence of strata as compared with equivelent sections in the Anadarko Basin. Evidence to support this claim is based largely on the occurrence of numerous closely spaced mature calcretes in the Meers Valley while equivalent sections in the Anadarko Basin are much thicker and contain fewer calcretes horizons. Calcretes occur elsewhere on the Wichita structural block and are significant because they represent periods of non-deposition. These period of non-depositon indicate that the Wichita Mountain block was relatively stable during the early Permian as compared to the subsiding Anadarko Basin. Thus, the stratigraphic section on the Wichita Mountain block represents an incomplete section containing numerous hiati (Figure 42).

Tectonic Summary

It is believed that granite conglomerates were deposited northward from the igneous Wichita Mountains prior to fault rejuvenation and depositon of the limestone conglomerates and "megabreccias". It is possible that these granite conglomerates and arkoses were transported over the limestone block, into the Anadarko Basin and may have at one time covered parts of the limestone hills. Uplift of the limestone block and/or changes in weathering rates brought about by climatic changes, allowed the limestone block to attain some topographic relief, resulting in the building of small alluvial fans southward into the Meers Valley (Figure 43). This was followed by significant uplift on the limestone block which probably produced cliffs and screes. Cliff collapse and rock avalanches, possibly triggered by earthquakes, led to the

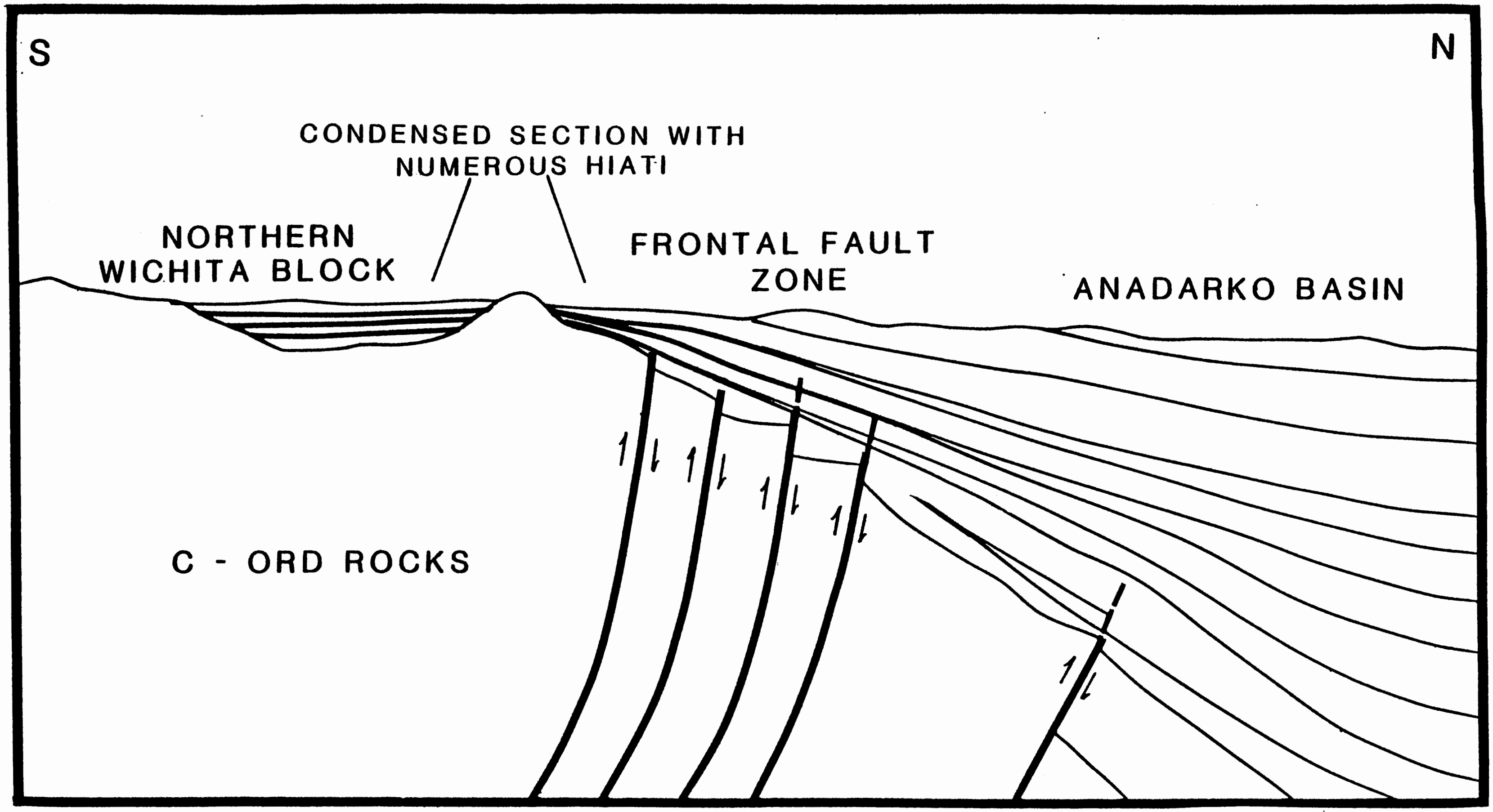


Figure 42. Schematic Model Illustrating a Condensed Sequence Along the Northern Wichita Block and Southern Anadarko Basin

