THE STRUCTURAL GEOLOGY OF THE SOUTHERN SLICK HILLS, OKLAHOMA

By

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THE STRUCTURAL GEOLOGY OF THE SOUTHERN

SLICK HILLS, OKLAHOMA

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PREFACE

The field mapping of the Slick Hills was initiated to provide a detailed geologic map of the area in order to illustrate the structural complexity of the region. The Lower Paleozoic rocks of the Hills are well exposed, allowing nearly complete definition of the structures present. Once the varying orders and styles of folding were recognized, representative folds were cataloged and their geometries analyzed in detail. Fieldwork also led to an understanding of the faulting and newly discovered shear zones in the Slick Hills. A transpressional model was then applied to account for the structural and stratigraphic relationships encountered. It was found that this model may ideally explain the overall structure of the Slick Hills, and may help to explain structural deformation elsewhere in southern Oklahoma.

The author would like to thank those individuals who assisted in the completion of this study, particularly Dr. Nowell Donovan, my thesis adviser who provided insight and assistance both in the field and in the preparation of the final text. Considerable tribute is given to Dr. Dave Sanderson for his conception of transpression, and to Dr. Carol Simpson for her advice in the field and during preparation of the text. Thanks are also given to Dr. Wayne Pettyjohn for his advice in the preparation of the final manuscript.

Appreciation is given to David McConnell and David Marchini both as co-workers in the field, and for their contributions toward the first synthesis of the geology. Further thanks are due Debbie Ragland, who contributed the general stratigraphic column of the Slick Hills.

I would especially like to express my gratitude to the land owners within the Slick Hills. Without their most generous cooperation this study would not have been possible. In particular, I owe many thanks to Mr. and Mrs. Charlie Oliver of the Kimbell Ranch for their hospitality and cooperation. In addition, appreciation is extended to Mr. Kimbell, the Reeders, the Dietrichs, the Woods, the Tullys, and others.

Appreciation is also expressed to the Oklahoma Geological Survey and to Sun Exploration and Production Company for their support of this thesis.

TABLE OF CONTENTS

TABLE

LIST OF FIGURES

Figure | Page

Figure Page

Figure | Page

LIST OF PLATES

CHAPTER I

PURPOSE

The purpose of this thesis was to map the Lower Paleozoic rocks within the Lawtonka Graben, an area of complex structure in the Slick Hills of southeastern Oklahoma. The mapping was undertaken in order to present a structural and stratigraphic synthesis of the area. The study is integrated with a regional project undertaken for the Oklahoma Geologic Survey.

Method of Study

Most of the study area has been folded to some extent, and a careful reconnaissance was necessary to delineate the trends and geometry of the folds. Following the mapping of the structure present in the Slick Hills, an analysis of data was undertaken in order to determine the principal mechanisms responsible for the field relationships encountered.

Surveying of the Limestone Hills was done by lines of transect on a bearing roughly perpendicular to the orientation of the major fold trends. Along these transects, strike and dip readings were taken at regular intervals. In areas of greater complexity, the transects were more closely spaced. Where appropriate, individual folds were analyzed. Stratigraphic boundaries in the Arbuckle Group were noted along the transects and integrated into the map with the help of air photographs.

Air photographs were used in conjunction with enlarged topographic sheets (scale: 6 inches = 1 mile), to plot the major fold and fault trends accurately. The use of air photographs with a zoom transfer-scope provided an accurate method of tracing bedding and formation contacts. However, in areas of highly complex minor folding and shearing, bedding planes could be mapped only in the field.

Strike and dip readings on many of the folds in the Slick Hills were used to plot stereographic and equal area projections for structural analysis. Cross-sections were produced to exhibit the fold geometry. Sketch maps and photographs of some of the discrete areas were used to illustrate characteristic structural patterns in the area.

Location and Description of Thesis Area

The Slick (or Limestone) Hills, which are located to the north of the Wichita Mountains, contain the study area. The Lawtonka Graben itself trends (NW-SE) through Caddo, Kiowa, and Comanche Counties (T4N-R13W; T5N-R14W). The graben is bounded by the Meers Fault to the south, and the Blue Creek Canyon Fault to the east and north (Figure 1). The area of study is further divided by a geologically insignificant line trending down the center of the graben, separating the study area from the area interpreted by McConnell (1983).

The Slick Hills Research Group

Presently, several individuals are partaking in an extensive and detailed analysis of the structure, stratigraphy, and sedimentation within the Slick Hills. Dr. Nowell Donovan is primarily responsible for the organization and advising of graduate students working within the area. This work is linked directly to support from the Oklahoma

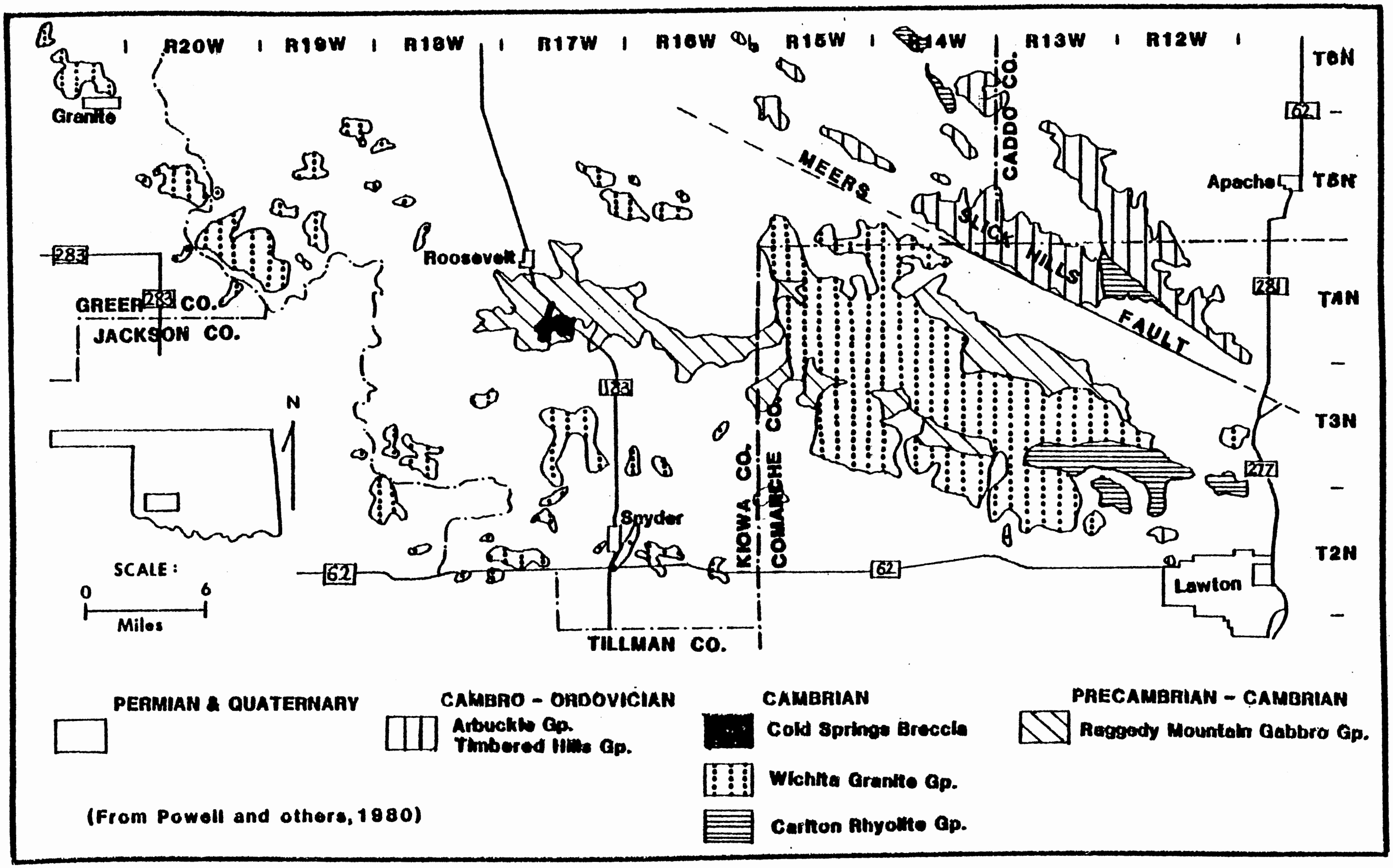


Figure 1. Geologic map of the Wichita Mountains and Slick Hills

Geological Survey and Sun Exploration and Production Company.

David McConnell (OSU) has worked in close conjunction with this study in an analysis of the area immediately to the north (also within the Lawtonka Graben). The two pieces of work have been tightly integrated. David Marchini and Dr. David Sanderson of the Queen's University, Belfast, Northern Ireland, are conducting a longer term of study which has as its primary objective in the testing of a hypothesis of transpressive shear behavior. Debbie Ragland (OSU) and Tekleab Tsegay are analyzing aspects of the sedimentology of the Lower Paleozoic Cool Creek and Reagon Formations, respectively. Milton Stubbs (OSU) is working on correlating outcrop of the Arbuckle Group on the horst, with the subsurface mapping in the immediate area.

CHAPTER II

PREVIOUS RESEARCH

Part I - Regional Setting

The Lawtonka Graben is a part of the structural province known as the "Frontal Wichitas." Lower Paleozoic rocks in this region are complexly deformed owing to their position between the Anadarko Basin to the north and the Wichita Uplift (Figure 2). The trend of the Frontal Wichitas was probably initiated in Pre-Cambrian Times (Dennison, 1982). Subsequently, this trend was rejuvenated during the development of the South Oklahoma Aulacogen (Milanovsky (1981). The aulacogen probably originated as a rift which formed one arm of a triple junction. The three rift arms spread with two of the rift arms forming a Paleozoic continental margin; the third arm, extending into the continent, formed the South Oklahoma Aulacogen. The formation of the latter rift formed a trough which was infilled by clastic sediments subsequently metamorphosed. Subsequent igneous activity resulted in the intrustion of gabbros, which were overlain by basalts. Further erosion and sediment deposition was followed by rhyolite extrusion and cogenetic intrusion by granitic magmas (reviewed by Gilbert, 1982). Subsequent rapid subsidence was associated with further downwarping of the rift basin (Figure 3).

Initial sedimentation is recorded by the Upper Cambrian Reagan Sandstone, following which prolonged carbonate-producing conditions resulted in the deposition of the Honeycreek Limestone and the Arbuckle

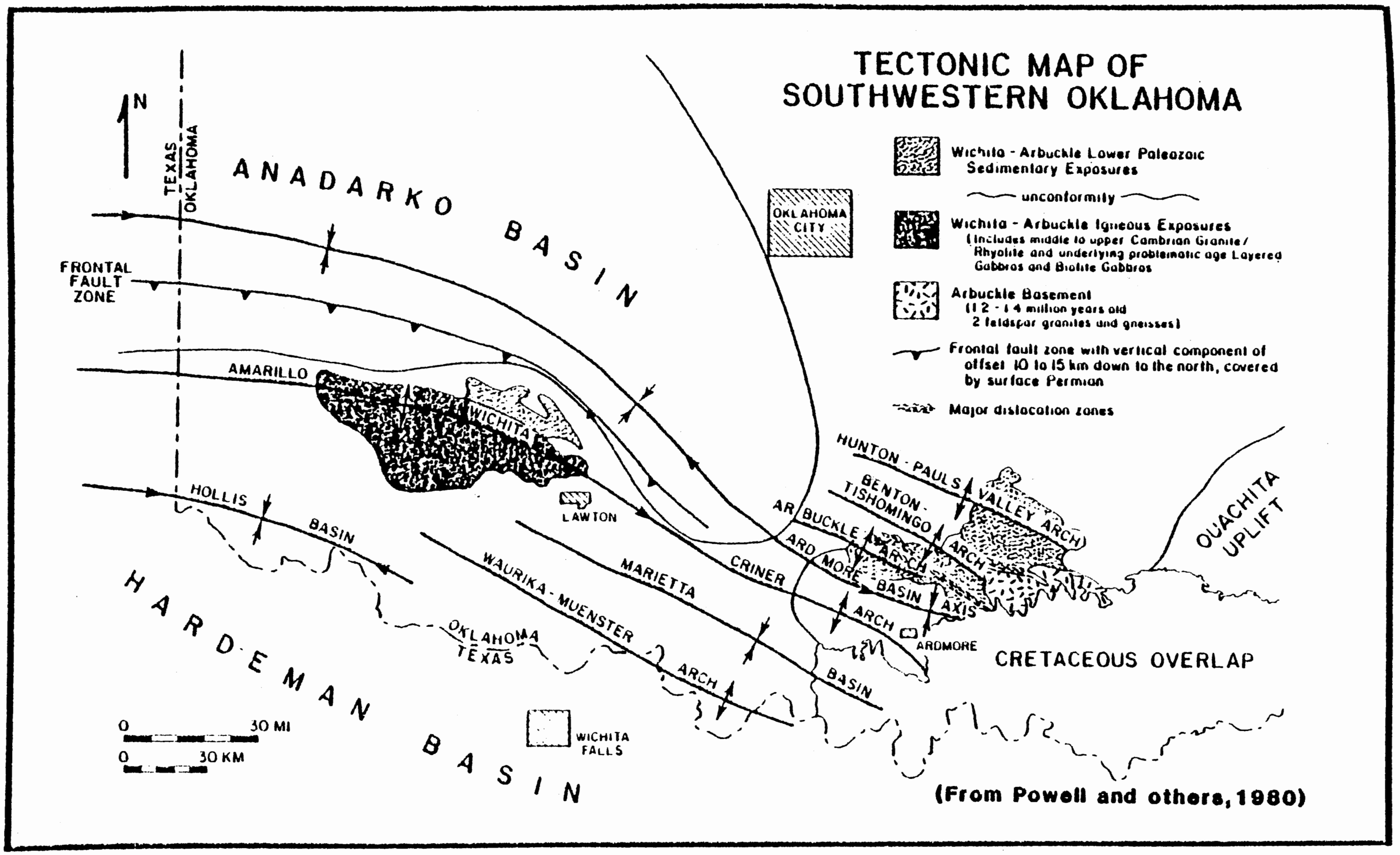


Figure 2. Tectonic map of Southwestern Oklahoma

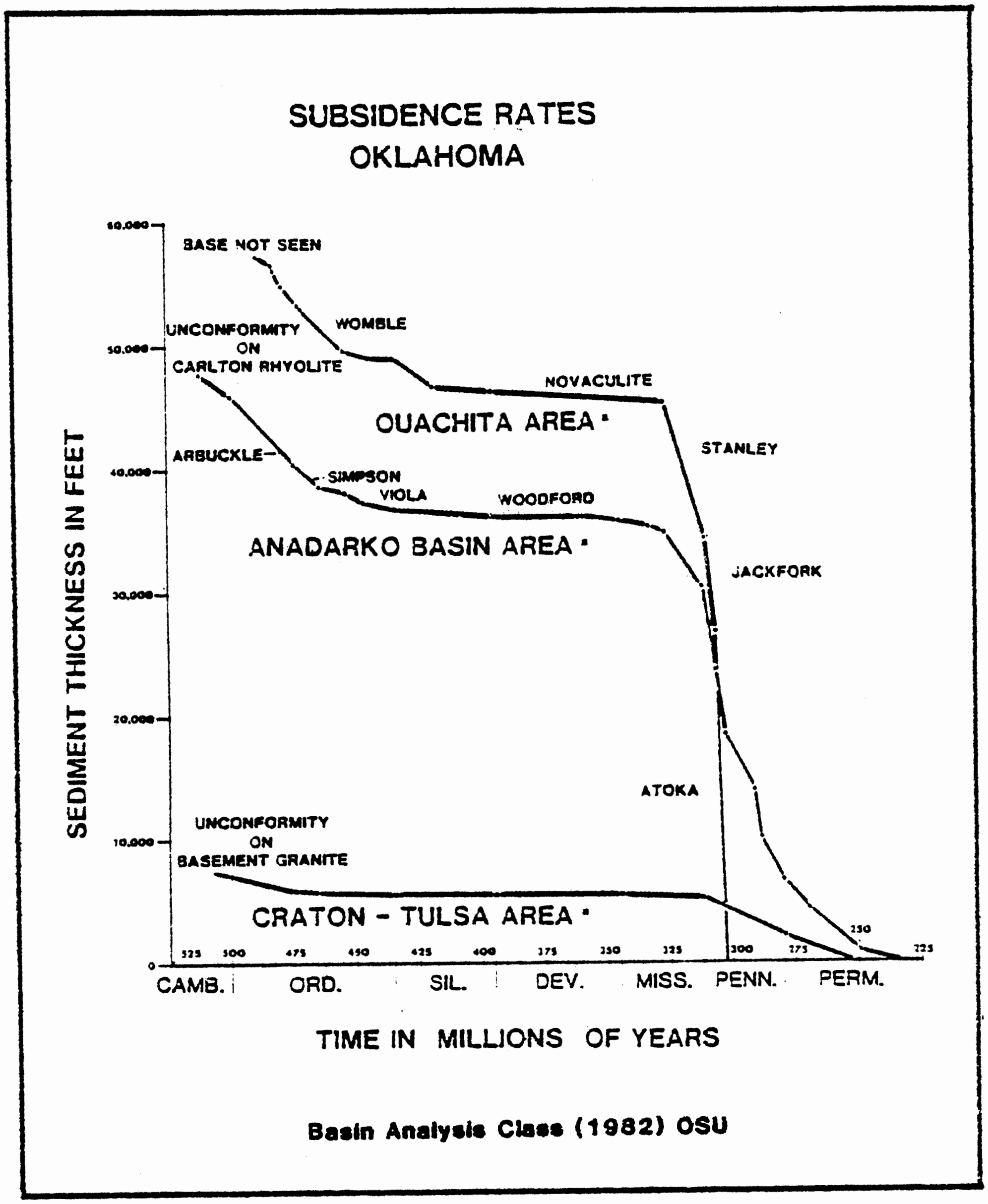


Figure 3. Subsidence Rates In Oklahoma. (Anadarko Basin Area and Ouachita Region)

Group. The latter is approximately 5,000 feet thick. Subsidence in the aulacogen area slowed greatly in the latter part of the Ordovician Period, and did not accelerate again until the late Mississippian. It is possible that at this time a collision of a continent or island arc along the southern Paleozoic margin of North America occurred. This collision would have initiated stresses along pre-existing zones of weakness, including the old aulacogen trend.

During the Pennsylvanian, this stress resulted in great changes in the geology of southern Oklahoma. Areas of uplift (e.g., Arbuckle, Criner, and Wichita blocks) and subsidence in southern Oklahoma (e.g., the Anadarko and Ardmore Basins) developed in a tectonic regime dominated by left lateral strike-slip (Brewer, 1982).

Analysis of southern Oklahoma by COCORP deep seismic reflectioning suggests the alignment of the aulacogen along the margin of a Proterozoic basin, and indicates major deep seated thrusting of the Wichita block over the southern margin of the Anadarko Basin (Brewer, 1982). In detail, both the Mountain View Fault and the Meers Fault appear as seismic lines which dip underneath the Wichita block (Figure 4). The Blue Creek Canyon Fault is also known to be high angle fault albeit of a different trend (Donovan, 1982). In addition to vertical motion, wrench movements are believed to have occurred along the pre-existing fault trends in a left-lateral sense(Pratt, 1975; Wickham, 1978; Donovan, 1982; Brewer, 1982). The Meers Fault and the Blue Creek Canyon Fault (which are the boundary faults of the study area in the Lawtonka Graben) are two such examples of rejuvenated faults.

Following the deposition of the Pennsylvanian sediments and the major deformation in the area, Permian sediments were deposited over the whole

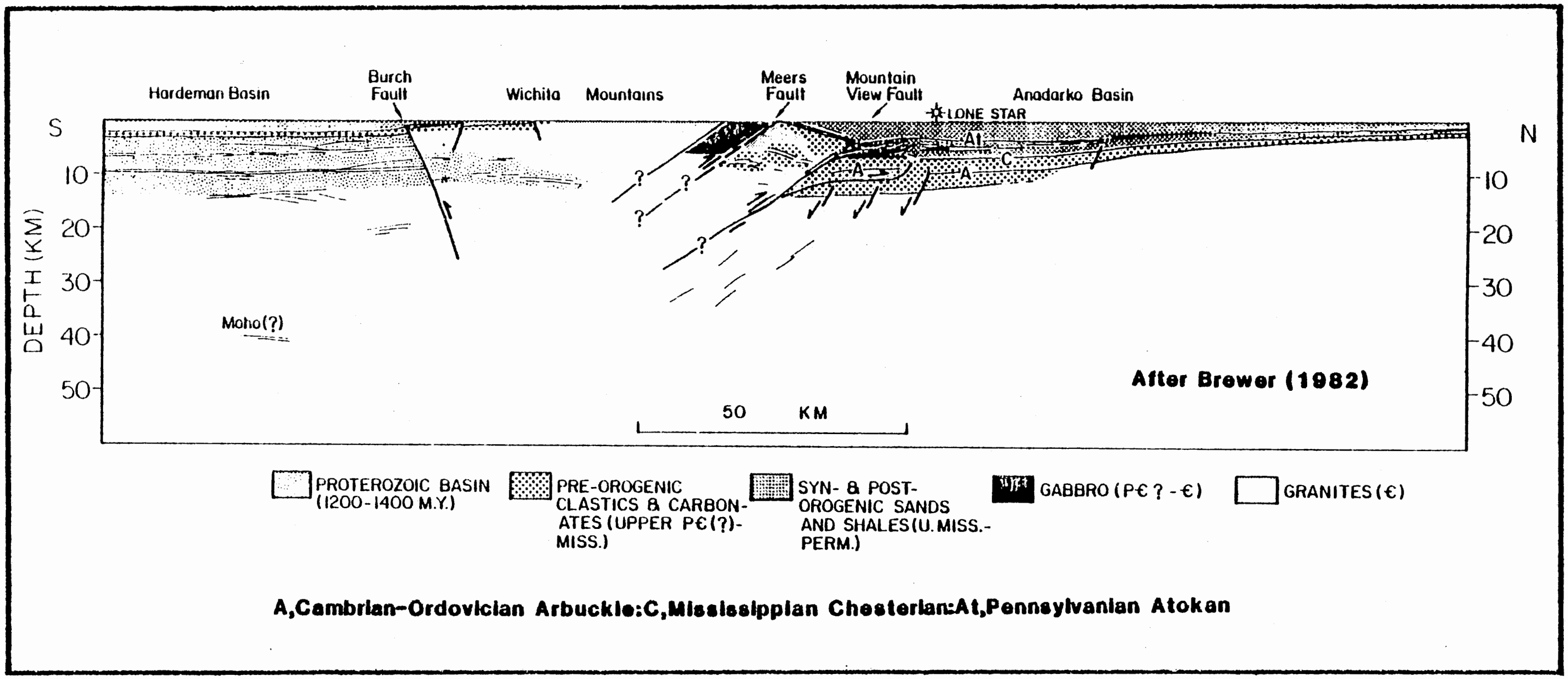


Figure 4. Section Across Southern Oklahoma Aulacogen. (From COCORP data)

area of the Wichita uplift with profound angular unconformity. In the area of study in the Slick Hills, the Permian Post Oak Conglomerate lies unconformably upon the earlier Paleozoic rocks. Within the Slick Hills, recent erosion has created a classic example of exhumation, in which the deformed Arbuckle Group protrudes through the onlapping Post Oak alluvial sediments.

Part II - The Slick Hills-Lawtonka Graben

There have been several prior studies of the Slick Hills, all of which have made significant advances in our understanding of the geology. This work has established a satisfactory stratigraphic framework (Figures 5 and 6), and has delineated the principal structual features.