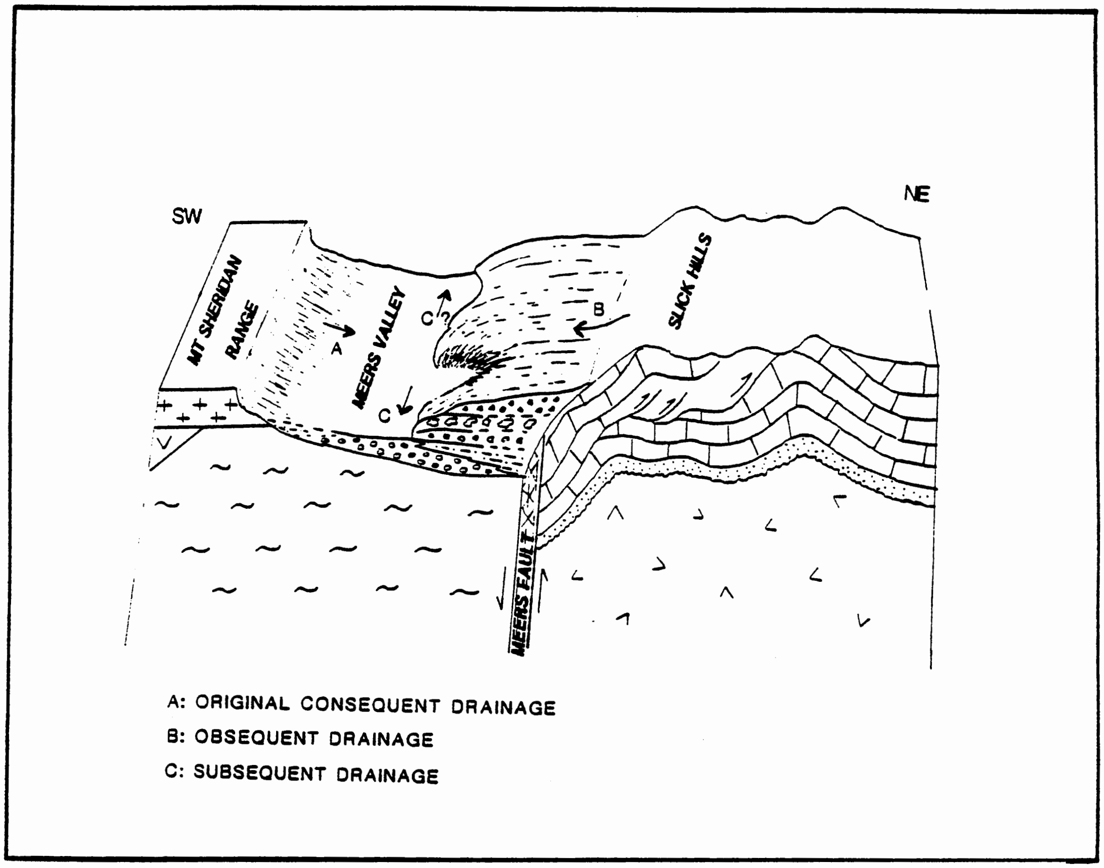


Figure 43. Relief of the Limestone Block Became Sufficient to Initiate Building of Small Limestone Alluvial Fans Southward into the Meers Valley

deposition of large blocks of limestone "megabreccia" into the Meers Valley (Figure 44). Significant relief coupled with earthquake triggering mechanisms are suggested because of similar Tertiary megaboulder deposits described by Eisbacher (1979) in the Canadian Rocky Mountains and because of the difficulty in accounting for present day relationships between these deposits and their source. Megabreccia deposits have been found as far away as 2 1/4 miles from the nearest Arbuckle outcrops and are presently only some 400 feet lower than the highest limestone peaks. It is therefore difficult to account for the transportation of these large limestone blocks given present relief.

The final episodes of conglomerate deposition were most likely resulting from the denudation of the previously uplifted limestone hills (Figure 45). The reduction of the Lower Permian topography probable continued with local uplift failing to keep pace with erosion. Eventually the limestone hills were covered over by conglomerates, sandstones and shales. Lawson (1906) identified that in arid environments hills can bury themselves in their own rubble. This might have occurred within the limestone hills, explaining the several patches of limestone conglomerate observed near the tops of limestone hills.

Gradual uplift of the Wichita Block and subsidence of the Anadarko Basin probably continued throughout the Paleozoic and probably into the Mesozoic.

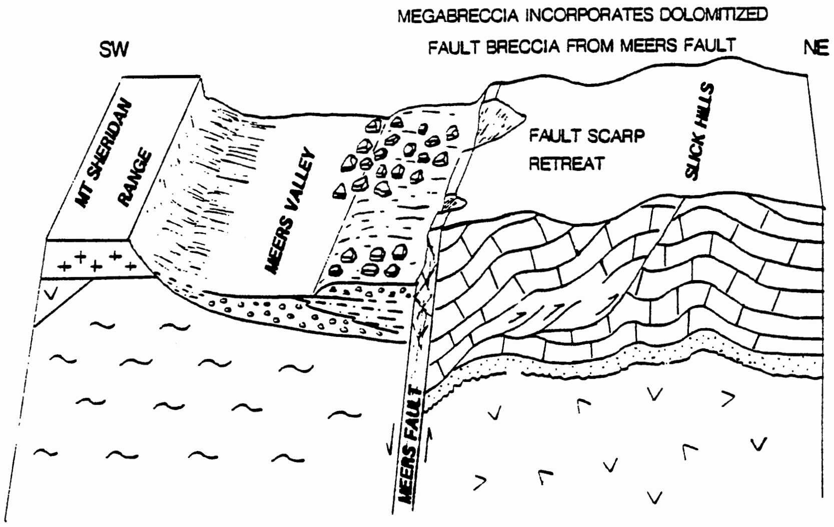


Figure 44. Rejuevenated and Reversed Movement along the Meers Fault Uplifted the Limestone Block, Earthquakes Probably Caused Large Boulders of Limestone to Tumble into the Meers Valley