Important early studies were those of Harlton (1951, 1963, 1971), who interpreted the structural geology of the sedimentary rocks north of the Wichita Mountains both at the surface and in the subsurface. Harlton's work led to the recognition of a structural province known as the Frontal Wichita Fault system. The primary achievement of this work was the recognition of the Meers Valley (or Thomas) Fault and the Mountain View Fault as the major bounding structures of the area. Between these two faults Harlton recognized the Blue Creek Horst and the Lawtonka Graben, the boundary between the two being the Blue Creek Canyon Fault. Harlton interpreted the Blue Creek Canyon Fault as a normal fault. However, the exposures he described as evidence of a normal fault plane have since been re-interpreted as an unconformity between the Honey Creek Formation and the Carlton Rhyolite (Donovan, 1982). Donovan (1982) located the trace of the Blue Creek Canyon Fault a short distance to the west of the unconformity, and re-interpreted the structure as a high angle

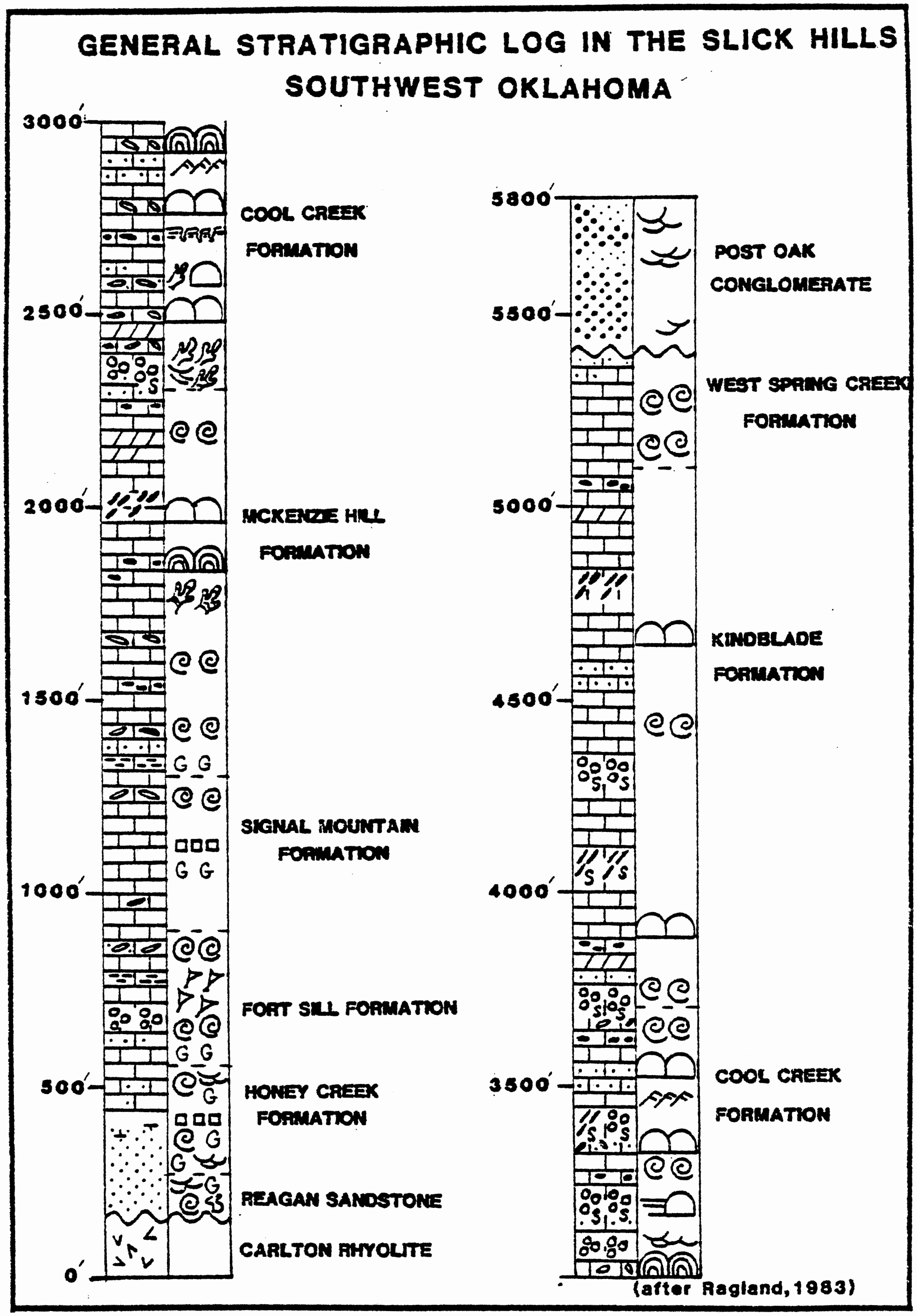


Figure 5. General Stratigraphic Section of the Slick Hills

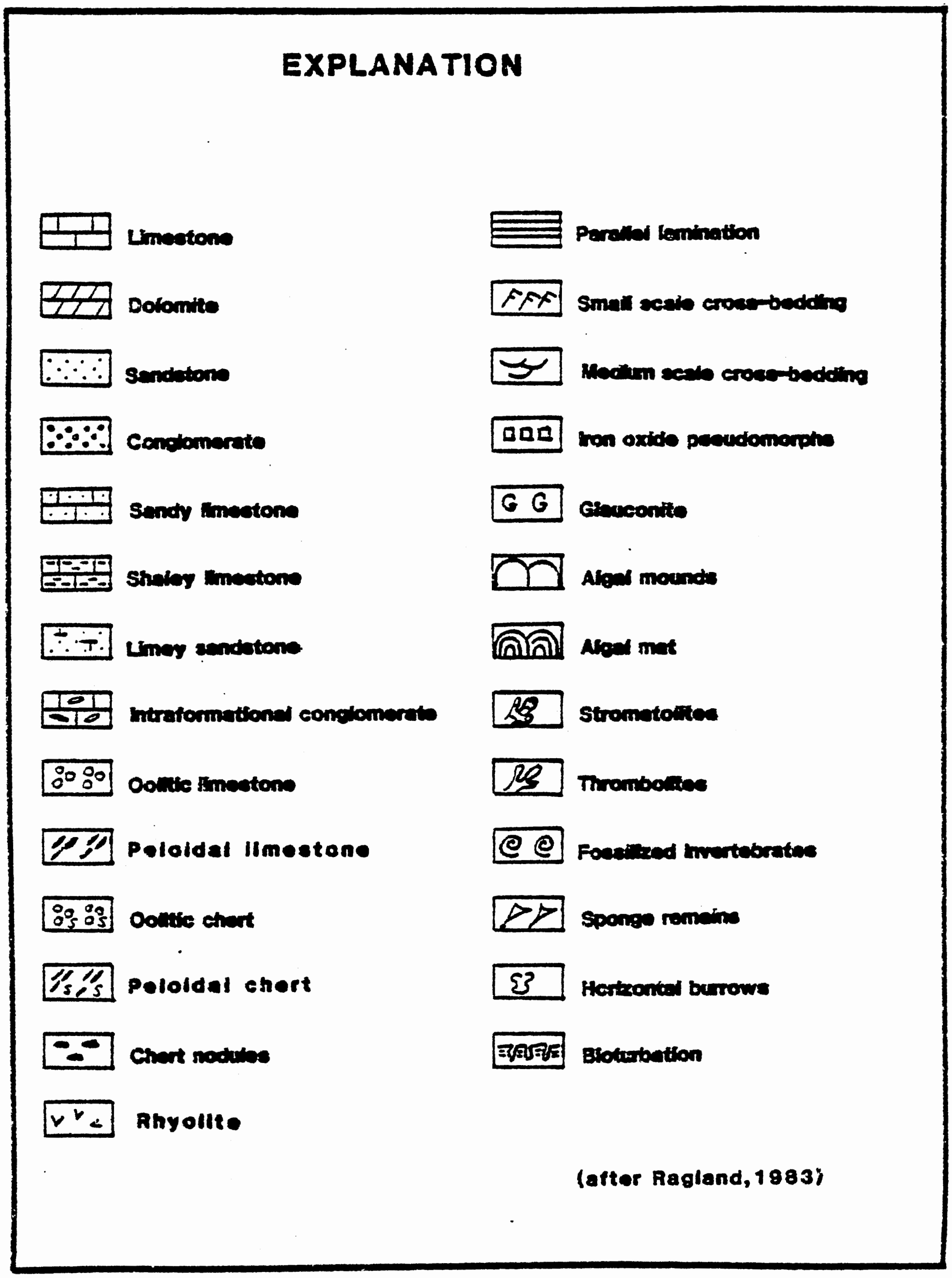


Figure 6. Explanation of Stratigraphic and Sedimentological Symbols

reverse fault, with the Timbered Hills Group on the upthrown block and the Arbuckle Group on the downthrown block.

The three large scale faults noted above were believed to be deep seated by Harlton (1971) due to their lateral extent and considerable stratigraphic displacement. In particular, the Meers Valley Fault was traced by Harlton (1971) for at least 20 miles. Harlton (1971) also described a series of faults stemming from the Meers Valley Fault northwestward, which he interpreted as thrust faults which he though responsible for intense folding in the graben.

Many of the faults on the Blue Creek Canyon Horst designated as cross faults by Harlton (1971) were linked by him to periods of tensional buildup. Harlton proposed that "during the Permian surficial compression resulted in renewed movement on existing faults to originate dip reversal on developed horsts" (pp. 995). Subsequently he believed that many of the faults on the horst were rejuvenated as thrust and high angle reverse faults, as evidenced mainly from subsurface and geological data. Harton considered "that the horst was initially deformed by vertical motion rather than lateral movement following an episode of rising magma and mantle flexure resulting in tensional faulting."

Barthelman (1969) mapped the Upper Arbuckle Group in the western part of the Slick Hills. This study was concerned primarily with the stratigraphic mapping of the Arbuckle Group, and referred to type sections established in the Wichita Mountains and in the Arbuckle Mountains. Many of the lithologic markers used by Barthelman (1969) have been of value in the present study. For example, the chert horizons within the McKenzie Hill Formation are very distinct and laterally persistent (Figure 7). Similarly, the siliceous horizons in the Cool

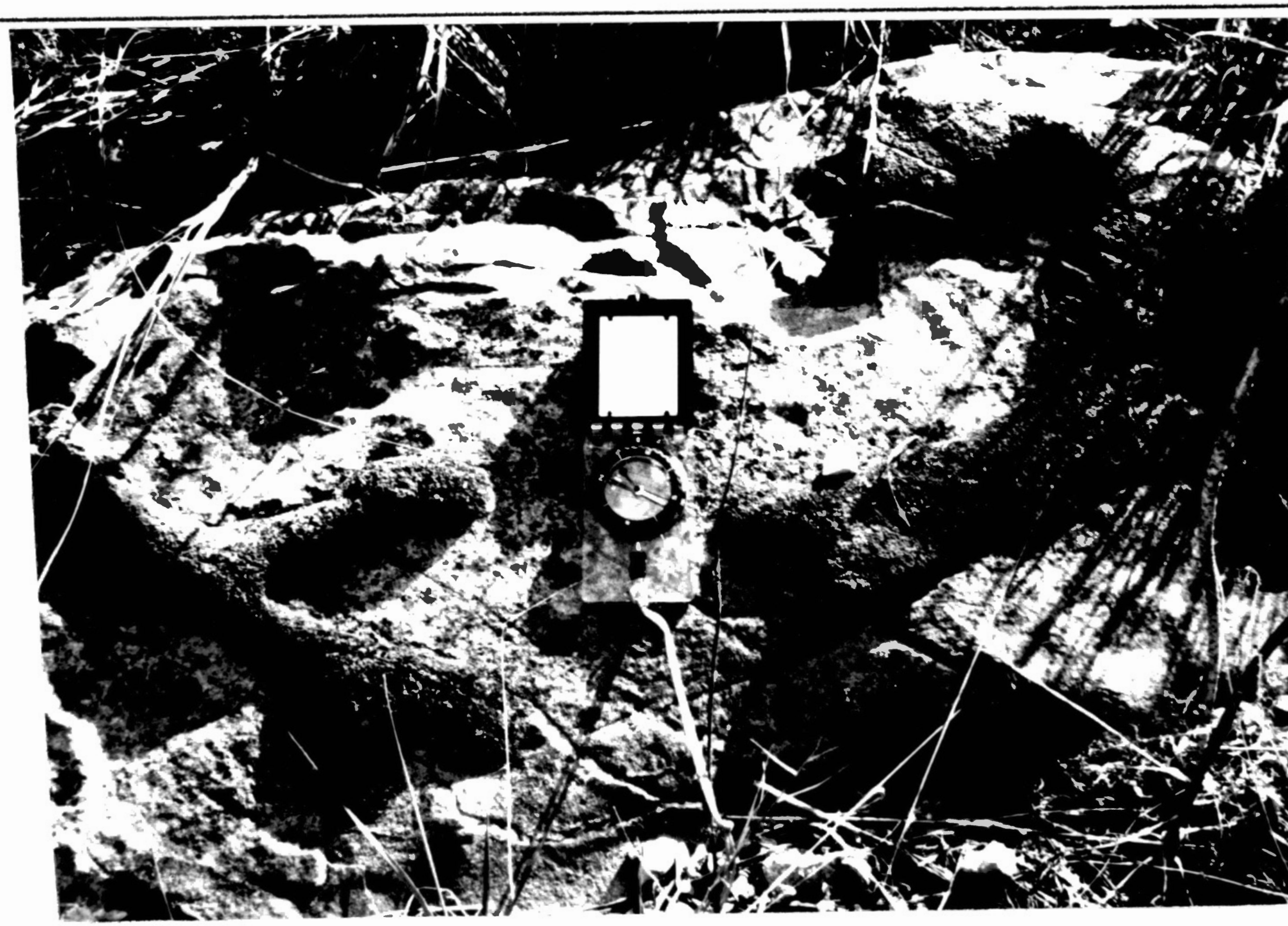


Figure 7. Chert Horizons (Branching Sponges) in the McKenzie Hill Formation

Creek Formation which contains abundant quartz sand and silicified oolites were of value in distinguishing the McKenzie Hill and Cool Creek Formations (Figure 8). In particular, the siliceous oolitic bed at the base of the Cool Creek proved to be extremely valuable in mapping. This horizon weathers as an entrenchment which can be traced for many miles in field and on aerial photographs.

Barthelman (1969) mapped dolomitic horizons within the Arbuckle Group, and noted that these horizons varied vertically as well as horizontally. Thus, dolomite was of limited value in stratigraphic mapping. Barthelman (1960) also recognized several important structures in the western part of the area.

Barthelman interpreted the Meers Fault as a vertical fault with a left-lateral strike-slip component. The vertical throw he believed to be approximately four miles following Ham, Denison and Merritt (1964). Barthelman (1969) followed Harlton (1959) in interpreting the Blue Creek Canyon Fault as a normal fault with a downthrow to the south of about 4000 feet. He also recognized an important fault trending approximately east-west in the area just to the south of Longhorn Mountain. He thought that the Longhorn Mountain Fault had a stratigraphic downthrow of 600-800 feet to the south, and considered that the fault separated the Rainy Mountain syncline to the north from the Saddle Mountain Syncline to the south. The Saddle Mountain Syncline is a major feature mapped by Barthelman (1969) as a broadfold with a variable axial trend (from northwest to southeast) closing to the southeast. Regions of minor folding in the area were interpreted to be the result of a combination of tensional and compressional stresses normal to the strike of the principal faults. However, Barthelman did not map minor folds in detail. He concluded his study by noting that the geology of the area was of limited economic significance, except as a source of limestone rock.

Figure 8. Quartz-rich Horizon at the Base of the Coal Creek Formation. Resistant Lithology is a Horizon of Silicified Oolites

CHAPTER III

RELATED STRUCTURAL THEORY

Wrench faults are the result of horizontal maximum compressive forces acting upon a vertical fault plane, so that the direction of movement is horizontal. The angle between the compressive force and the resulting shear fractures is about 30 degrees (Figure 9). The study of wrench faults has led to the recognition of these faults as a major type of crustal failure.

A set of conjugate shears may form where a rock fails under uniaxial compression. After the formation of these shears, the maximum stress orientations may change to allow for a second set of conjugate shears to develop (Moody and Hill, 1956). However, many strike-slip environments are characterized by a single dominant shear couple. The major faults within these environments are shear zones that may pass into the lower crust at depth. The relatively undeformed areas between these large scale shears are affected by a rotational couple, causing the rock between the shears to be strained. This zone of strain between the shears may be characterized by parallel slip planes, but if any compressional component is present, then shortening across the zone will potentiate folds within a "strain rhomb" (Spencer, 1977). The formation of "en echelon" belts of folds (or faults) between major strike-slip faults has been recorded (for example) in the Zagros Fold Belt (Figure 10), Western Saudi Arabia and the San Joaquin Valley, California. Thrust

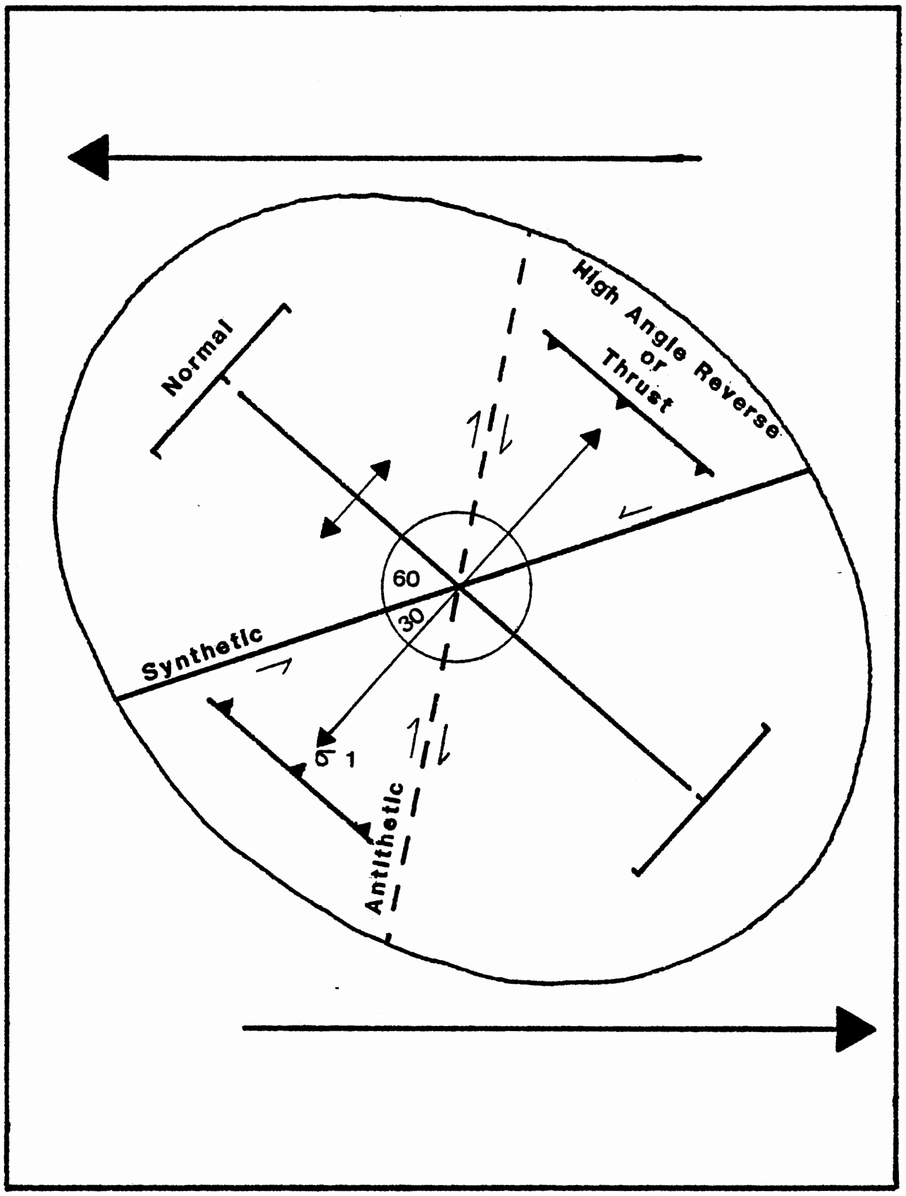


Figure 9. Strain Ellipse Under Left-Lateral Simple Shear, With Orientations of Related Structural Features (J. P. Moody, 1973)

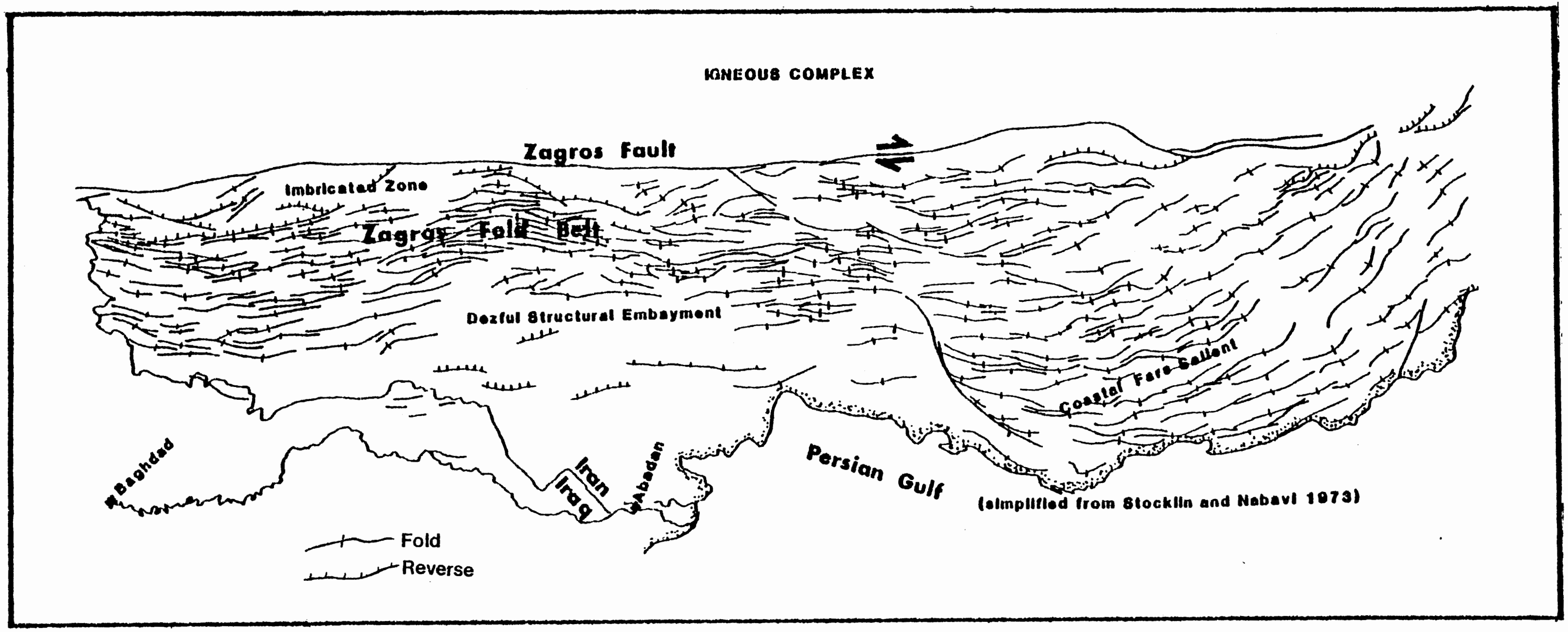


Figure 10. Geologic map of the Zagros Fault (Right-Lateral) and Related Folds and Faults Within the Zagros Fold Belt

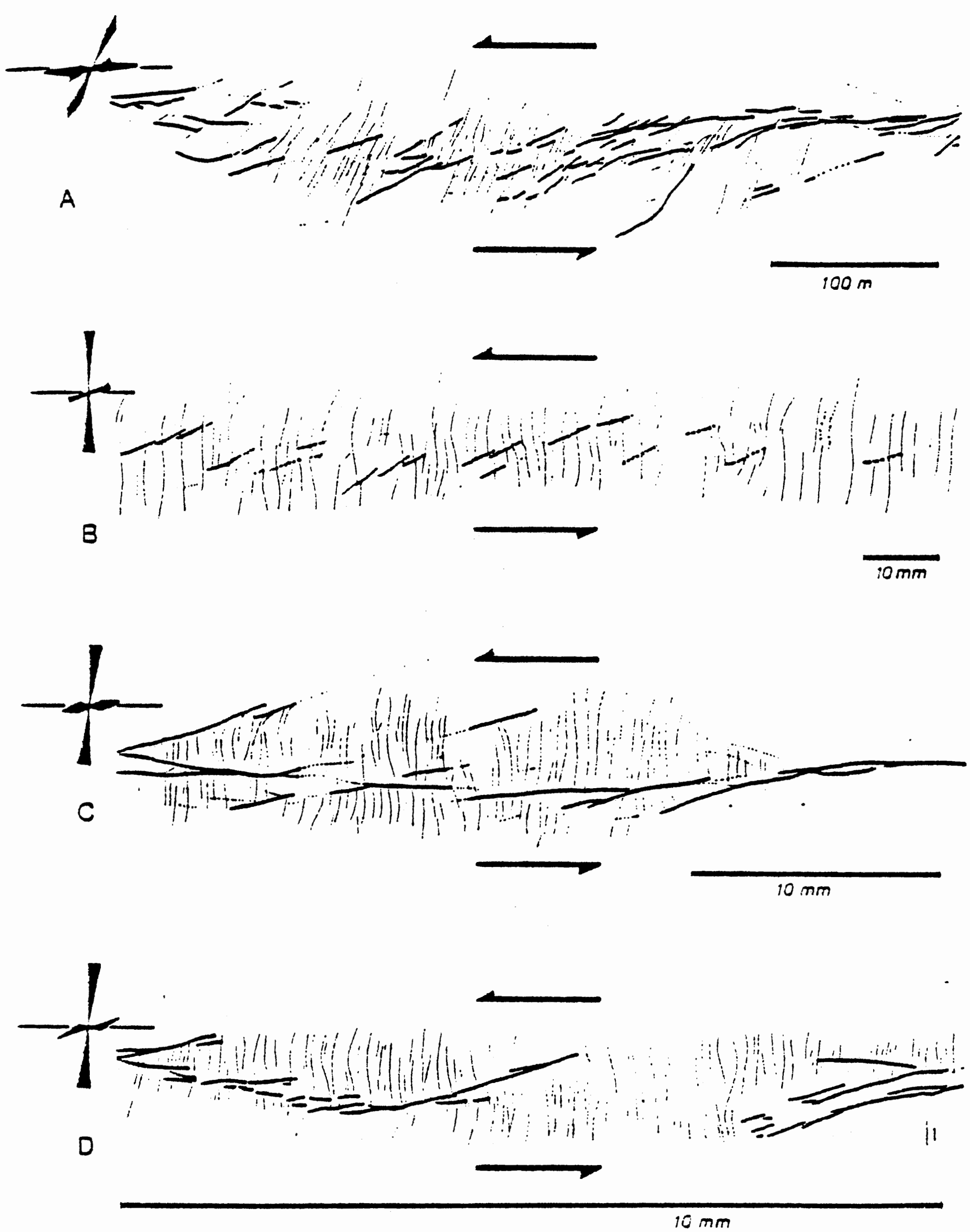
or high angle reverse faults may also accommodate shortening. Normal faults form in response to extension perpendicular to fold axes (Figure 9).

When faults terminate, motion may be taken up by an adjacent "side-stepping" parallel fault. At the terminus of a fault, there will be compression on the leading edge and dilation on the trailing edge (Reading, 1980).

Shear zones of various magnitudes by Tchalenko (1970) exhibit three kinds of secondary shears: R and R' Reidel shears, and P-shears (Figures 11 and 12). Experiments have shown that both R and R' Reidel shears occur prior to the peak of shearing. The R' shears become inactive, whereas the R shears become active faults in the post-peak shearing stage. P shears form during the post-peak stage as the Reidel shears are extended and rotated into parallelism with the shear zone boundaries. Studies performed by Bartlett, Friedman and Logan (1981) showed that the fracture or shear zone may increase in width with increasing shear displacement.

Horizontal displacements are a function of extension, transcurrence or compression (Harland, 1971). Horizontal movement is generally concentrated in "mobile zones" surrounding regions that display strike-slip, compressional or extensional features (Figure 13). The combination of strike-slip movement (transcurrence) and compression is termed transpression; that of strike-slip motion and extension is transtension. While these are not ideal situations, combinations of various types of movement may occur, resulting in a wide variety of structural provinces and features.

Transtensile regimes are the result of both extension and strike-slip motion and are characterized by stepped oblique movement along horizontal planes. Transtension is marked by normal faulting with associated drape folding, basin formation and, in some cases, volcanicity. Sediments



Comparison of peak structure in shear zones of different magnitudes. (A) Dasht-e Bayaz earthquake fault (*after* Tchalenko and Ambraseys, 1970, Fig. 8). (B) Riedel experiment (*after* Tchalenko, 1967, Fig. 132). (C) entire shear box (*after* Morgenstern and Tchalenko, 1967a, Fig. 5). (D) detail of shear box sample (*after* Morgenstern and Tchalenko, 1967a, Fig. 12). Total displacements are given in the text. Dotted lines indicate less prominent shears. The structures plotted in the form of rose diagrams show Riedel and conjugate Riedel directions.

(after J.S. Tchalenko, 1970)

Figure 11. Comparison of Structures Illustrating Reidel and Conjugate Reidel Shears

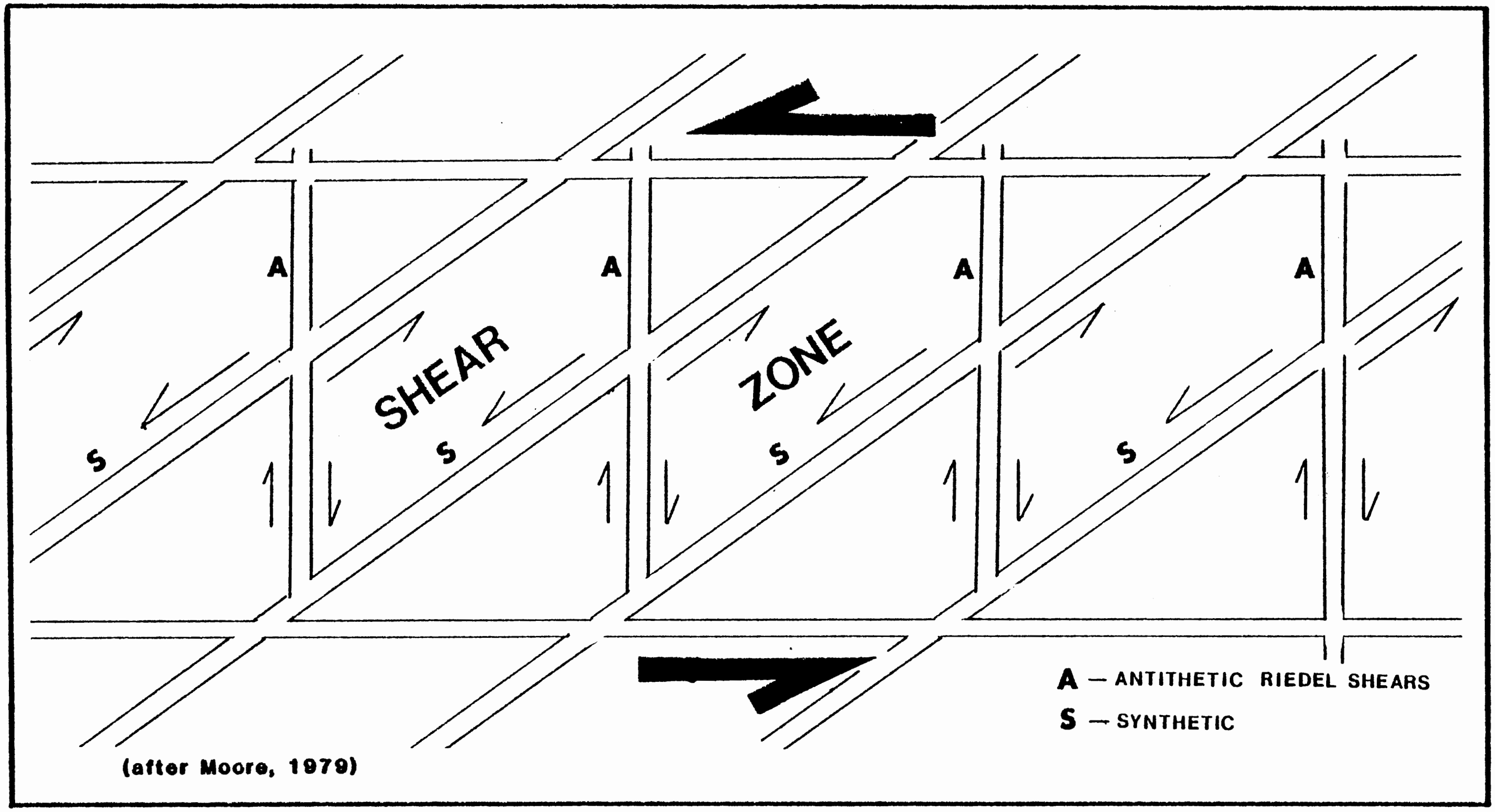


Figure 12. Geometry of Reidel Shears Related to the Producing Shear Direction

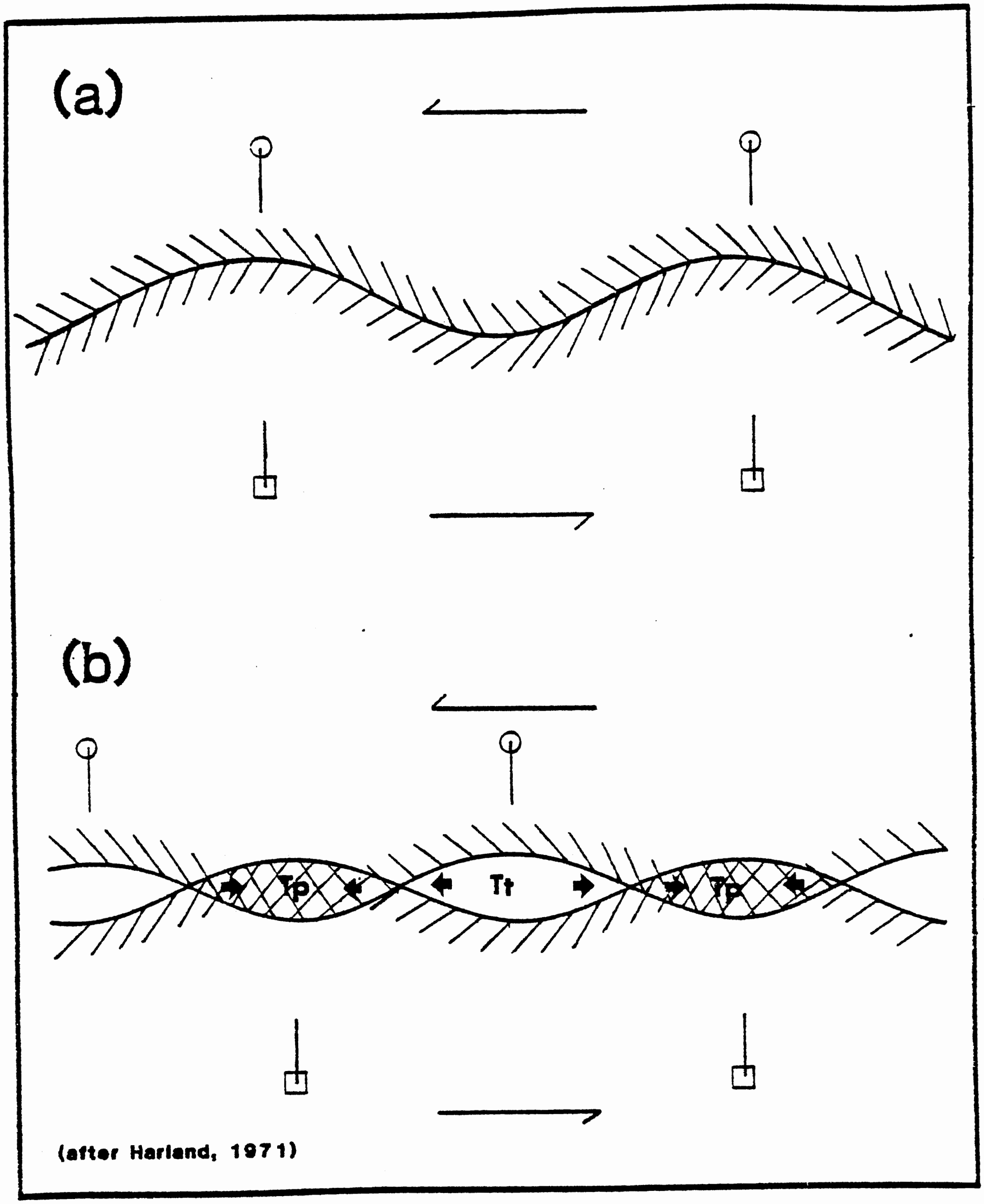


Figure 13. (a) Incipient Fracture Along a Sinuous Line; (b) Transtention (Tt), and Transpression (Tp)

may be deposited directly in localized basins contained within the transtensive regime (Harland, 1971).

Transpression is the sum of the effects of compression and strike-slip movement. Transpression does not result in the development of basins; instead, sediments are transported out of the strike-slip regime. If the maximum principal stress is horizontal, shortening occurs by thrusting parallel to the maximum compression direction. However, if there is a pre-existing non-vertical fault plane, the maximum compressive force will not only initiate a sense of dip-slip movement, but there will be a component of strike-slip movement as well (Spencer, 1977). In cross-section, the fault plane may appear as a high angle reverse fault. A fault of this nature is known as an oblique-slip fault (Harland, 1971). An oblique-slip fault can occur where the maximum compressive force is oriented at 30 degrees or less to the fault plane (Figure 14). At a greater angle than 30 degrees, the sense of movement becomes more vertical than horizontal, due to the dip of the fault plane. Oblique-slip faults may also be controlled by the planar anisotropy of the lithology, due to the axes of principal stress being oblique to bedding.

In the primary stages of transpression, compressive features occur over a wider region than in the later stages (Figure 15). Within the transpressive zones, folds and thrusts (or high angle reverse faults) reflect shortening perpendicular to the maximum principal stress. The oblique orientation of the maximum shear stress to the boundaries of the deforming zone will create folds in an en echelon arrangement. Continuing compression results in a reduction in the angle between the fold axes and the shear plane (Fig. 16). Folds that have been rotated towards the shear plane become asymmetrical. Incompetent layers on the steeply dipping

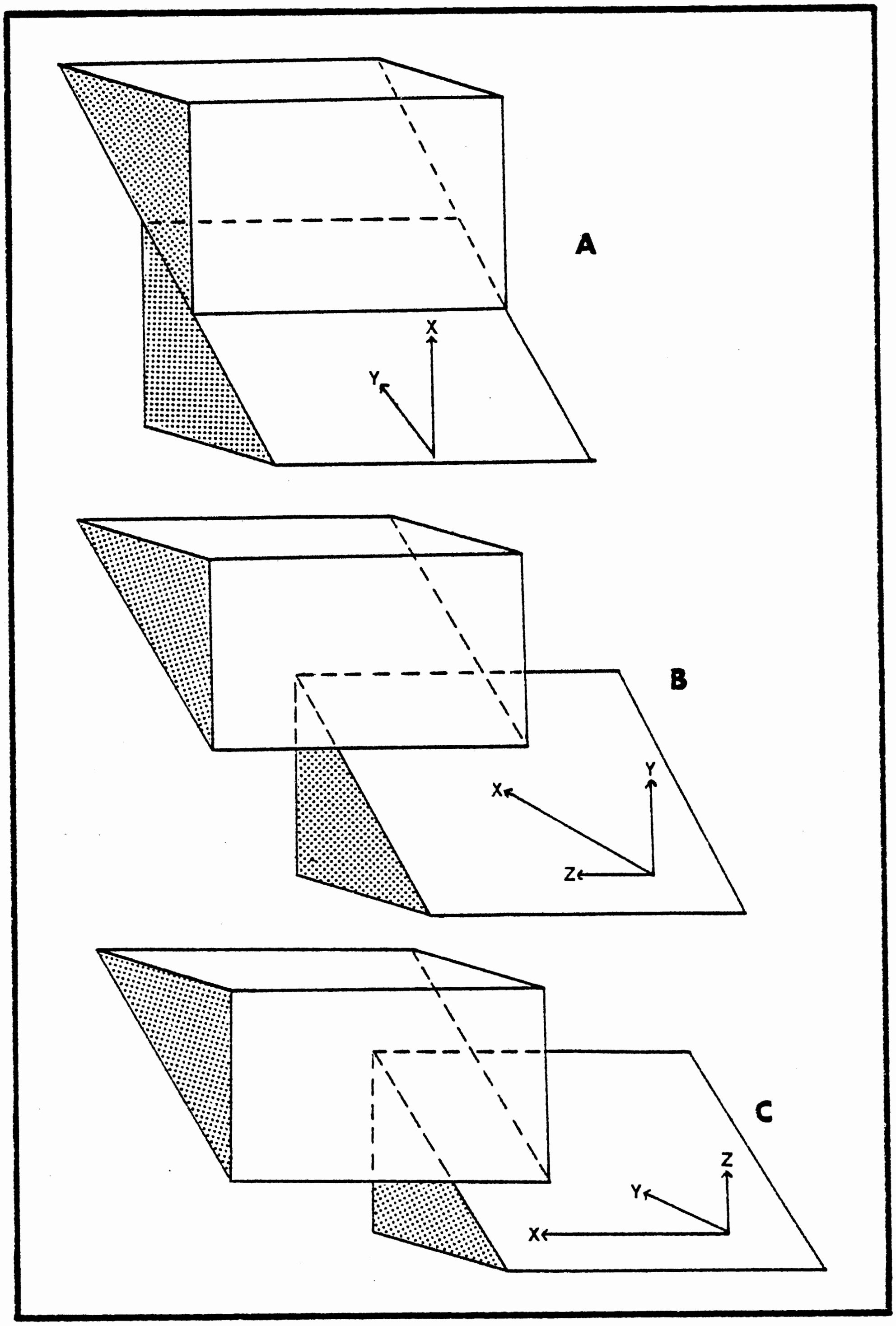


Figure 14. Models of Faulting Related to the Orientation of the Maximum Compressive Force. A, High Angle Reverse; B, High Angle Reverse > Left-Lateral Component; C, Left-Lateral > High Angle Reverse Component. (X = maximum movement vector; Y = intermediate; Z = minimum.)

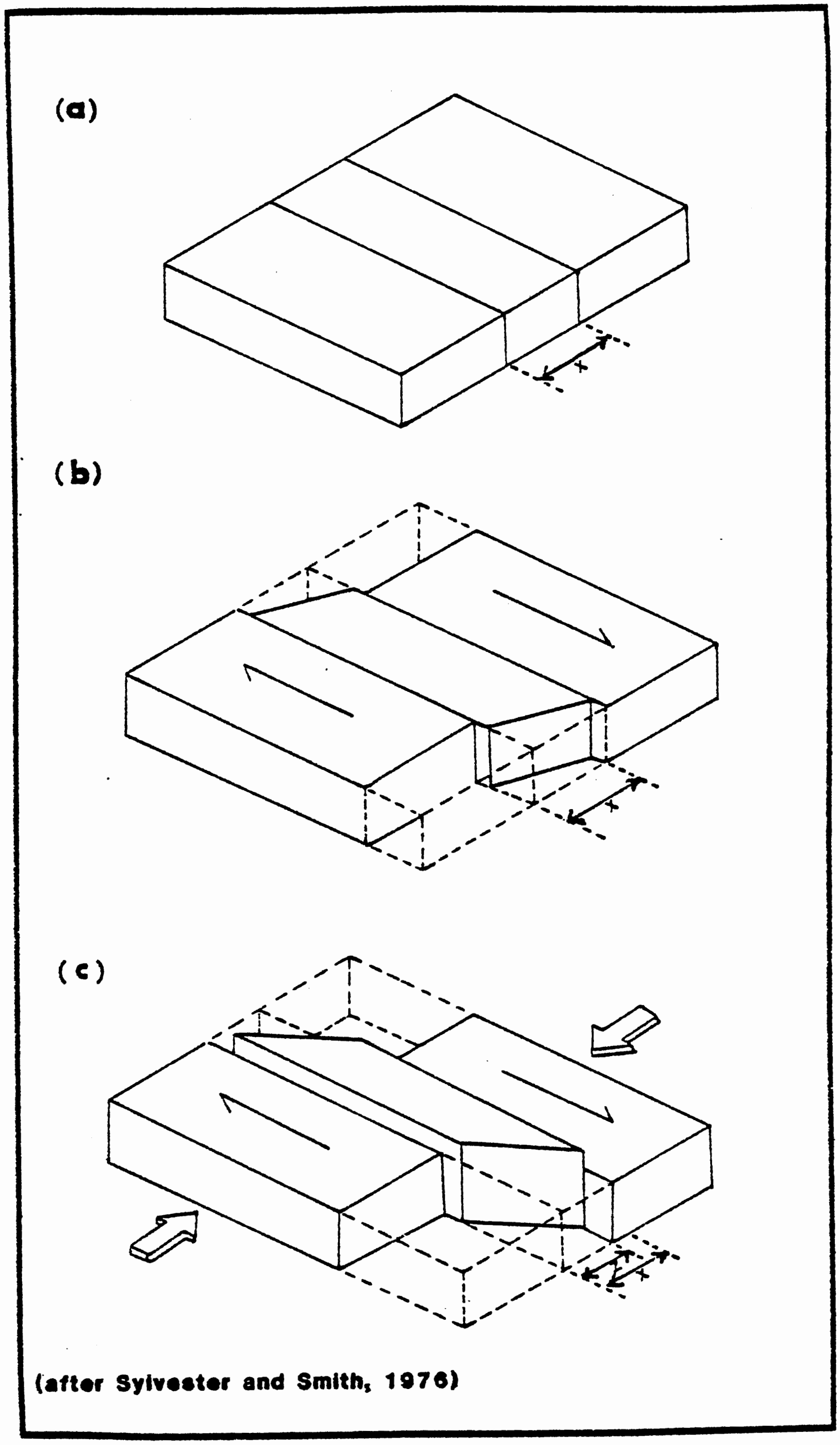


Figure 15. Model of Transpressional Basement Deformation. A, Undeformed; B, Transcurrent Movement; C, Transpressional Deformation

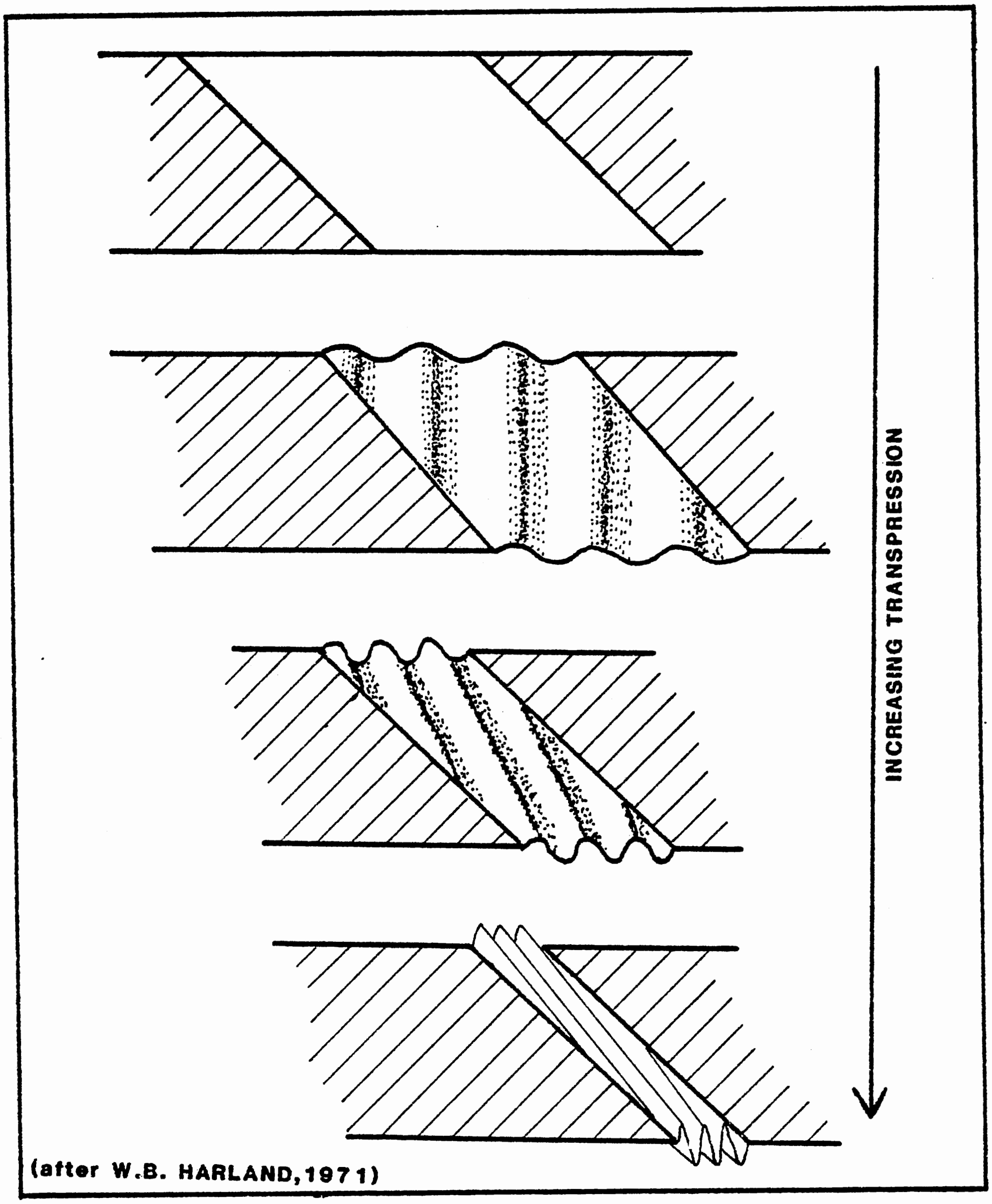


Figure 16. Oblique Compression Resulting in the Rotation of Early en echelon Folds Into Near Parallelism With the Boundaries of the Zone of Shortening

limb then become the planes along which shearing occurs (Harland, 1971). A useful definition which relates oblique-slip movement to transpression and transtension is given by K. B. Sporli (1980) in Sedimentation in Oblique-Slip Mobile Zones:

> . . . Across an oblique-slip mobile zone the relative motion of the blocks which are in contact along the zone is oblique, that is, in plain view there are components of movement both parallel and perpendicular to the zone. The zone may be a plate boundary, in the form of an active continental margin, an island arc, a collision zone between various plate features (e.g., continent/continent, arc/ridge) or an oceanic or continental transform. One may also wish to include rift zones with oblique directions of spreading, at least during their initial stages of opening, especially in the case of narrow back-arc basins and of continental aulacogens. Oblique-slip mobile zones may lie within a non-rigid plate. The width of the mobile zone is usually measured in tens to hundreds of km.
>
> In oblique-slip mobile zones, transpression and/or transtension may occur if subduction is taking place, the third dimension in the form of a vertical component of movement will also be important, and the definition of oblique-slip then becomes identical with that for oblique-slip faults (Spencer, 1977); i.e., oblique slip subduction has both strike-slip and dip-slip components of movement. Vertical movement is also important at a smaller scale and as a second order component in the oblique-slip mobile zones without subduction (p. 3).