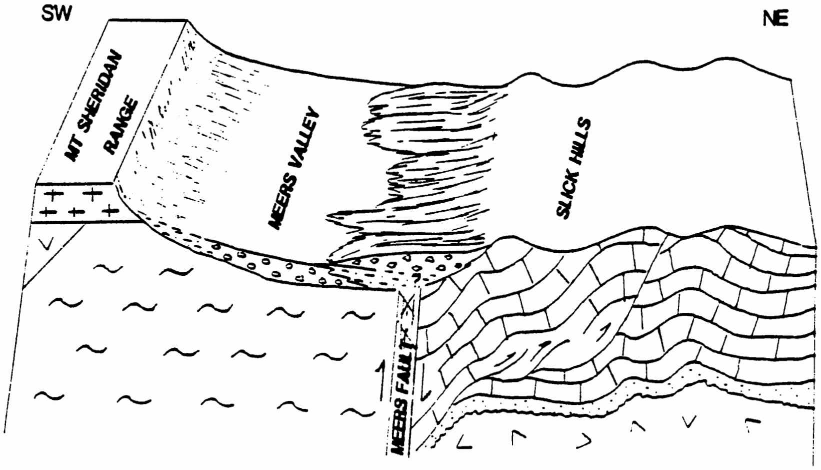


Figure 45. A Final Episode of Relief Related Limestone Conglomerates were Deposited Southward into the Meers Valley

Timing

The occurrence of the "megabreccies" and conglomerates implies that significant tectonic activity occurred (at least locally) in the vicinity of the Wichita Mountains. There is however uncertainty as to the timing of this activity. Chase (1954) believed that conglomerate adjacent to the Recent Meers Fault were possibly Upper Pontotoc equivalents (Lower Permian). Collins (1985) and Donovan, Bridges, and Collins (1985) speculated that the "megabreccias" might be as old as Late Pennsylvanian in age. This could not be possible if the granite conglomerates that underlie the megabreccias are Permian in age, which most of the previous investigators have suggested. It is very likely, that the conglomerates adjacent to the mountains represent a condensed section of strata and might therefore contain conglomerates of both Pennsylvanian and Permian age. Unfortunately, not enough evidence has been collected to verify this theory primarily because dating techniques cannot be satisfactorily applied to these continental deposits. Thus, uncertainties about the timing of these tectonic events still exist.

Tectonic Effects on Hydrocarbon Migration

Traces of hydrocarbons are found in the Lower Permian strata throughout most of the study area. Hydrocarbons have been observed in the form of stains, veins, nodules, and vugs fillings in host rocks of sandstones, calcretes and travertines (Figure 46). It is suggested that these hydrocarbons (along with associated brines) migrated up through existing faults and fractures during the Early Permian. Reactivation of some of the major fault systems in the area caused fracturing and allowed this fluid migration. Possible sources for the hydrocarbons have not been determined but could include much of Cambrian to Pennsylvanian section. As the hydrocarbons and brines migrated they left traces of their existence. Many authors have noticed that diagenetic alterations have taken place in the Permian "red beds" over many oil fields in southern Oklahoma (Gouin, 1956; Ferguson, 1977; Al-Shaieb et al., 1985). Alterations often include mineralization, of pyrite, marcasite, and feroan, manganese, and magnesium rich carbonates. Bleached host rocks have also been noted by these investigators and are believed to have been caused by reducing conditions that resulted from the migration of the hydrocarbons and brines. The rocks within this study that are green, white and tan were possibly effected by the reducing conditions that resulted from this hydrocarbon migration.

Travertines in fissure fills located in Sec. 26, T. 6 N., R. 14 W. were noted in Chapter IV to contain hydrocarbons. It is believed that at least some of these hydrocarbons were incorporated into the calcite as the travertines formed, possibly indicating timing of

Figure 46. Bitumens Filling Vugs and Fractures in a Calcrete Nodule

hydrocarbon migration.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Work for this thesis included mapping the Lower Permian strata, reviewing previous stratigraphic studies, and examining stratigraphic sections for areas surrounding the eastern Wichita Mountains. From this study certain conclusions concerning aerial distribution, stratigraphic definition, and tectonic implications of the Lower Permian strata have been reached.