An example of deformation in a transpressive regime is found in the sedimentary rocks of the central block between the Painted Canyon Fault and the San Andreas Fault zone (Figure 17a). In this region, folding occurs by buckling and bedding plane slip, especially in the overturned limbs of major anticlines. The northern flank of the Mecca Anticline is folded into a series of smaller folds which are overturned towards the Painted Canyon Fault.

Oblique-slip or high angle reverse faults may assume the geometry of thrust faults as they propagate towards the surface. Geometries of this type are known as flower structures (Figure 17b). The recognition of flower structures related to compressive blocks is expressed as an

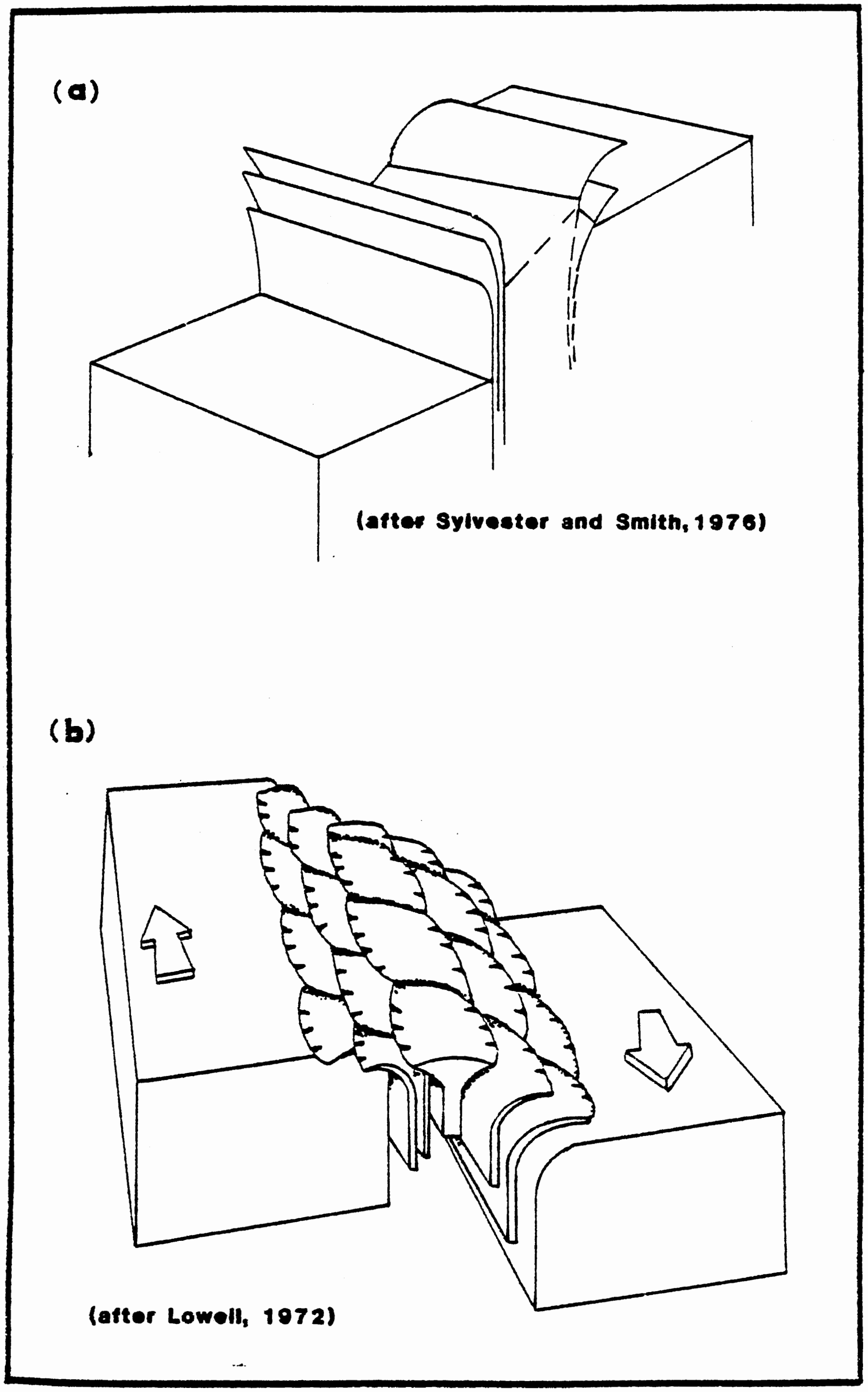


Figure 17. Models Illustrating Flower Structures. (a), San Andreas-Painted Canyon Faults, California; (b), Transpressive Related Flower Structures in the Spitsbergen Fracture Zone

upward spreading fault zone, and has been widely noted in strike-slip regimes (Harding and Lowell, 1979). Flower structures are enhanced when strike-slip motion is accompanied by compression. Flower structures have been recognized in the Salton Trough, California, where convex upward fault planes were seen in field mapping (Sylvester and Smith, 1976). These authors concluded that the Painted Canyon Fault was a high angle reverse fault, in which the vertical component of oblique-slip dominated in the development of the structural geometry (Figure 17a).

Flower structures have also been recognized on seismic profiles across the Ardmore Basin and Ouachita Mountains, Oklahoma (Figure 18).

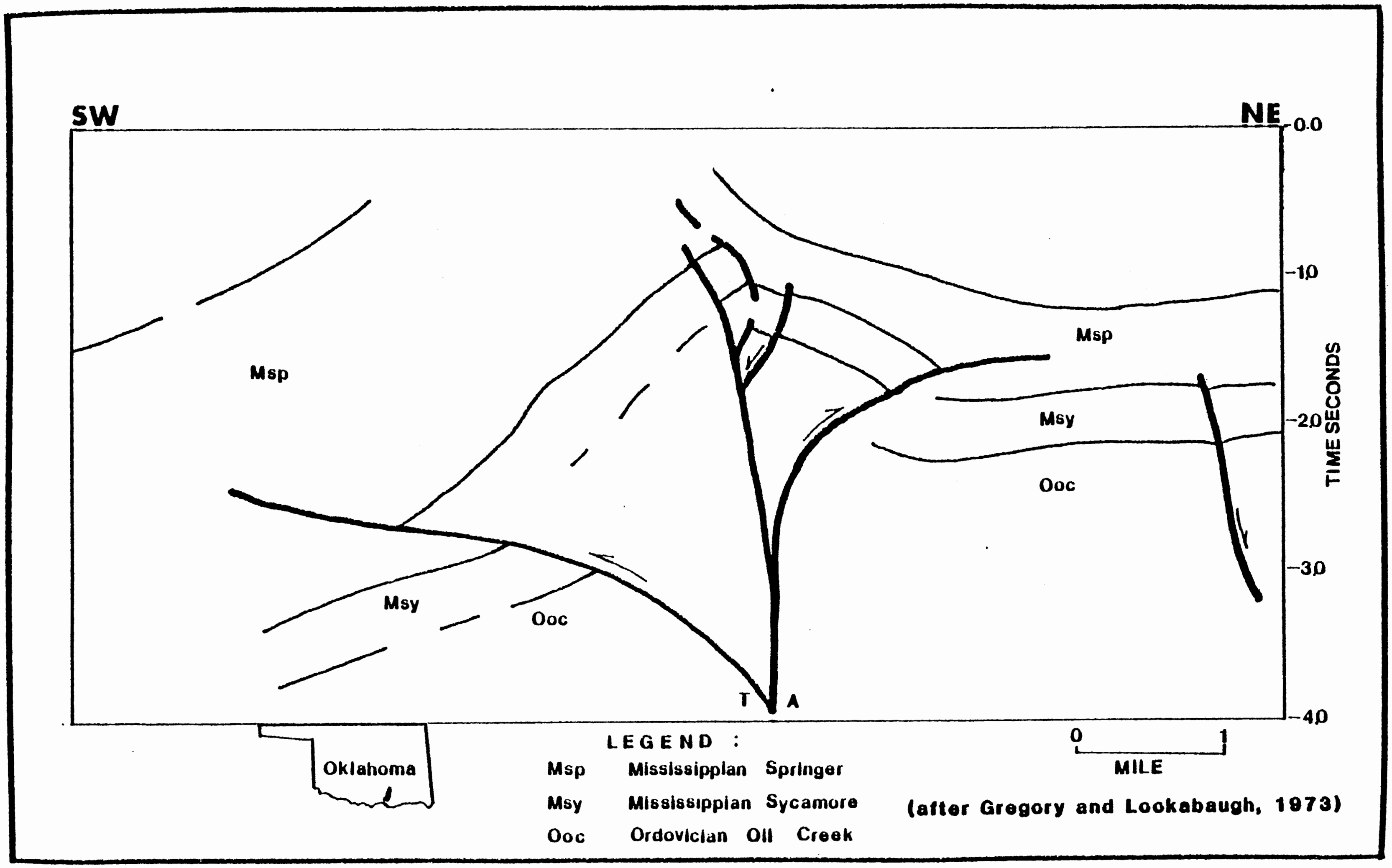


Figure 18. Flower Structure Illustrated by a Seismic Cross-Section in the Ardmore Basin

CHAPTER IV

STRUCTURAL GEOLOGY OF THE SOUTHERN SLICK HILLS

The field mapping of the structures in the Slick Hills was principally achieved by a closely-spaced pattern of transects. In addition, an understanding of the stratigraphic relationships of the Arbuckle Group proved to be very important to the understanding of the more complex structural provinces. Because there is a general homogeneity to the Arbuckle Group, specific marker horizons (such as the base of the Cool Creek Formation) were extremely valuable. Other contacts, such as the McKenzie Hill-Signal Mountain boundary, were more ambiguous, and in many complexly deformed areas a clear distinction between the two formations could not be made. In the field, the top of the Signal Mountain Formation was taken as the first dolomitic intraclast horizon which was devoid of the cherts that are characteristic of the McKenzie Hill Formation. This horizon weathers to a distinctive yellow color and appears to be laterally extensive.

The base of the Cool Creek Formation was taken as the first incoming of detrital quartz above the McKenzie Hill Formation. The lower Cool Creek Formation contains a high percentage of quartz sand, is thinly bedded, heterogeneous, and often weathers as an entrenchment.

The base of the Kindblade Formation was picked as the first massive limestone bed containing the silicified gastropod opercula, genus Certopia (Toomey and Nitecki, 1979).

In some instances, the structure and stratigraphy is reflected by the topography. Where the Signal Mountain Formation outcrops in the thesis area, it forms ground of significantly lower relief. Much of the field area in which the Signal Mountain outcrops is gently rolling grassland. Consequently, it can be easily mistaken for the Permian Post Oak Formation (which forms similar topography) on air photographs.

Many of the larger folds in the area develop saddles between topographic highs along the trend of their axes. In the case of the Comanche Anticline (CA), the outcrop of the steep limb of the fold forms a noticeably straight and sharp break in the topography at the Signal Mountain-McKenzie Hill boundary.

Folding and Disturbed Zones

The structure of the Slick Hills contains many folds and fold styles, most of which appear to be concentric. A generalized structure map (Figure 19) displays the major folds.

A fold nomenclature has been devised to facilitate communication. Large scale folds (1st order) have been given names (e.g., the Oliver Syncline). The name has been abreviated (e.g., OS). Folds which are not considered major folds (2nd order) have been labeled as to whether they occur on the north or south limb of named folds (e.g., OSn or OSs). Such folds have been further identified as anticlines or synclines (e.g., OSsa or OSss). Where more than one second order fold is present adjacent to a first order fold, the second order structures have been numbered (e.g., OSsa1 or OSss2, etc.). Minor folds (3rd order) have been identified by a section number followed by a group number (sec. 5, group 1, 5-1). A letter has been used to distinguish

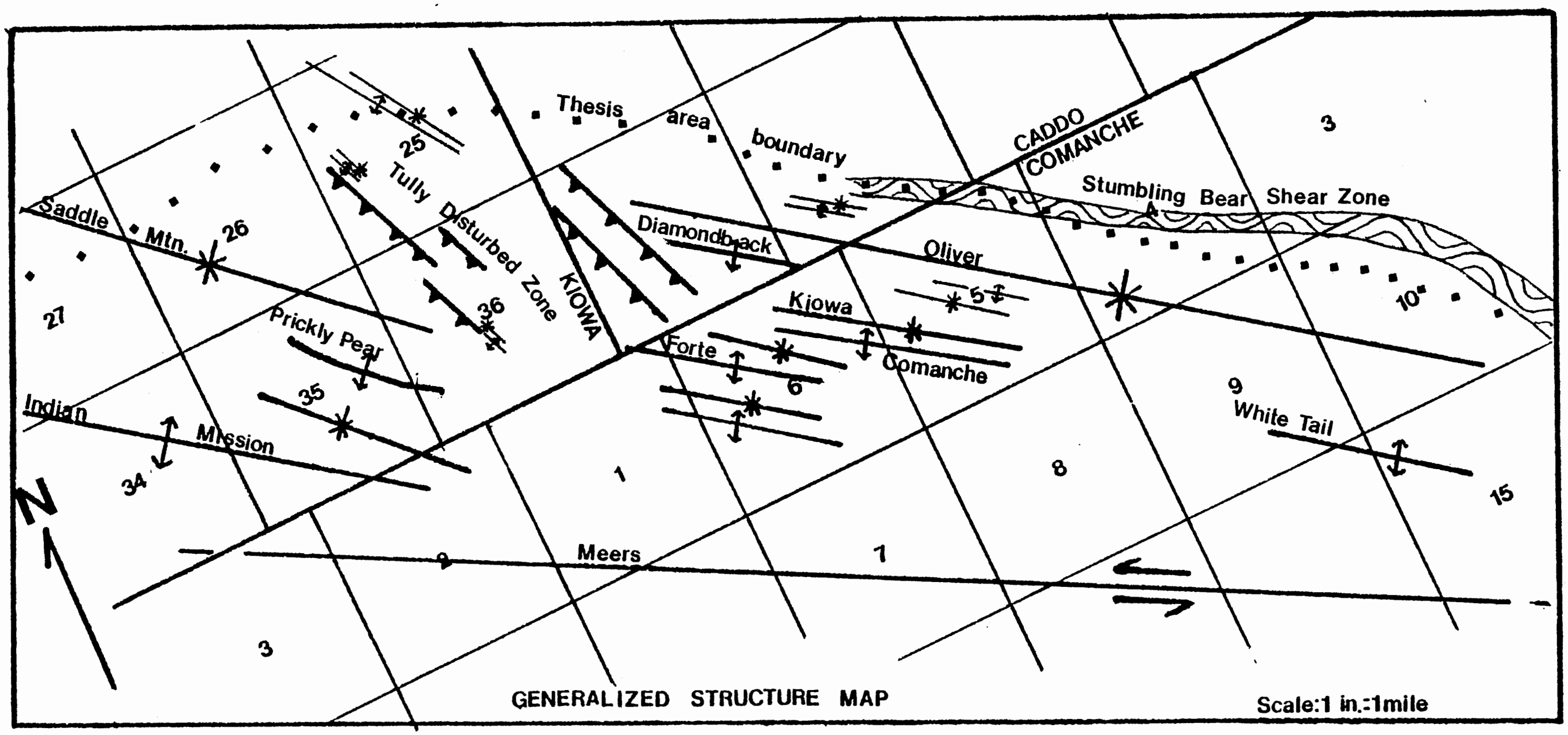


Figure 19. Generalized Structure Map of the Southern Slick Hills

TABLE I

FOLD NOMENCLATURE

NAME-ABBREVIATION	PLUNGE/TREND
Oliver Syncline (OS)	04/321
OSsa1	08/319
OSsa2	
OSss3	
OSna7	08/328
OSns8	10/330
Saddle Mountain Syncline (SS)	10/314
Prickly Pear Anticline (PA)	04/317
PAss1	
Indian Mission Anticline (IA)	06/316
Diamondback Anticline (DA)	05/320
Kiowa Syncline (KS)	10/310
Comanche Anticline (CA)	22/307
Css1	08/314
Forte Anticline (FA)	06/314
FAss1	10/140
FAsa2	16/136
White Tail Anticline (WA)	02/120
WAns1	05/310
WAss1	06/110
WAna2	04/312
Bull Run Anticline (BA)	13/332
Bull Run Syncline (BS)	10/328
31-1	
31-2	
6-1A	04/320
6-1S	04/140
6-1A1	04/138
25-1A	06/160
25-1S	06/160
25-2A (Bat Cave)	10/347
10-1A	10/328
10-1S	10/326

(EXAMPLE Sec. 5, Group 1, Anticline, No. 1) such folds as anticlines or synclines, followed by a number if more than one fold has been analyzed in a group (5-1A1). The fold nomenclature is represented in Table I, and is used on maps and equal area nets in the Appendix.

Several types of folds have been observed in the field, although symmetrical and asymmetrical folds dominate (Figure 20). In many instances, asymmetrical folds have locally overturned limbs, and in some cases folds are isoclinal.

<u>Saddle Mountain Syncline</u> (SS)

Symmetrical folds can best be illustrated by the Saddle Mountain Syncline (SS), the Prickly Pear Anticline (PA) and others (see Appendix). The Saddle Mountain Syncline is a broad open fold, dominating the northwest end of the Slick Hills, which closes to the southeast near the Tully Distrubed Zone. There is a pair of minor folds along the axial trace of the Syncline (Sec. 35 NE) which are developed due to an apparent space problem in the hinge zone (where beds are locally steep to overturned) (Section B-B' - Plate 4). The folds to the southwest of the Syncline (SS) are of a smaller magnitude, the symmetric Indian Mission Anticline (IA) being the largest. This Anticline passes under the Post Oak Conglomerate in the southwest corner of Section 27 (TSN-R14W)(Section B-B').

<u>Oliver Syncline</u>

A large portion of the Slick Hills (southern) structure is dominated by a major asymmetrical fold named the Oliver Syncline (OS). This Syncline extends from Section 10 (T4N-R13W), northwestward into

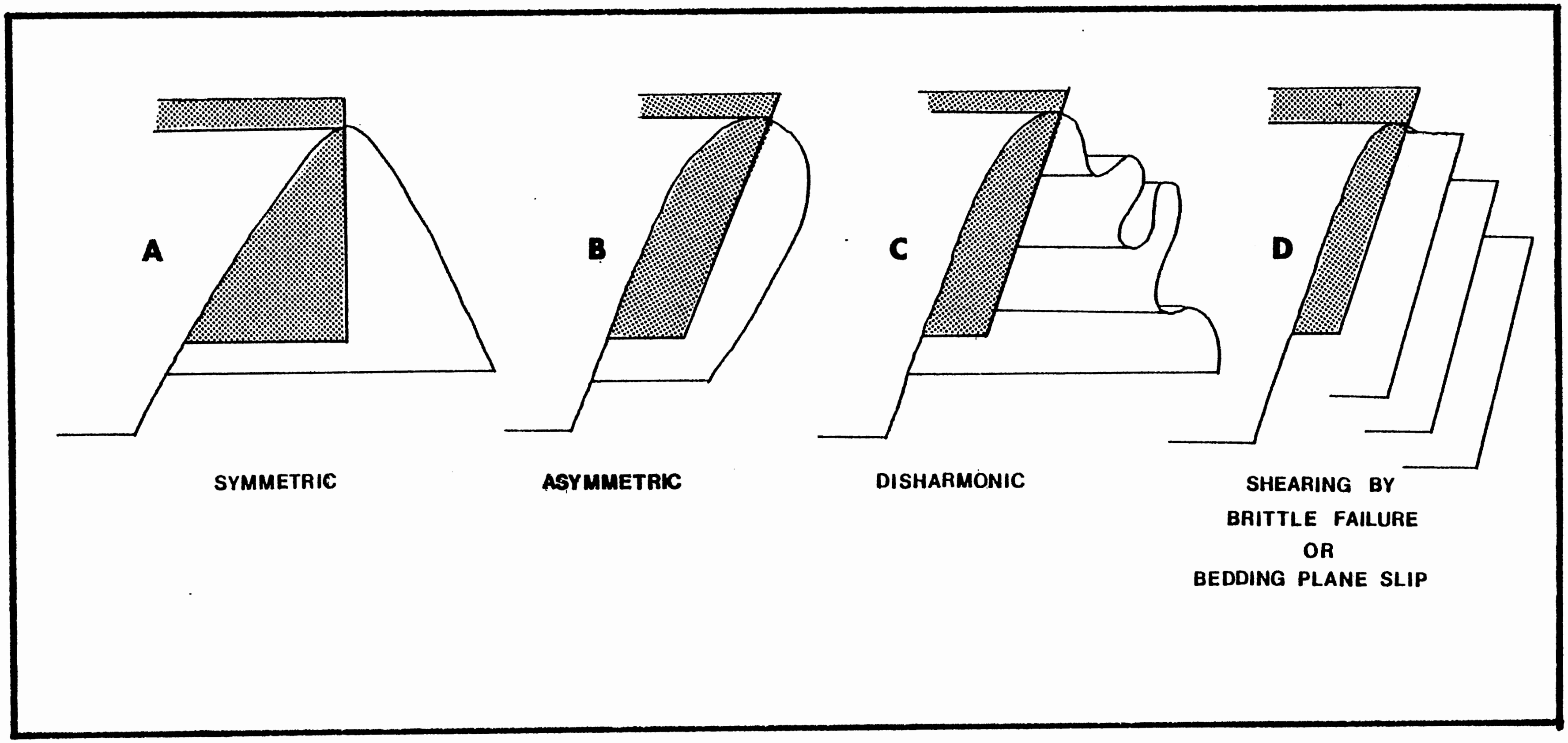


Figure 20. Types of Folds Observed in the Slick Hills

Section 31 (T5N-R13W). The Cool Creek Formation is preserved within the syncline in the southeast half of the syncline, while there is only a scant outcropping of the Cool Creek Formation to the northwest on top of the highest hill in T5N-R13W Sec. 31 E½, E½. There are two axes within the Oliver Syncline. One earlier axis trends through the south half of the large hill in Section 10 (Figure 21). This axis is the hinge of what was originally a symmetrical fold. Continuing transpression steepened the southwest limb, creating an asymmetrical (and locally overturned) fold. The second later axis is developed on the gentle limb (which was flattened during transpression)(Section A-A', Figure 22). In essence, the geometric axis of the syncline is not the same as the topographic axis.

The steep limb of the Oliver Syncline exhibits varying degrees of shear. Due to the width of the steep limb of the syncline, a great amount of stratigraphic section is exposed over a short distance (Figure 23). Stream dissection of the terrain has exposed more than one structural level of the Oliver Syncline. Some of the lower structural levels are considerably more complicated by minor folding, which may be due to a space problem at depth (Figure 24). This can best be seen in a hill in the north half of Section 9 (Fleabitten Hill), in which there are several minor folds exposed in the lower part of the hill (Figure 25). There is an apparent change in the levels of folding, from the asymmetrical form of the Oliver Syncline at higher levels, to disharmony represented by minor asymmetrical folds at lower levels (Figure 26). This is a common observation throughout the extent of the Oliver Syncline. In places, the Cool Creek boundary along the southwest limb of the Oliver Syncline is folded by minor folds, and in one instance these

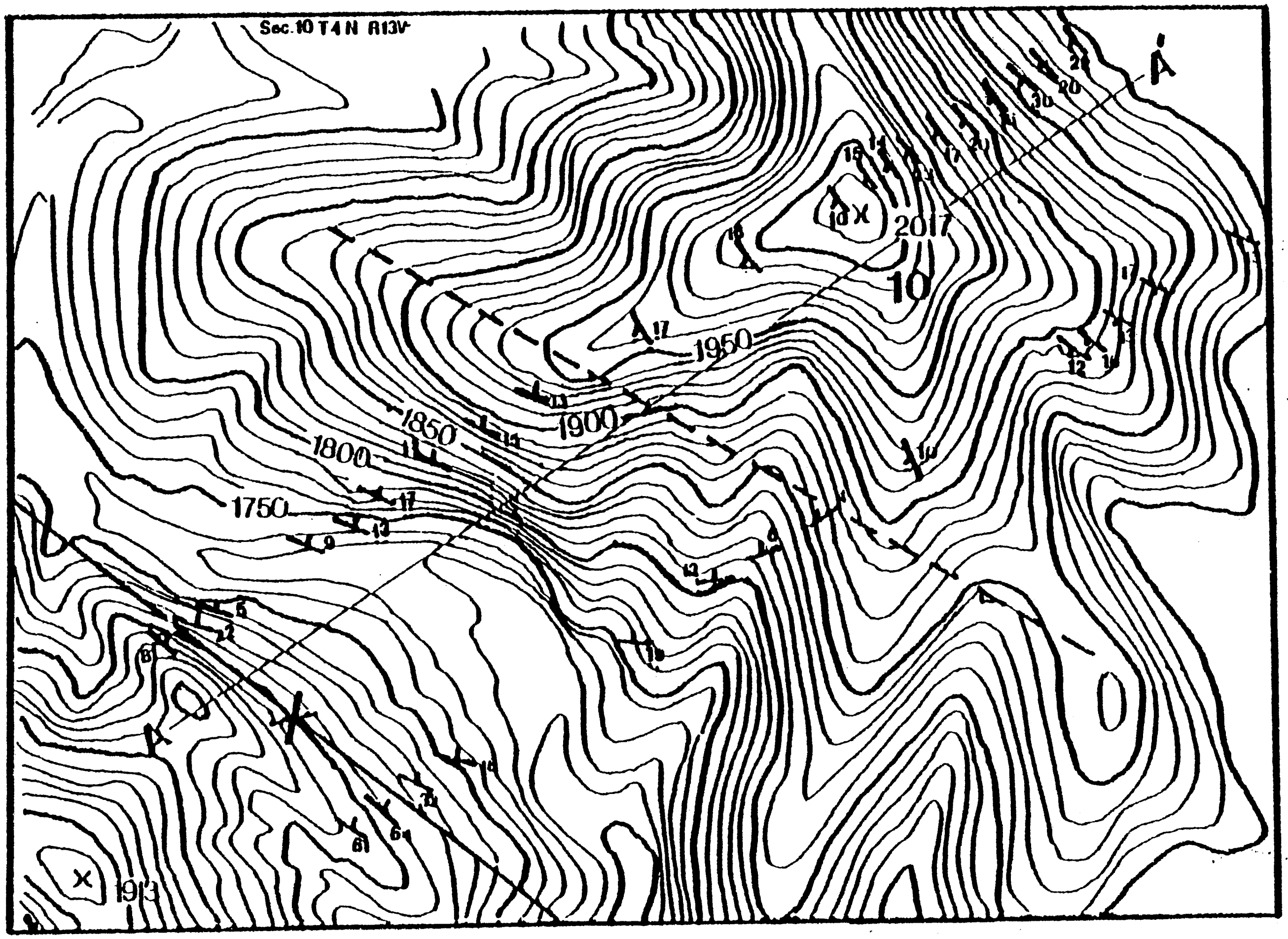


Figure 21. Sketch Map Showing Structural and Topographic Relationships in Part of the Oliver Syncline. (Dashed line is the earlier syncline axis; the darker axis is the latter axis formed by the steepening of the SW limb.)

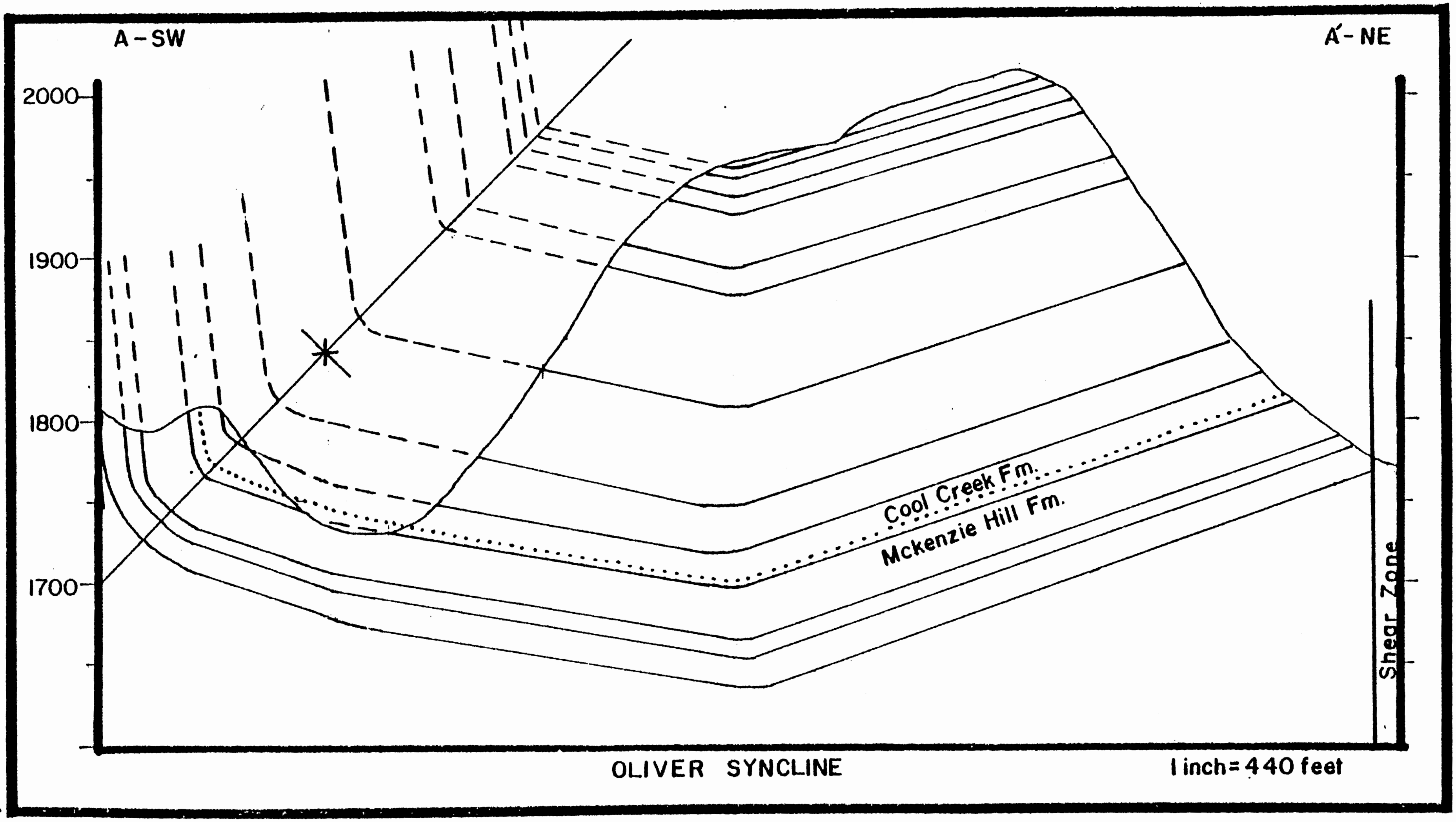


Figure 22. Cross Section A-A' Across the Oliver Syncline. The Stumbling Bear Shear Zone is to the NE of the Section, and the White Tail Anticline is to the SW

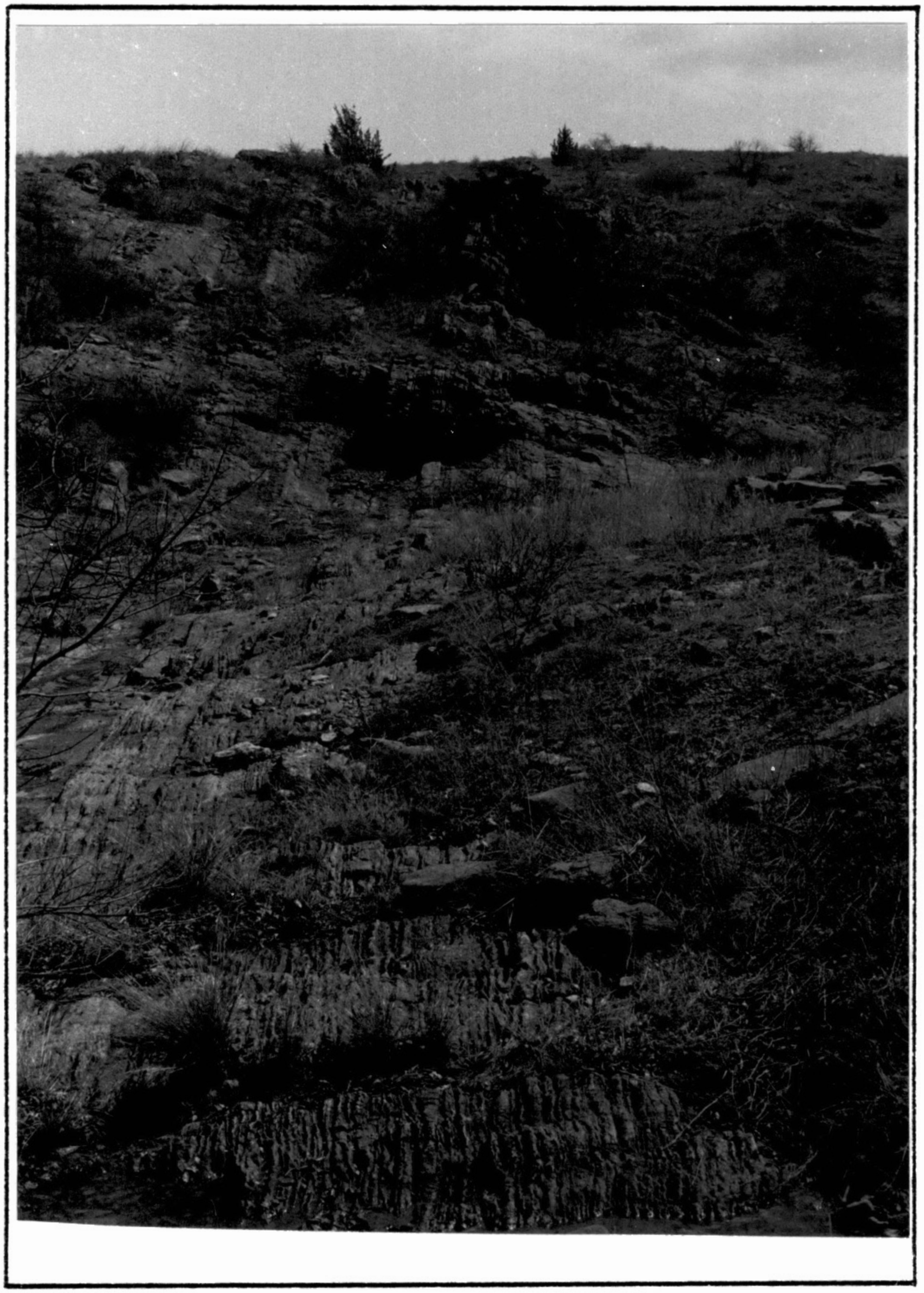


Figure 23. Vertical Beds in the Steep SW Limb of the Oliver Syncline (McKenzie Hill Fm) (Sec. 15 N½-T4N-R13W)

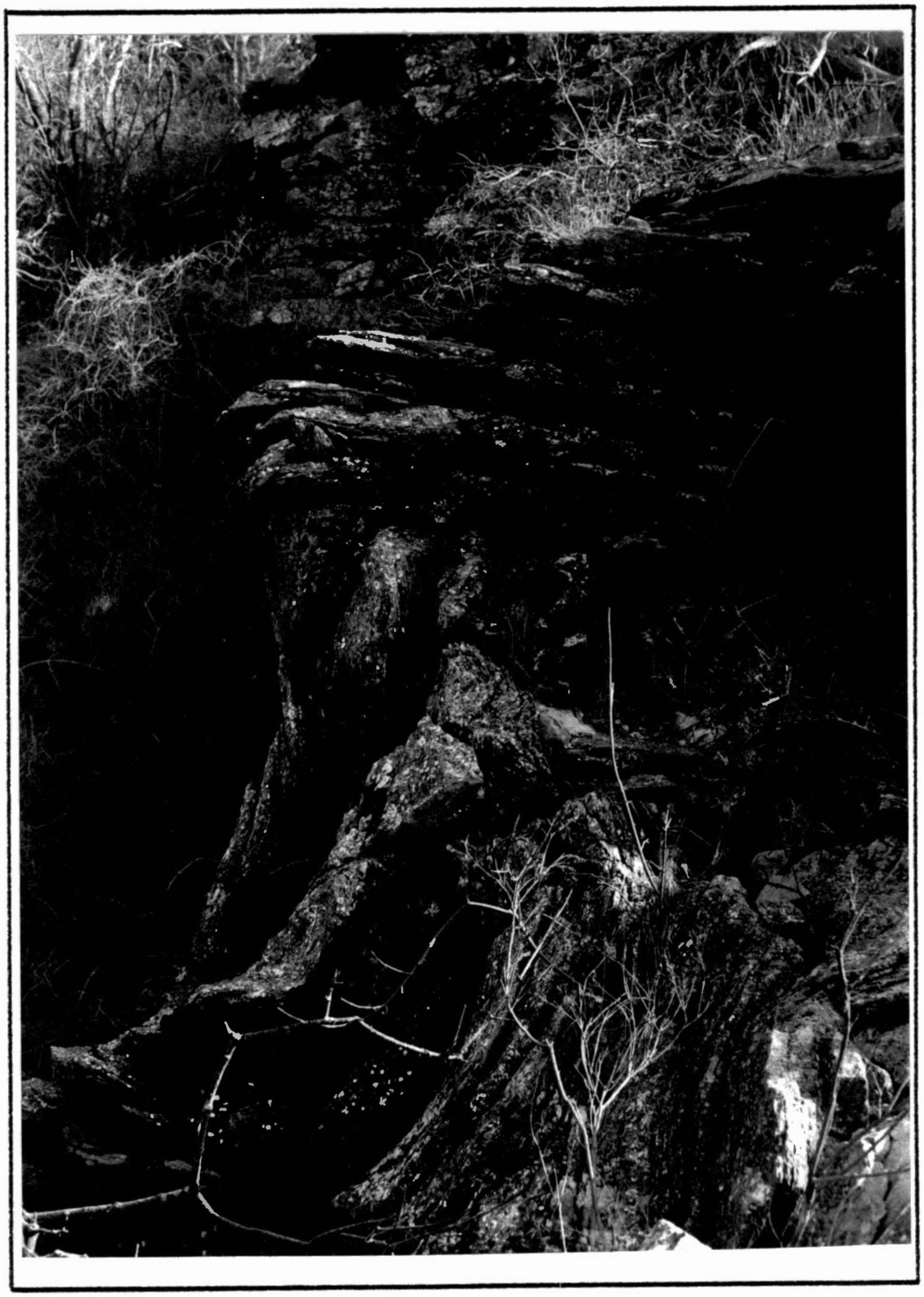


Figure 24. Minor Folding (Disharmonic) Near Axis of the Oliver Syncline

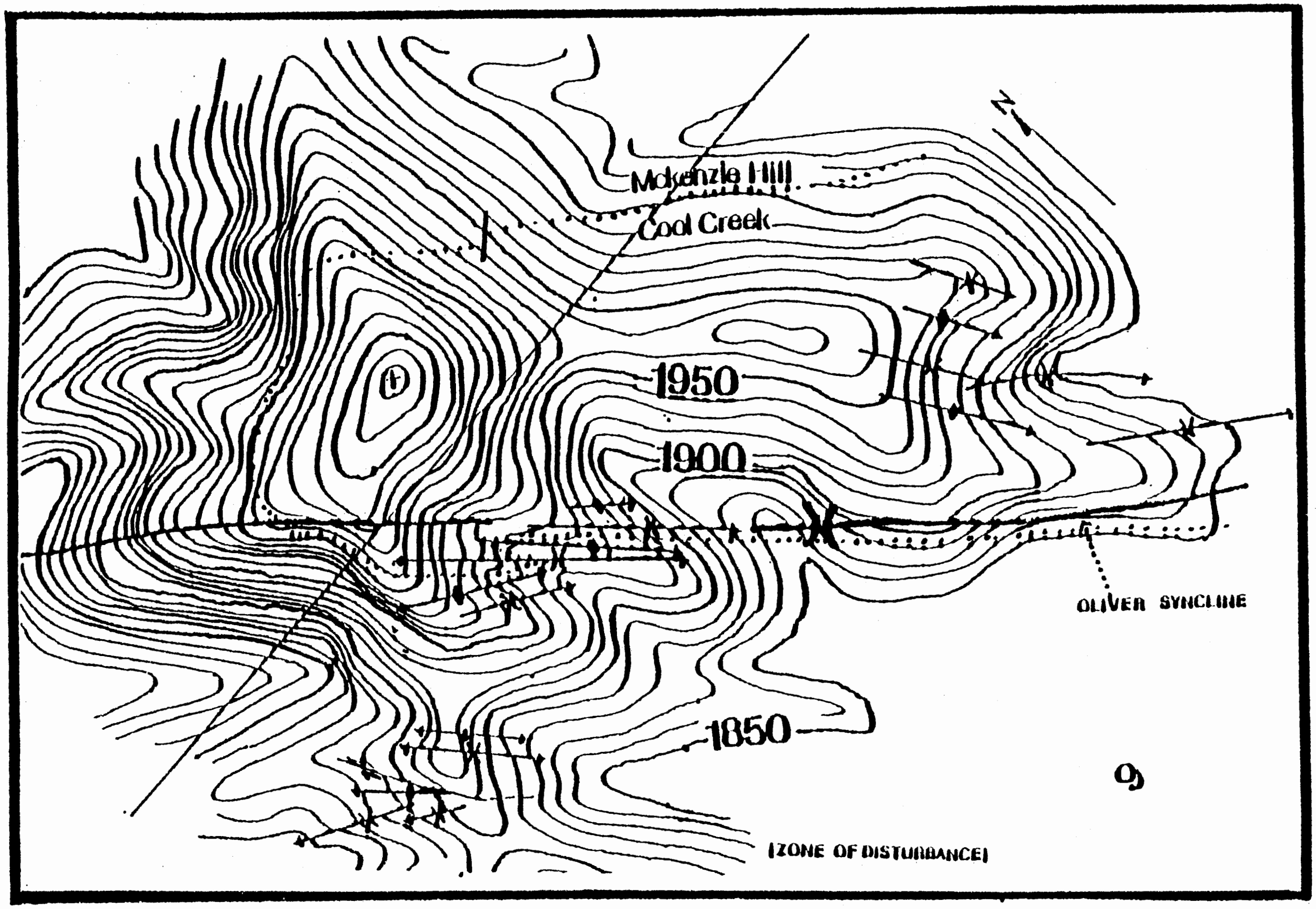


Figure 25. Sketch Map of Minor Folding at Fleabitten Hill Sections 9 and 4. (These folds have a small amplitude and an oblique trend.)

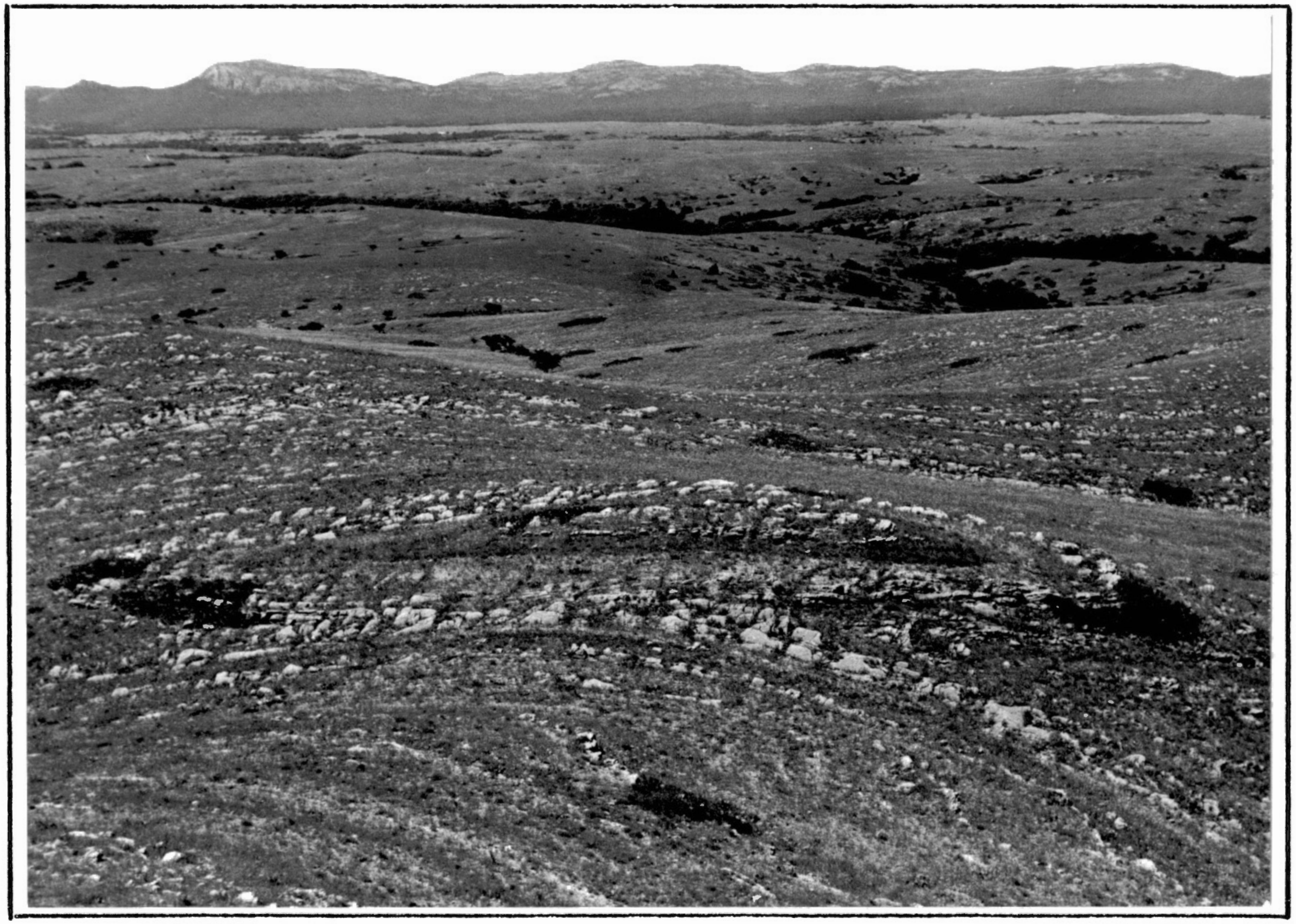


Figure 26. Minor Fold Pair Along the Axis of the Oliver Syncline (illustrating varying levels of folding/shipfold)

folds are offset by a small left-lateral fault which parallels the fold limbs. This fault is due to shearing along the steepened limb (Figure 27).

The northeast limb of the Oliver Syncline is gentle and is disrupted to the north by the Stumbling Bear Shear Zone. The latter separates the Oliver Syncline from the Kimbell Anticline in David McConnell's thesis area to the north (MS, 1983). The axis of the Oliver Syncline terminates in the southeast against the Stumbling Bear Shear Zone, where the latter feature curves towards the south.

The Oliver Syncline extends northwestward into Section 31, where it flattens and ends in a structural terrace. The latter is cut across by a zone of high angle reverse and thrust faults (Tully Disturbed Zone), which are trending at an oblique orientation to the Oliver Syncline.