This field study indicates that Chase (1954) has incorrectly mapped a large portion of the study area. Some of the areas mapped as Permian "Post Oak Conglomerate" by Chase (1954) are interpreted herein as superficial Pleistocene deposits. The resemblance of these Permian and Pleistocene rocks is striking and can be partly attributed to similarities in their composition and environments of deposition. Many other areas mapped as conglomerates by Chase are found to consists more typically of sandstones and shales and have been reclassified as parts of the Wichita Formation. In addition to these corrections, the "Post Oak Conglomerate" of Chase (1954) is herein reduced to informal status because:

i) the unit cannot be adequately separated from the informal "Granite Wash

ii) the unit cannot be positively correlated with the surrounding strata

iii) these conglomerates probably correlate to multiple formations

The conglomerates represented on the geologic map (Plate 1) indicate surficial distribution, resulting from the present erosional surface. Because of this distribution these conglomerates probably represent multiple horizons and cannot be considered as a single correlatable horizon.

Throughout the study area the Lower Permian stratigraphy is highly complex. Exposed sections often consist of discontinuous sandstone and conglomerate lentiles encased in mudstones. Extreme lateral and vertical lithologic changes are common with color changes occurring frequently. Colors sometime cut across bed boundaries and cannot be used as stratigraphic indicators.

The complex stratigraphy has caused problems for most investigators. As a result, many of the previous stratigraphic studies are not in agreement. Attempts by Fay (1968) and Havens (1977) to break down the Wichita Formation into separate formations are considered by the author to be unsuccessful. The differentiation of this formation into separate mappable units is not possible in this study. Because of this, the use of the term "Wichita Formation" is used to describe much of the Lower Permian strata and is sustained from Miser (1954). In addition, the proposed stratigraphic section in this thesis is based on the work of Miser (1954) and Chase (1954) because of the similarities between their work and the observations made in this study. Within the study area boundaries between the Wichita Formation, the Hennessey Group and the El Reno Group are indefinite and difficult to distinguish.

Lithostratigraphic correlations are difficult because markers are generally absent within the study area, however it is suggested that certain calcrete horizons may serve as markers for future investigations. Previous biostratigraphic age determinations for the two vertebrate sites are inconclusive and are not useful in this study. Future studies utilizing vertebrate fossils may prove to be useful but will probably be hindered because of the scarcity of fossil materials, and because most vertebrate fossils are extremely disarticulated which complicates indentification.

It is determined in this thesis that tectonic activity occurred intermittently from the Late Pennsylvanian and Early Permian. This activity was probably locally isolated and less common than the activity that occurred earlier in the Pennsylvanian. The stratigraphic evidence supporting the occurrence of this tectonic activity is best exemplified in the Meers Valley. Tectonic activity throughout the study area is indicated by coarse clastics while tectonic quiescence is indicated by finer clastic and periods of non-deposition is often represented by calcretes. Some of the tectonic deposits were greatly influenced by the paleo-climate. It is suggested that the climate changed from predominantly humid during the Late Pennsylvanian to predominantly semi-arid during the Early Permian. The later semi-arid climate enabled certain limestone outcrops to attain significant relief. Along the northern mountain front this relief combined with the reactivation of the Meers, Blue Creek Canyon, and possibly other faults causing earthquakes resulted in the deposition of large "megabreccias".

In addition to the localized tectonics, regional tectonic activity consisting of uplift or subsidence is indicated by thicknesses and distributions of the Lower Permian strata. This strata indicates that the Wichita Mountain block was relatively stable during the Early Permian in contrast to the subsiding Anadarko Basin. Strata that was deposited on this block is thin and contains numerous hiati, representing a condensed sequence. Equivalent strata in the Anadarko Basin is thicker and is more complete,indicating more continuous deposition. These gradual tectonics may have continued into Mesozoic times.

Conclusions about the precise timing of the tectonic events cannot be reached because of the inability to accurately date the strata. However, it is believed that the deposition of the conglomerates and megabreccias occurred sometime during the Late Pennsylvanian or Early Permian.