<u>The Diamondback Anticline</u> (DA)

Southwest of the Oliver Syncline in Sections 31 and 32 is the Diamondback Anticline, which is slightly asymmetric and plunges (c.5 degrees) to the northwest. The northeasterm limb of this fold is separated from the steep limb of the Oliver Syncline by a zone of disturbance and shearing. The fold plunges northwestward and terminates against the Tully Disturbed Zone. The south limb of the fold develops into another disturbed zone. This disturbed zone extends southward to the Kiowa Syncline (KS). All of the beds within the disturbed southern limb are of the McKenzie Hill Formation. These rocks exhibit a wide outcrop pattern due to the amount of minor folding which maintains more or less the same stratigraphic position at the present level of exposure. A schematic fold model (Figure 28) illustrates some of the

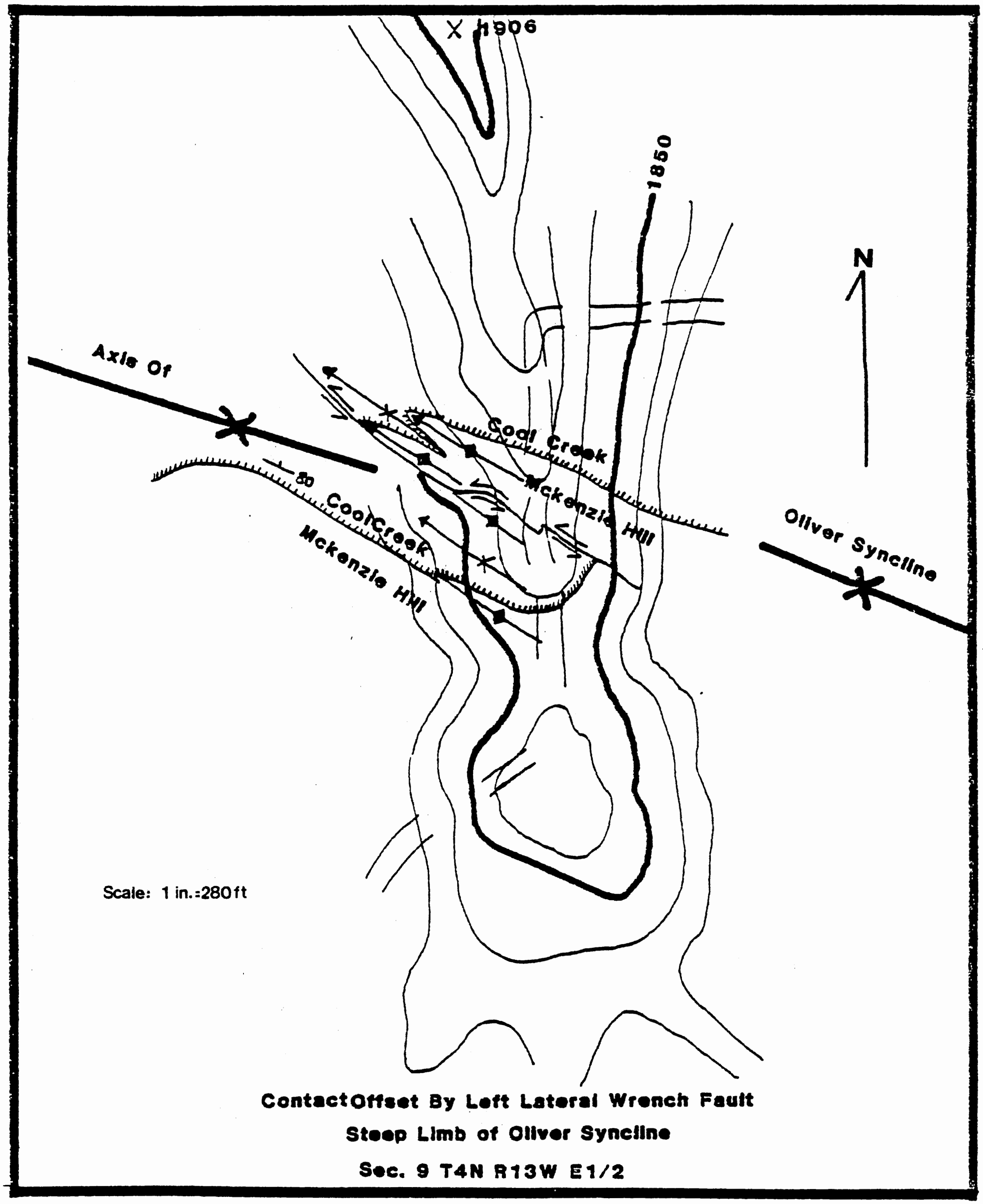


Figure 27. Sketch Map Illustrating Shearing (Left-Lateral) Along the Axis of the Oliver Syncline. McKenzie Hill-Cool Creek Contact is Offset and Folded

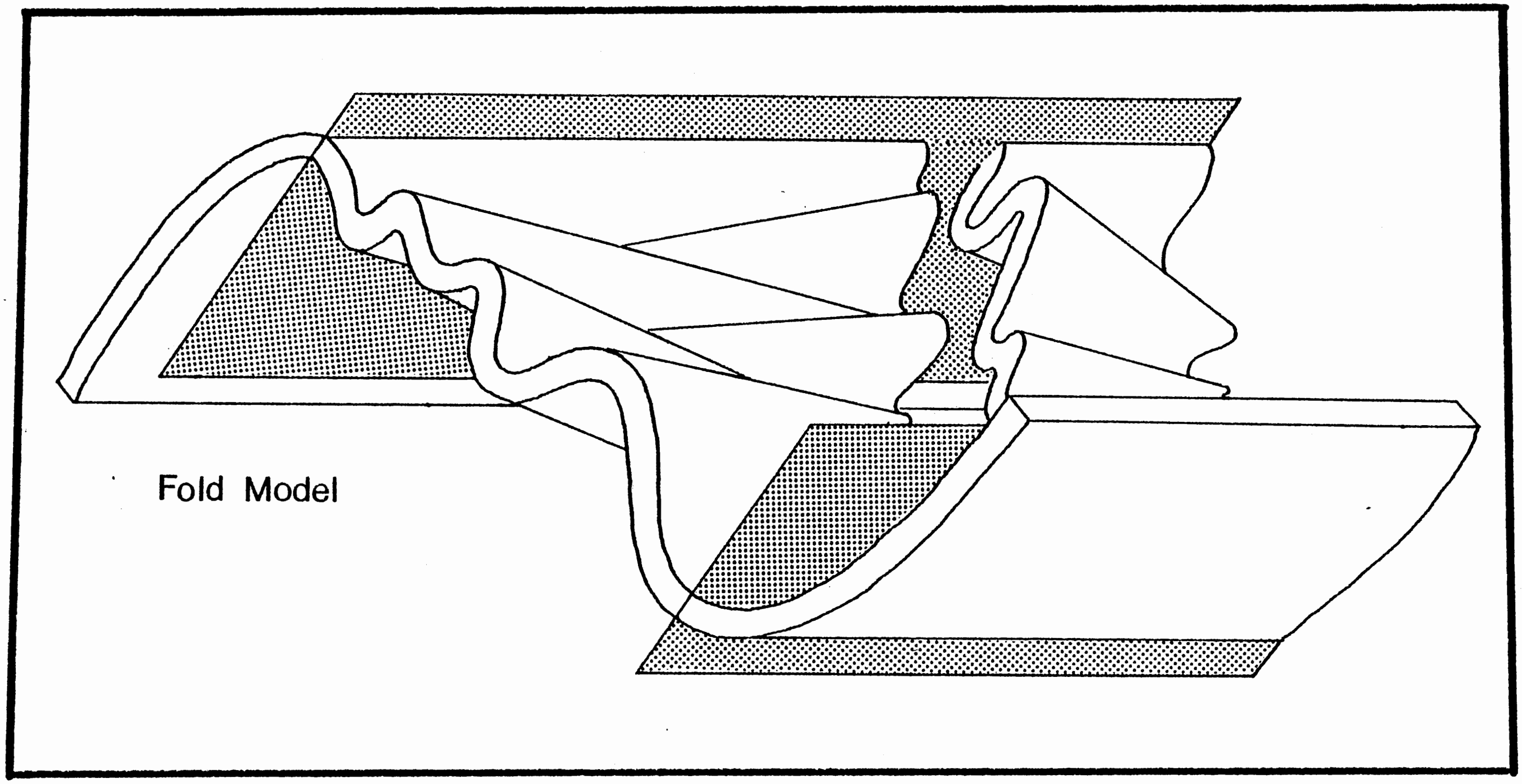


Figure 28. Schematic Fold Model Illustrating Minor Folding in the Disturbed Zone Between the Diamondback Anticline and the Kiowa Syncline

fold relationships which are present in the disturbed limb between the Diamondback Anticline and the Kiowa Syncline. This model is simplistic because it is impossible to reconcile compressional and shearing structures in a two-dimensional section (C-C', plate 4). Furthermore, no attempt has been made to map all of the minor folds and disturbances. The areas described as "disturbed areas" are some of the most complex structural terrains in the thesis area (Figure 29). These zones would require mapping on a very detailed scale in order to be fully understood. However, detailed mapping of specific areas within the disturbed zones illustrates some of the interesting and more obvious relationships.

Kiowa (KS) and Comanche (CA) Folds

The fold pair designated as the Kiowa Syncline (KS) and the Comanche Anticline (CA) are asymmetrical folds, with axial planes verging to the southwest (Section C-C'). The sense of overturning is to the northeast. The northeast limb of the Comanche Anticline is very steep to overturned and forms a sharp topographic discontinuity (Figure 30). The northeast limb of the Kiowa Syncline is more gentle, until such a point that it is disrupted by the minor folding of the aforementioned disturbed zone between the Kiowa Syncline and the Diamondback Anticline. The hinge region of this fold is fairly flat (Figure 31).

The disturbed zone north of the Kiowa Syncline is dominated by minor folding (Figure 32). Detailed mapping of this area shows that the axial traces of these minor folds are offset by minor faults (trending 280°). In several instances the amount of displacement can be judged from the offset of individual fold axes across the sheared zones (6-1A, 6-1S,

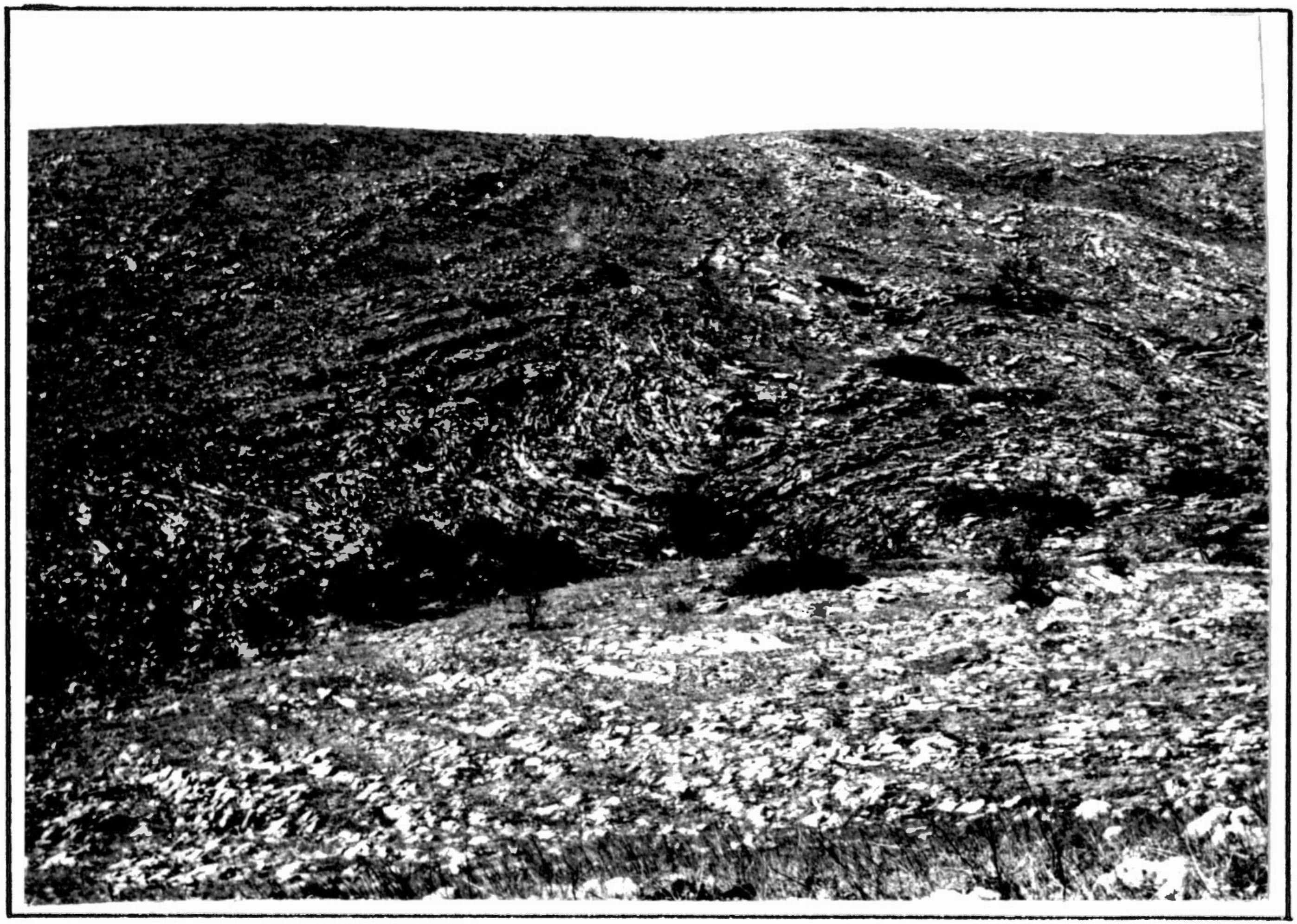


Figure 29. Disharmonic Character of Beds in the Disturbed Zone North of the Kiowa Syncline

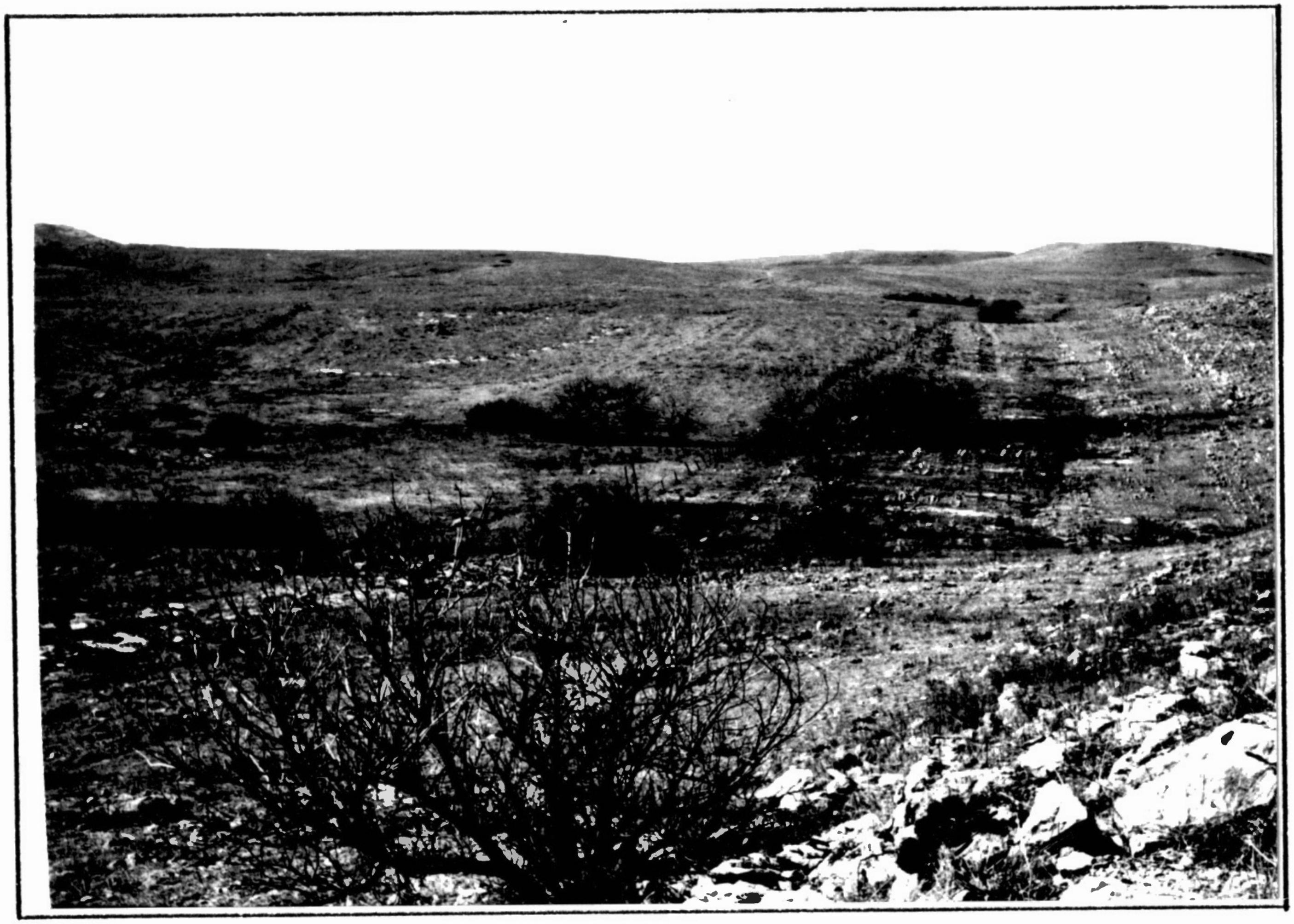


Figure 30. Comanche Anticline. The Steep Limb is to the North, and the Gentle Limb is to the South

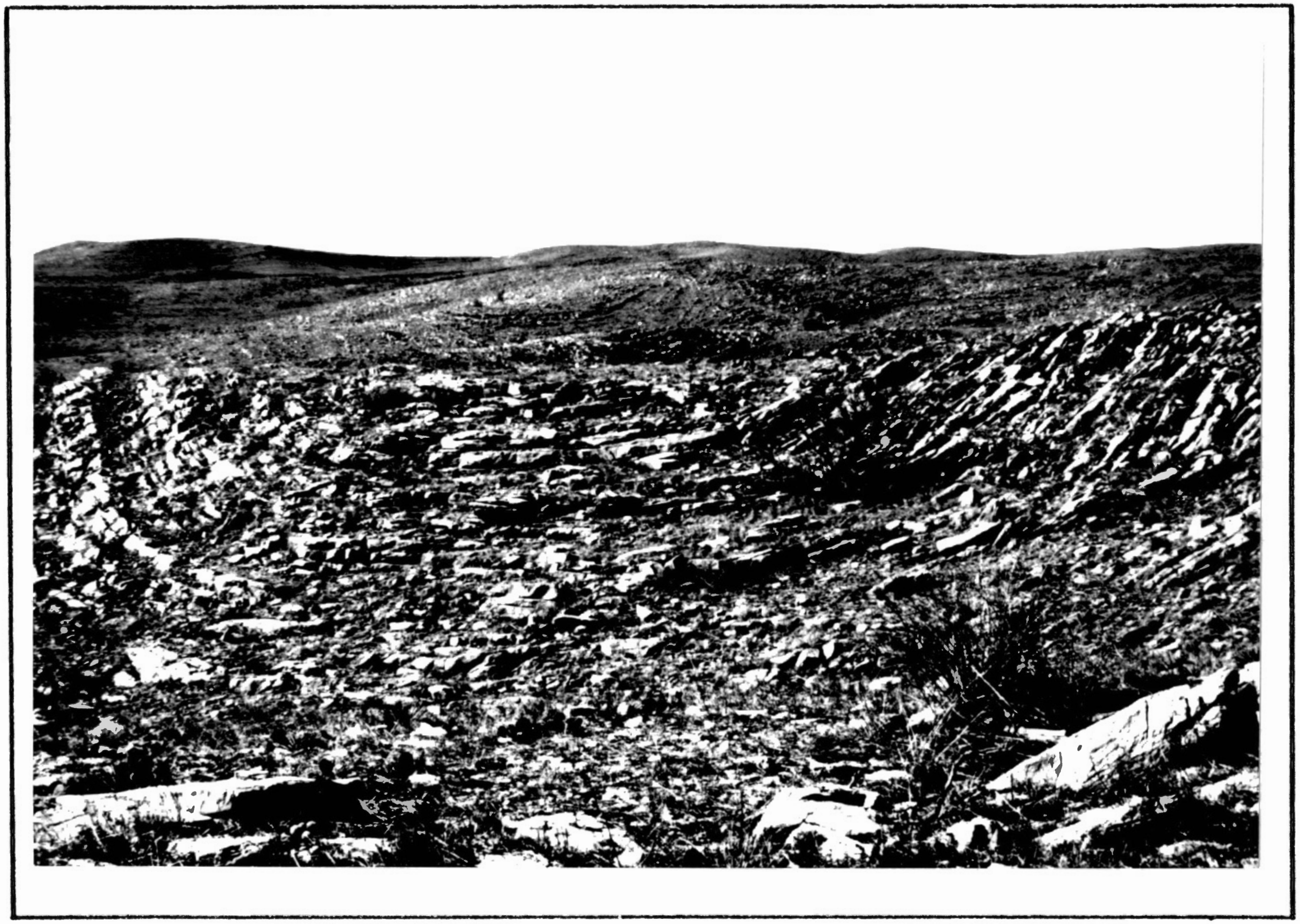


Figure 31. Axis of the Kiowa Syncline Just North of the Comanche Anticline

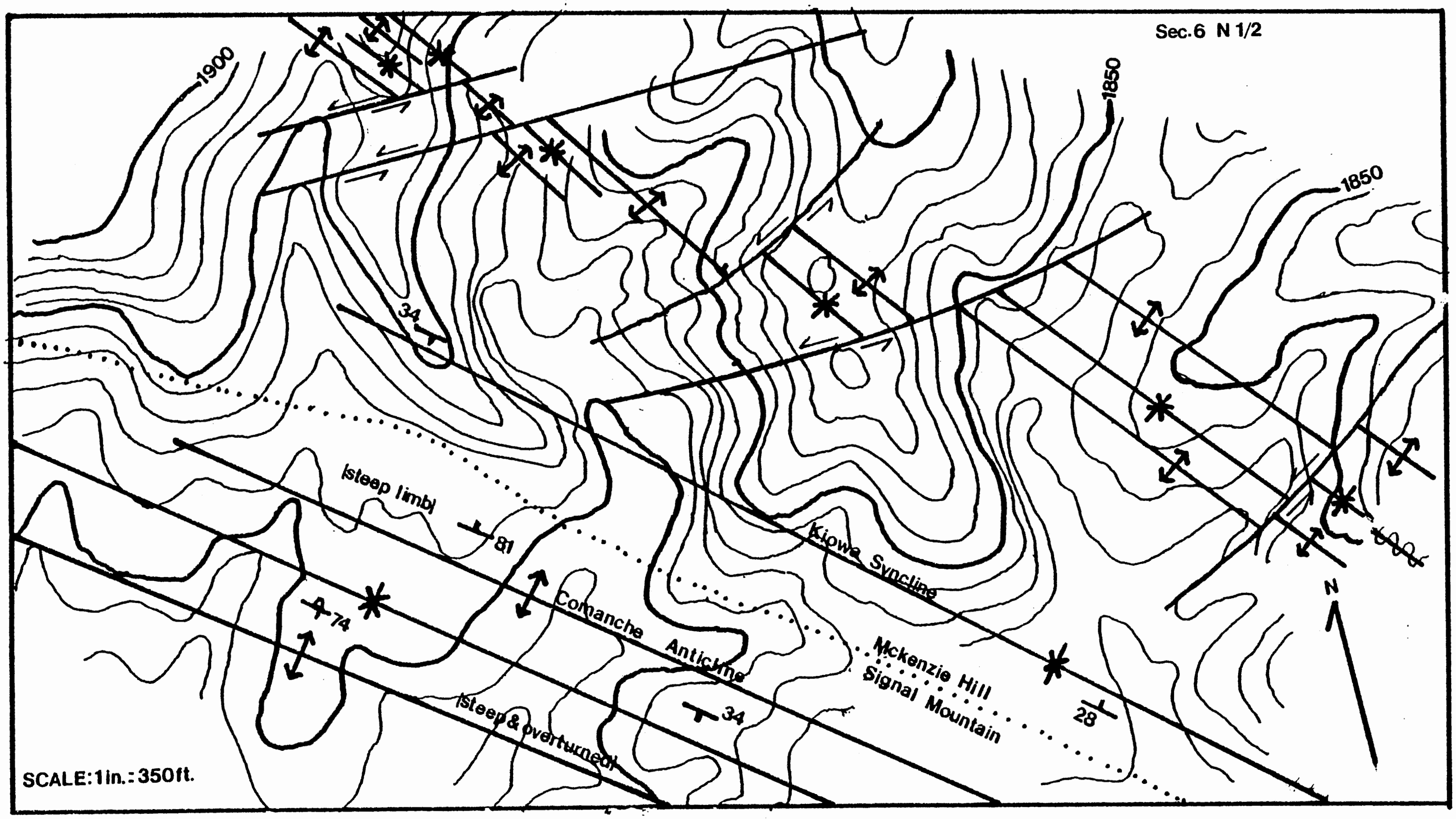


Figure 32. Sketch Map of Complicated Structure North of the Kiowa Syncline. En Echelon Folds are Offset (Left-Lateral) by Small Wrench Faults

6-1A1). The en echelon folds which occur between these faults appear to be symmetrical (Section C-C'). The shears or minor faults which disrupt the axial trace of the folds may not always be well defined fault planes, but rather are (c. 30 ft wide) zones characteritzed by shear fabric. Some of these shears are evident on enlarged air photographs. In some instances, folds between these faults appear to have been effected by shearing, as the faults form small shear couples which in turn refold the original folds.