Hydrocarbons have migrated into and through much of the Permian strata. This migration may have been initiated or aided by the localized tectonic activity. The migration of the hydrocarbons and associated brines probably caused bleaching in some of the strata. Hydrocarbons are presently found in the asphaltic sandstones, calcretes, travertines, and as nodules in mudstones and siltstones. It is suggested that some hydrocarbons have been incorporated into the crystal lattice of the travertine. This could possibly indicate timing of at least some migration.

Suggestions for Future Investigations

It is suggested that further detailed field mapping be conducted within and surrounding this study area. Such a detailed project should include available subsurface data as well as surface information. Stratigraphic correlations state wide should be examined and possibly reevaluated to better match the surrounding areas. Stratigraphic terminology should be applied in order of precedence and conventionality, with investigators refraining from the use of recent "loose" stratigraphic nomenclature. Dating techniques should be developed and applied to this strata in order to better define the age and timing of tectonic events and hydrocarbon migration.

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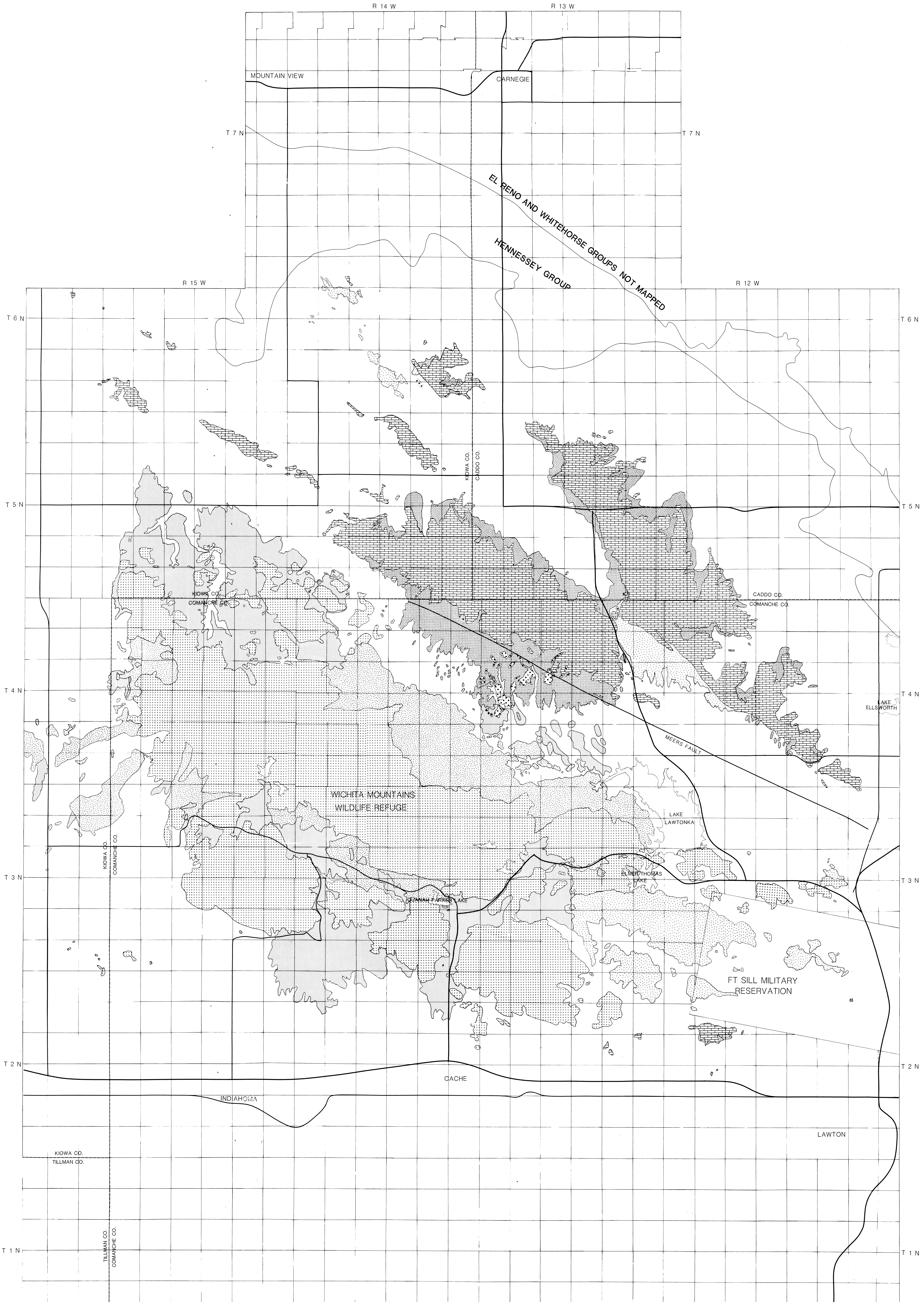
Education: Graduated from Russellville High School, Russellville, Arkansas, in May, 1978; received Bachelor of Science degree in Geology from Arkansas Tech University in May, 1982; completed requirements for the Master of Science degree at Oklahoma State University in December, 1985.

Professional Experience: Research Assistant and Field Geologist for the Arkansas Mining and Mineral Resources Institute, August, 1980 through May, 1981; Laboratory Assistant in Geology at Arkansas Tech University, August, 1981 through May, 1982; Field Geologist for Arapaho Petroleum Corp. January, through September, 1982; Reclamation Geologist for the Arkansas Department of Pollution Control and Ecology, November, 1982 through August, 1983; Graduate Teaching and Research Assistant, Department of Geology Oklahoma State University, January 1984 through May, 1985.



GEOLOGIC MAP OF THE LOWER PERMIAN ROCKS EASTERN WICHITA MOUNTAINS, SOUTHWEST OKLAHOMA

INCLUDES CAMBRIAN THROUGH ORDOVICIAN OUTCROPS EXCLUDES PLEISTOCENE AND RECENT DEPOSITS

BY STEVE BRIDGES

ASSISTED BY DEBORAH A. RAGLAND
KATHRYN H. COLLINS
R. NOWELL DONOVAN

EXPLANATION

EL RENO AND WHITEHORSE GROUPS — NOT MAPPED IN THIS STUDY

HENNESSEY GROUP — CONTACTS ADAPTED FROM MISER (1954)

PERMIAN ☐

WICHITA FORMATION

- ▨ LIMESTONE "POST OAK — INCLUDES "POST OAK CONGLOMERATE" AS AN INFORMAL MEMBER
- ⁘ LIMESTONE"MEGABRECCIA" — CORRELATIVE FORMATIONS INCLUDE THE UPPER PART OF THE PONOTOC GROUP, WELLINTON FORMATION, AND GARBER SANDSTONE
- ░ GRANITE, ANORTHOSITE, AND GRANITE/ANORTHOSITE POST OAK

ORDOVICIAN ▤ CAMBRO-ORDOVICIAN LIMESTONE, SANDSTONE AND SHALE: UNDIFFERENTIATED TIMBERED HILLS, ARBUCKLE, SIMPSON, AND VIOLA GROUPS

CAMBRIAN

- ⁘ WICHITA GRANITE GROUP — INCLUDES UNDFFERENTIATED HALE SPRINGS PEGMATITES, QUANAH GRANITE, SADDLE MOUNTAIN GRANITE, MT. SCOTT GRANITE, COLD SPRINGS BRECCIA, AND HYBRID ROCKS
- ░ CARLTON RHYOLITE GROUP
- ░ RAGGEDY MOUNTAIN GABBRO — INCLUDES UNDIFFERENTIATED ROOSEVELT GABBROS AND GLEN MOUNTAIN LAYERED COMPLEX

0 1/2 1 MILE
SCALE

NORTH