To the south of the Comanche Anticline is an en echelon synform (CAss1). This fold is difficult to trace in the field, since both limbs are dipping in the same direction. However, there are limited exposures of the hinge, which is demarcated by a sharp change in the amount of dip. The fold plunges steeply near its northwest end (>50 degrees).

The Forte Anticline (FA)

To the south of (CAss1) is the Forte Anticline (FA), which is also an asymmetric fold. The north limb of this fold is overturned near (CAss1), and remains steep towards the northwest where it is complicated by minor folding and faulting. The south limb is fairly gentle and is also involved in minor folding. This structure folds the Signal Mountain-McKenzie Hill Formation boundary around its termination in the northwest. This fold is lost in a disturbed zone to the northwest which is cut by high angle reverse faults and folded into isoclinal folds (Tully Disturbed Zone).

In mapping the McKenzie Hill-Signal Mountain boundary, several discrepancies arose which led to the recognition of an area of isoclinal folding (Section B-B'). Originally transects taken across this region indicated a broad zone in which beds were all homoclinal, with some minor folding and dip reversals. However, more detailed mapping showed that narrow inliers of the Signal Mountain Formation are present. This suggests that folds with overturned limbs and a general isoclinal geometry are present. The only problem with this interpretation is that fold hinges or axial traces are difficult to define. It is also possible to explain the outcrop pattern by high angle reverse faults, but no good evidence for this interpretation exists either. The hypothesis of isoclinal or overturned folds is supported by the presence of some isoclinal fold hinges in Sections 31 and 36 (S½). It is possible that these folds are a part of a larger anticlinorium which generally trends northwestward.

Generally in the Slick Hills, fold planes almost always verge towards the southwest, with folds having a sense of overturning to the northeast. The steep or overturned fold limbs are potential loci for faults to develop along the hinge of the anticline.

Tully Disturbed Zone

In mapping the area in Sections 31 and 36, designated as the Tully Zone, a problem arises in accounting for an apparently abmornally thick section of the McKenzie Hill Formation. In this area, an approximate thickness of the McKenzie Hill Formation was calculated from the contact with the Cool Creek in Section 36. Using an averaged dip, an apparent thickness of almost 6,000 feet is arrived at. As the McKenzie Hill Formation is only 1,000 feet thick, this means that there must be a considerable amount of shortening due to compression. This shortening may be due to either isoclinal folding and/or reverse faulting (Section D-D').

On the edge of the disturbed zone, just north of the Forte Anticline in Section 6, evidence for a small scale secondary folding event is present. An early minor fold was found in this area which has an axial trace about 310-N70W. However, later fold axes (F2) have refolded the original fold. The secondary compressional event was weaker and more localized than the original event (Figure 33).

Bull Run Folds

Just to the north of the Tully Disturbed Zone in Section 25, a fold pair named the Bull Run Anticline and Syncline is present. Both of these folds are asymmetrical and overturned locally; they terminate in minor folds at their southern ends. The overturned limb between the two folds is characterized by small scale minor folds and shear fabrics. Again, the sense of overturning is to the northeast (Figure 34).

Faulting

An understanding of fault relationships is extremely important to an interpretation of the structural geology of the Slick Hills. The Meers Fault is the most prominent structural feature of the area; its Post-Permian trend is obvious on air photographs as a lineation cutting the Post Oak Formation. The Pre-Permian movement of this fault apparently contains elements of both high angle reverse and left-lateral movement (Brewer, 1982). Vertical stratigraphic movement was estimated by Bartleman and others (1968) to be approximately four miles down to the north.

In the north half of Section 29 (T5N-R14W), field relationships suggest that the Upper Cool Creek or Lower Kinblade Formations are

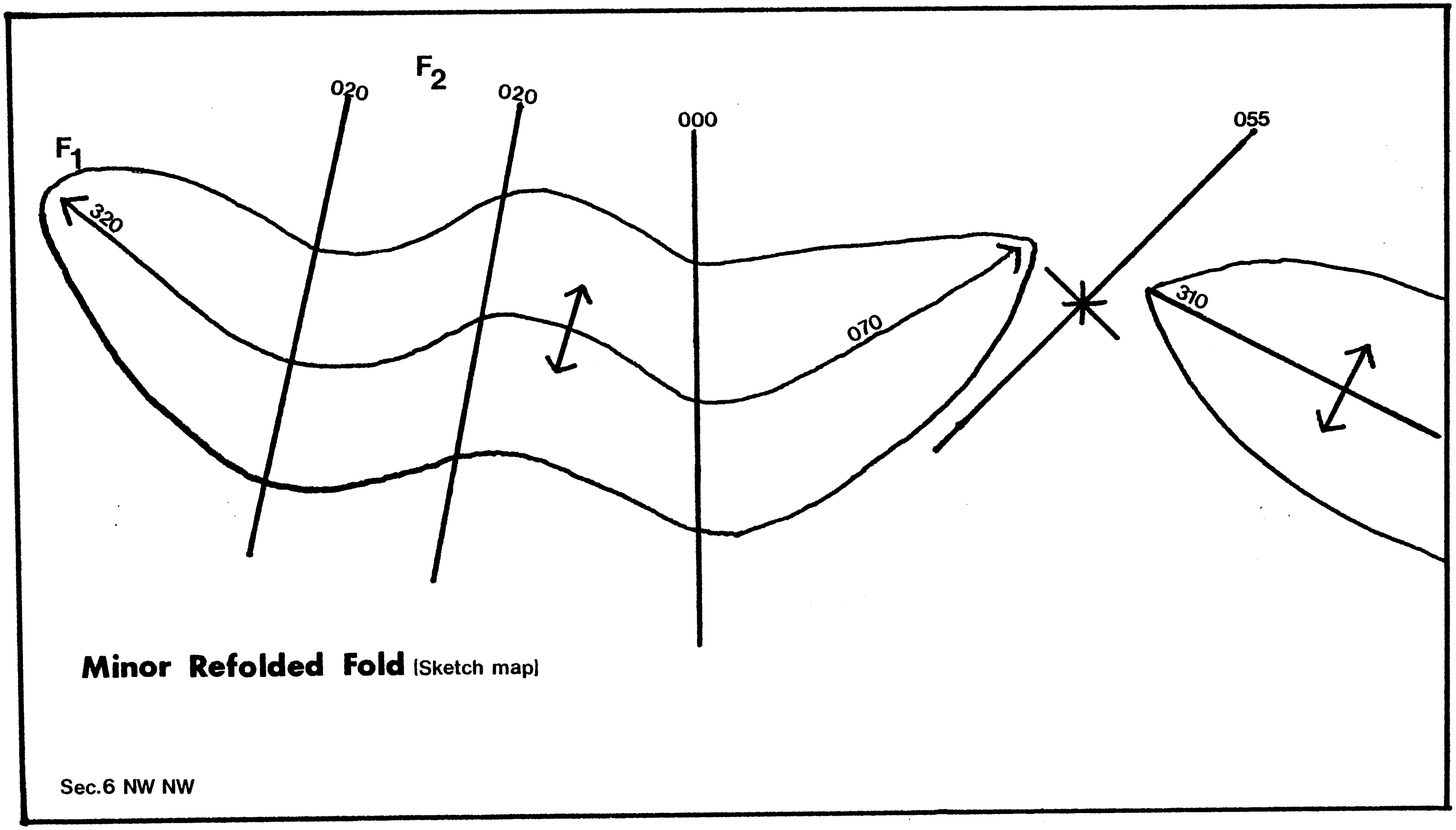


Figure 33. Refolding of a Minor Fold Near the Tully Disturbed Zone

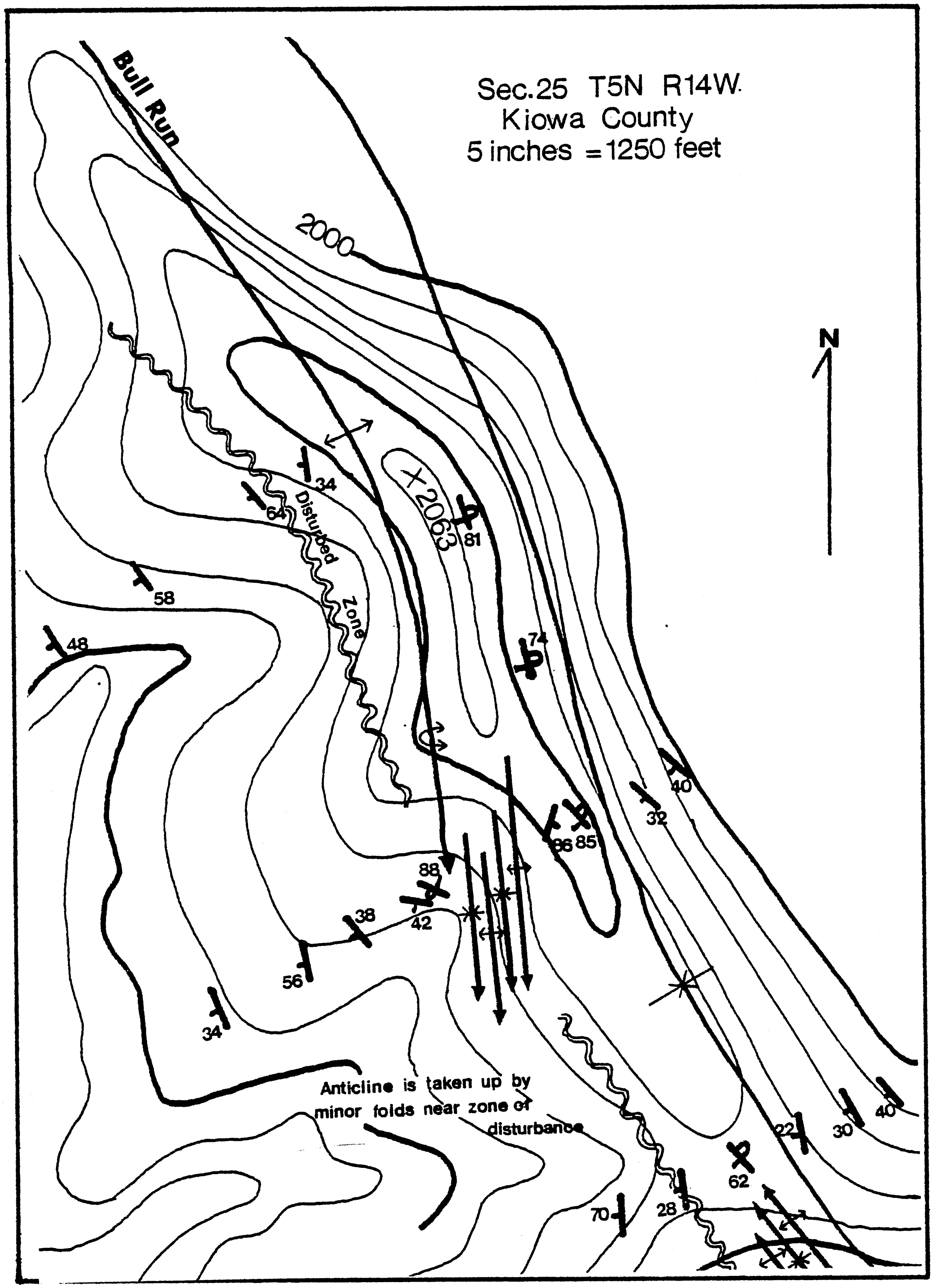


Figure 34. Sketch Map of the Bull Run Anticline and Syncline. The Bull Run Anticline is Taken up by Minor Folding to the South

faulted against the Wichita Granite which outcrops just to the south of the Meers Fault (Section 32). This suggests at least 4,500-5,000 feet of vertical throw by the Meers Fault.

Left-lateral movement of the Meers Fault is evidence by the orientation of northwest trending en echelon folds to the north of the fault. Furthermore, fabrics within shear zones near the fault and in the Stumbling Bear Shear Zone indicate left-lateral displacement. In addition, several small faults parallel to the Meers Fault trend offset fold axes and stratigraphic boundaries in a left-lateral sense.

Within the Tully Disturbed Zone are several high angle reverse and Thrust faults. In Section 25 (T5N-R14W), a high angle reverse fault repeats the base of the Cool Creek Formation, placing upper McKenzie Hill on top of Lower Cool Creek (Figure 35). This fault terminates in a fold pair to the northeast and southeast (Figure 36). Its trace within the McKenzie Hill Formation is a fractured and sheared zone across which there is an abrupt change in dip. Due to the lack of stratigraphic marker horizons within the McKenzie Hill Formation, the existence of such zones with their associated dip changes was, in several instances, the only criterion for recognition of faults. In consequence, where a movement involves only the McKenzie Hill Formation, it is not possible to determine the exact amount of displacement. In addition, the dip of a fault plane may change from a high to a low angle along its traces. This can be seen in the southwest corner of Section 31 (T5N-R13W) where two faults deviate from a straight trend and follow the topography near their termination (Figure 37). Both of these faults trend northwest, through Section 31 to the top of the principal topographic ridge in the

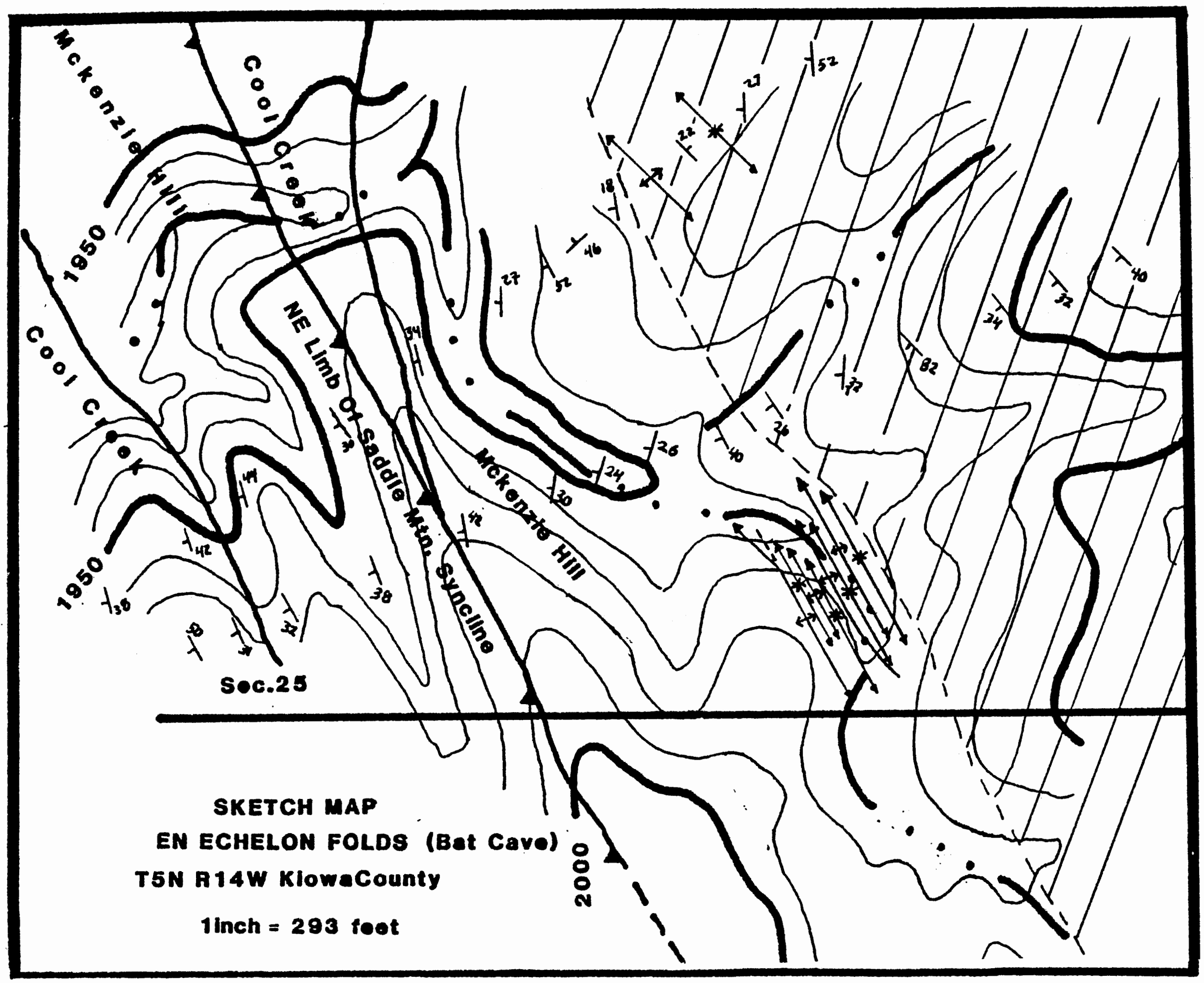


Figure 35. High Angle Reverse Fault Repeating the Base of the Cool Creek Fm. Minor en echelon Folds Parallel the Fault to the East

Figure 36. Minor Folding Associated With the Bat Cave Fault Within the Tully Disturbed Zone. Looking Northward Across the S½ of Sec. 24 and the N½ of Sec. 25. High Angle Reverse Fault in the Left (west) of Picture as it Dies out a Fold Pair to the East (air photo)

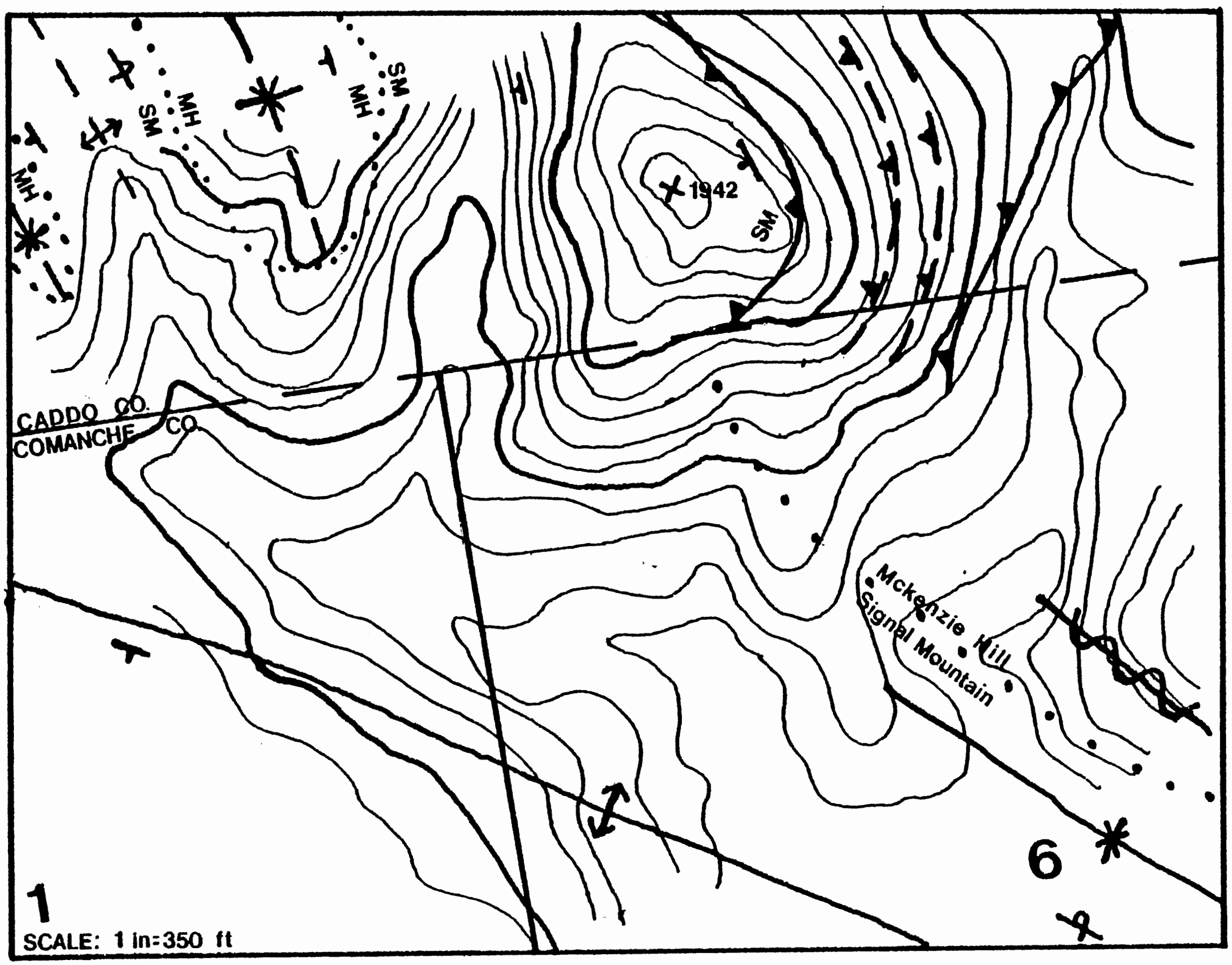


Figure 37. Thrust Faults in the Tully Disturbed Zone, With Associated Isoclinal Folds

north of the section, where their trace is marked by a well developed pink cataclasite.

Approximately parallel to the aforementioned faults in Section 31 are minor en echelon folds. These may be a response to the same compressional forces which initiated the faults (31-1), since both folds and faults are at a different orientation to similar structures elsewhere (OS, DA, etc.) (Figure 38).

Shear Zones

Shear zones in the Slick Hills are linear belts in which there is no continuity of bedding. Unlike disturbed zones, shear zones contain no folds or faults of any magnitude, although folding (small scale) is common, and rocks are intensively fractured (Figure 39). These small scale faults and folds exhibit similar characteristics to large scale features. Calcite vein filling is more pronounced in shear zones than elsewhere. The larger shear zones can be clearly seen on air photographs as areas in which bedding traces are incoherent.

Shear fabrics are common in parts of the shear zones. Within areas characterized by such fabrics, all of the original bedding and textures of the rock are obliterated and replaced by phacoidal-shaped lenses of left-lateral style, related to the increasing strain (Figure 40). The most intensely deformed shear zone is the Stumbling Bear Shear Zone which separates the Oliver Syncline from the Kimbell Anticline along the northern boundary of the thesis area. To the southeast, the Shear Zone curves southward across the southeastern termination of the Oliver Syncline. A little further to the south the Shear Zone terminates in an area of intense minor folding. To the northwest the Shear

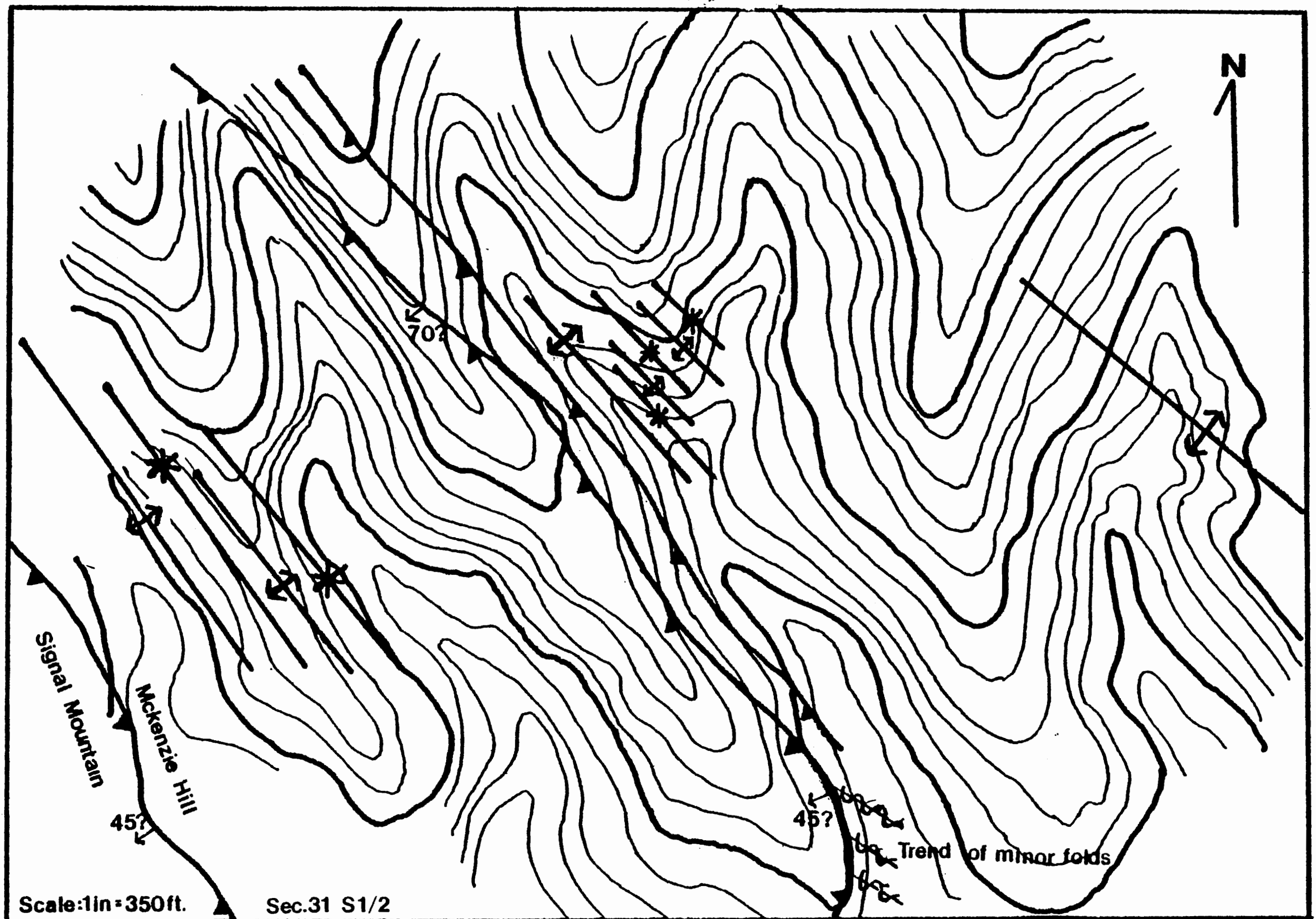


Figure 38. Faults in the Tully Disturbed Zone with Associated Folding (31-1 and 31-2)

Figure 39. Minor Folding Within Shear Zones

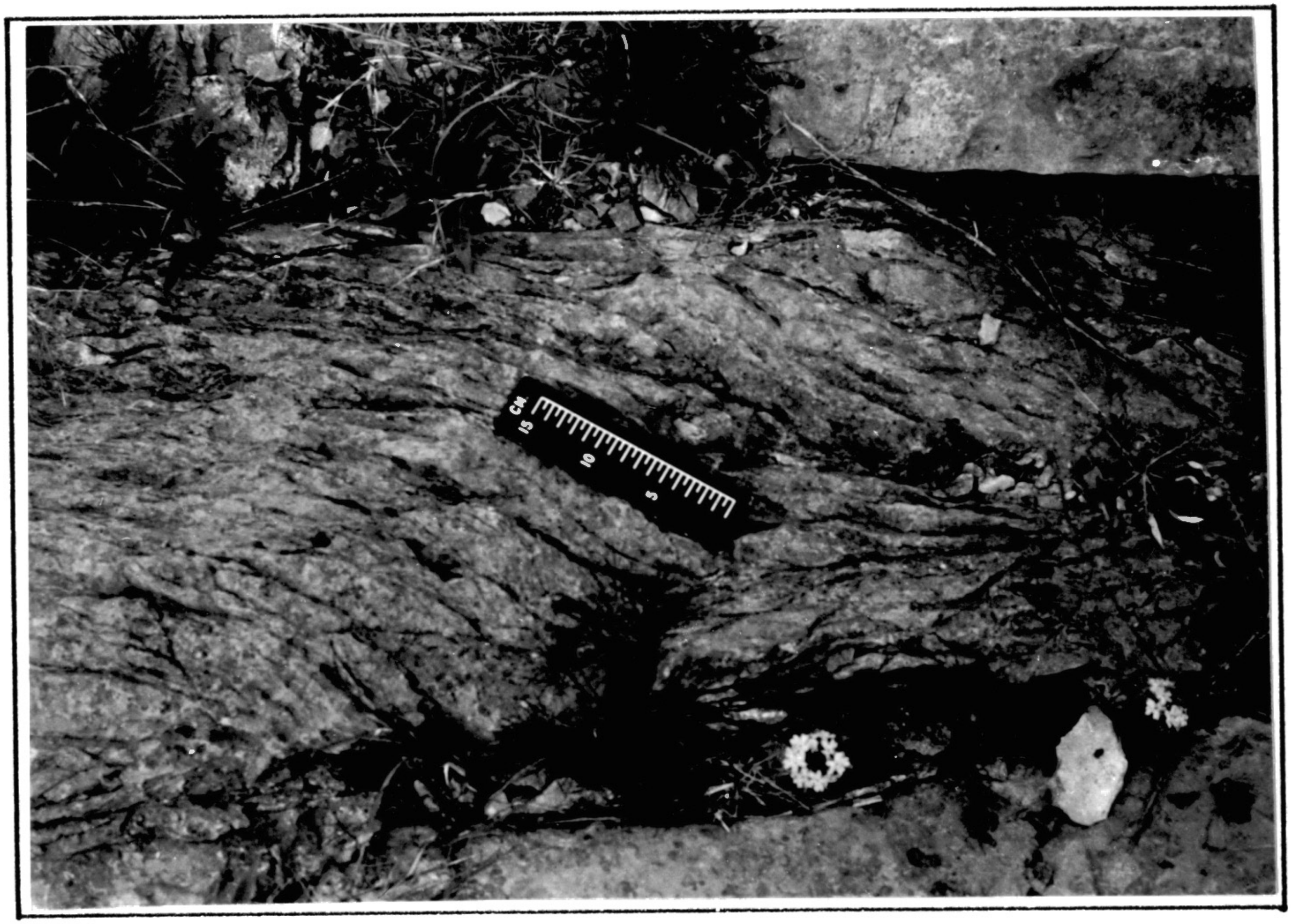


Figure 40. Phacoidal-shaped Lenses Created by Left-Lateral Shearing

Zone passes into McConnell's thesis area. Within the writer's thesis area the Stumbling Bear Shear Zone is over three miles long and is as wide as a quarter of a mile.

Other smaller scale shear zones exist in the thesis area; they are usually located on the steep limbs of asymmetric folds, e.g., the southwest limb of the Oliver Syncline and the steep limb (northeast) of the Comanche Anticline (Figure 41). It is speculated that this shearing is due to bedding slip along the steepened limb as the fold rotates from a symmetrical to an asymmetrical structure. Shear fabrics are also present in certain areas close to the Meers Fault where inliers of Lower Paleozoic rocks have been exhumed from beneath the Permian unconformity (Sec. 7-T4N-R13W).

Figure 41. Shear Fabric Along the Steep Limb of the Oliver Syncline

CHAPTER V

ANALYSIS OF STRUCTURE

This chapter presents a general model for the development of the structural relationships within the Slick Hills. Previously discussed in Chapter III were the basic mechanics of transcurrence (strike-slip) and compression. The merging of these two modes of structural deformation results in transpression. In zones of transpressive deformation, shortening occurs principally by the formation of folds and reverse faults.

In the Slick Hills, the most characteristic structural feature is the development of en echelon folding at an oblique angle (c.30° and less) to the Meers Fault (Figure 42). As noted previously, the Meers Fault is a left-lateral fault with a great component of vertical movement; i.e., it is an oblique-slip fault. The generation of the structures in the Slick Hills is believed to be due to transpressive deformation resulting from the oblique compressional movement of the Meers Fault. A model developed by Sanderson and Marchini (1983) illustrates transcurrence, transpression and transtension (Figure 43 A, B, and C), and the resultant structures. Another model shows the three successive stages of progressive rotation of folds and accompanying faulting and shear features. It is assumed that the initial folding originated from a maximum compression which was oriented perpendicular to the fold axial trends. This resulted in an oblique (c.30°)

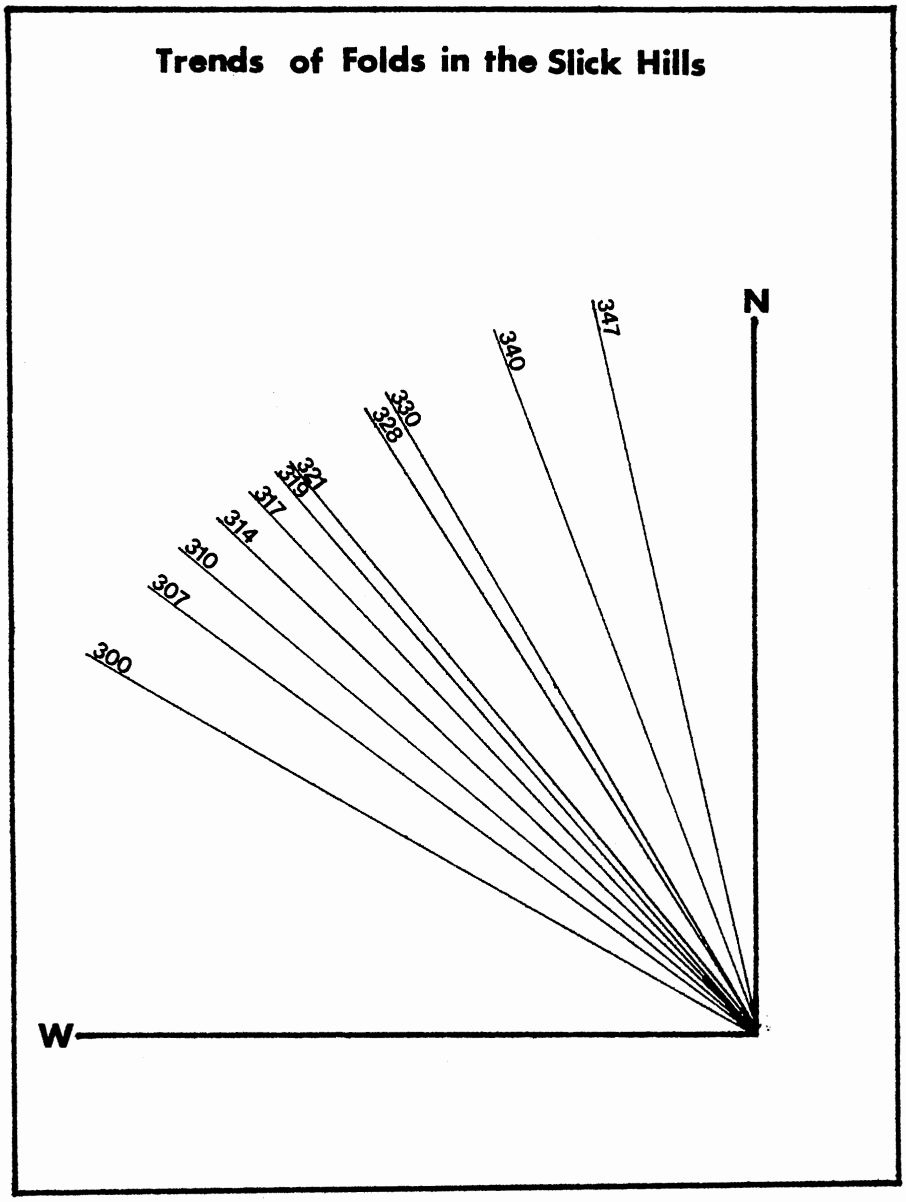


Figure 42. Rose Diagram of Fold Trends

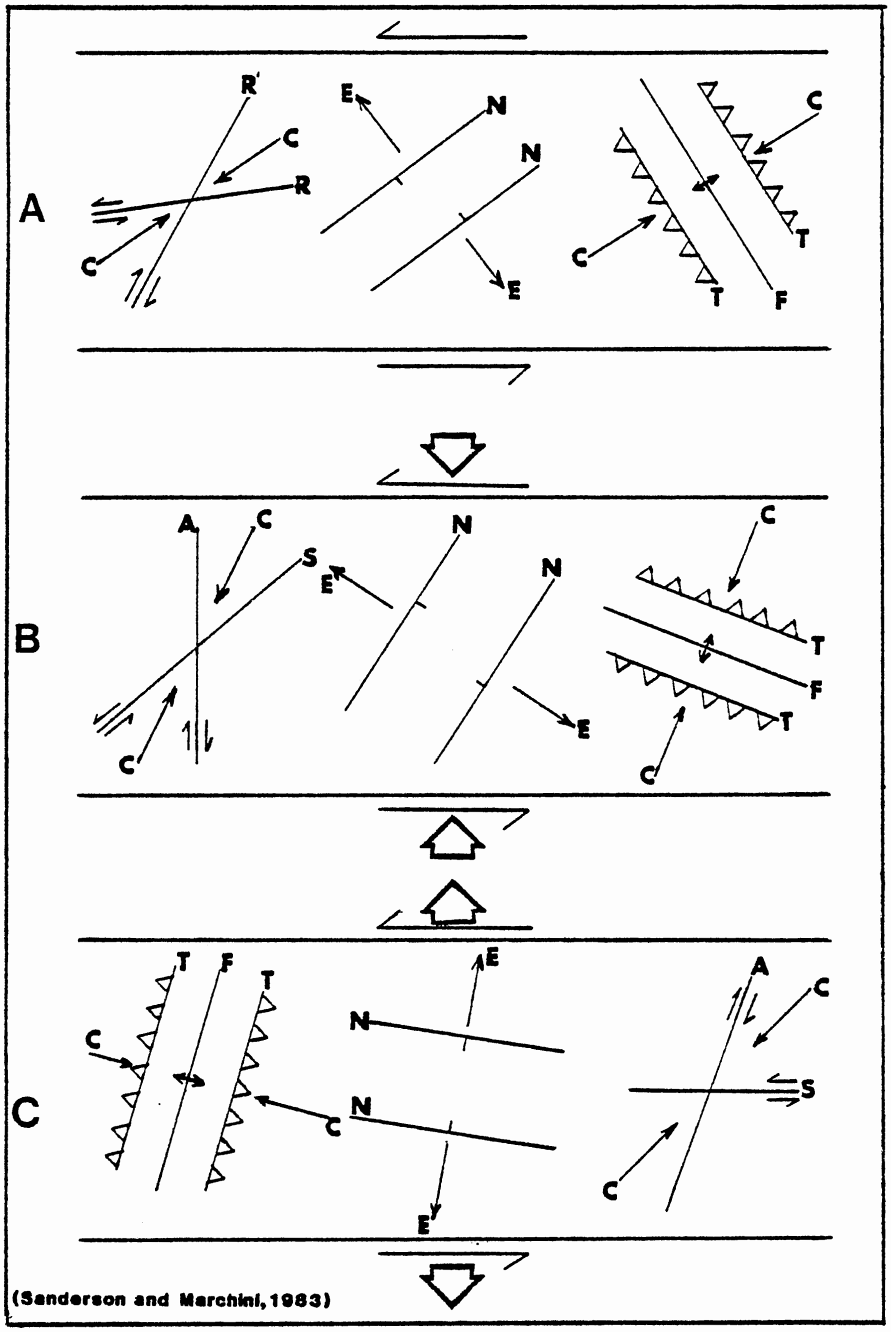


Figure 43. Wrench Regimes and Minor Structures. A) Transcurrent; B) Transpression; C) Transtension

orientation of the folds to the Meers Fault. Transpression decreased this angle and rotated the folds subparallel to the Meers Fault (Figure 44). This is particularly the case with folds (such as the White Tail and Indian Mission Anticlines) close to the Meers Fault. Originally, the folds may have been symmetrical (i.e., the product of simple transcurrence); later they became asymmetric due to continuing transpression. The sense of steepening in the folds occurs most often in the northeast limb of the anticlines, resulting in axial planes dipping to the southwest. The constancy of the sense of asymmetry indicates that the compressive force from the southwest was stronger due to the presence of a rigid block (the Wichita Igneous Complex) to the south of the Meers Fault, and because of northeastward movement of this comples along this fault.

Fold asymmetry of this type is illustrated by the geometry of the Oliver Syncline (Figures 21 and 22). Where the compressional element of transpression was dominant, folds may have become isoclinal with one limb overturned by as much as 40 degrees. The vertical or overturned limbs probably became loci for bedding-plane slip movements of oblique-slip type. In the field, many faults are not seen as single fault planes, but appear to be zones with movement apparently taken up along many discrete bedding planes. It is apparent that the steepened limbs are potential shear zones along which small or large amounts (as in the case of the Stumbling Bear Shear) of shearing may occur. Where considerable movement has taken place, left-lateral shear fabrics are common, although the amount of horizontal movement is difficult to quantify.

The Tully Disturbed Zone is the area where the compressional

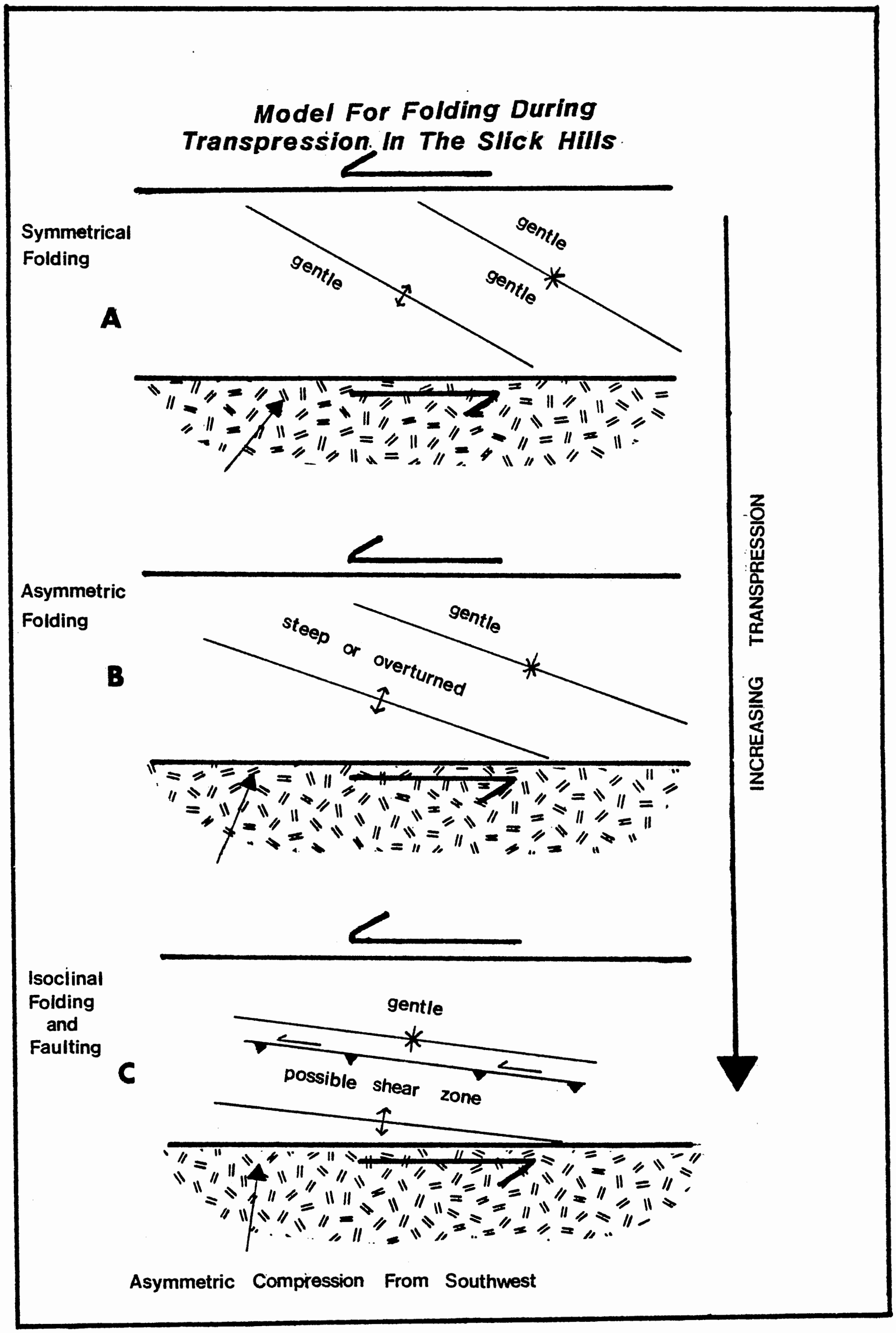


Figure 44. Model for Folding During Transpression in the Slick Hills

element of transpression was strongest. As a result, much reverse faulting is found. These faults are usually high angle reverse faults with 60 - 70 degree dips, although low angle thrusts are also present. Most of these faults parallel the local strike of beds. One of the most obvious faults is the Bat Cave Fault, which is a high angle reverse structure on the northeast limb of the Saddle Mountain Syncline. Sense of movement of this and associated faults is similar to that of the Meers Fault, i.e., the hanging wall block has moved towards the north and east. The high density of faults in the Tully Disturbed Zone may record a zone of basement weakness between the Saddle Mountain Syncline to the west and the principal area of the Lawtonka "Graben" to the east.

In a transpressive regime, normal faulting would be expected to occur perpendicular to the folds and thrusts (Figure 43). However, such normal faulting was not seen except on a small scale. Fractures occurring perpendicular to fold axes appear to be the only expression of extension in most areas.

More common than normal faulting are small left-lateral faults or shears. These shears are later than most of the folding, and probably occurred at a late stage as shortening by compression was lessening and the horizontal component of transpression remained effective. These small faults offset fold axes and shear fold limbs. In section 6 (Figure 32), small left-lateral faults cut across minor folds and have a trend of about 280, N80W. The orientation of these minor faults suggests that they are synthetic shears forming at a late stage in transpression.

Regional Relationships

The work undertaken by the author plus that of McConnell is a detailed examination of a single sub-horizontal surface in a relatively small area of the Wichita Frontal Fault Zone. It is becoming increasingly clear that models developed in the Slick Hills can be applied to the subsurface and, when tied to vertical seismic profiles, such models are a useful exploration framework for the petroleum industry.

Seismic evidence shows that flower structures are present in the Arbuckle Mountains and the Ardmore Basin. Such structures typify both transcurrent and transpressive deformation. COCORP seismic lines within the Wichita Mountain region (Figure 4) indicate northeastward directed thrusting along the northern flank of the Wichita Mountain Front (Brewer, 1982). These thrusts have a dip of 30-40 degrees, and appear to steepen with depth. Major faults such as the Meers and Mountain View Faults are basement seated and have a great vertical component of throw. The Mountain View Fault is estimated to have a vertical throw of at least 24,000 feet, as indicated by subsurface well control. These major faults may be an expression of a large flower structure. Interestingly, the Burch Fault (Figure 4) to the south of the Wichita Igneous Complex is a major northward-dipping structure, which provides a likely southern boundary to the postulated flower structure.

Related Regional Structures

Subsurface mapping of structures to the north of the Slick Hills has revealed several folds which are arranged in an en echelon fashion, and are of an oblique orientation to the Mountain View Fault (Plate 2). The most southerly of these structures is a well known asymmetrical anticline in the Apache Field. Mapping of the structure on top of the Viola Limestone has produced similar results to previous interpretations (Scott, 1945; Coryn, 1948). The structure is an asymmetrical anticline, trending northwest (320, N40W), which is overturned to the northeast (Figure 45). To the northeast of the Apache Field is a zone which appears to be very disharmonic and may be a Disturbed Zone.

North of the Apache Field is another anticlinal feature (in the Broxton Field). This field has not been as productive as the Apache Field, and therefore is less developed. However, both folds have a similar geometry (Figure 46). The Alden Field, which lies northest of the Broxton Field, is close to the Mountain View Fault. This field is also an asymmetrical anticline (Figure 47).

The geometry and orientation of all three folds is similar to that of the folds which are present in the Slick Hills. If the Mountain View Fault has a comparable sense of lateral movement as the Meers Fault, it is hypothesized that these anticlinal structures may have been developed by transpression in the same fashion as the folds in the Slick Hills.

Another region to the northeast of the Slick Hills which exhibits similar styles of deformation is the Cement region. An interpretation, contoured on top of the Morrow Formation (Hermann, 1961) depicts anticlinal structures trending northwest. The northwest limb of this anticline is cut by a high angle reverse fault (Figure 48). This may indicate rotation and overturning of the original fold by an asymmetric compression, followed by faulting of the steepened limb.

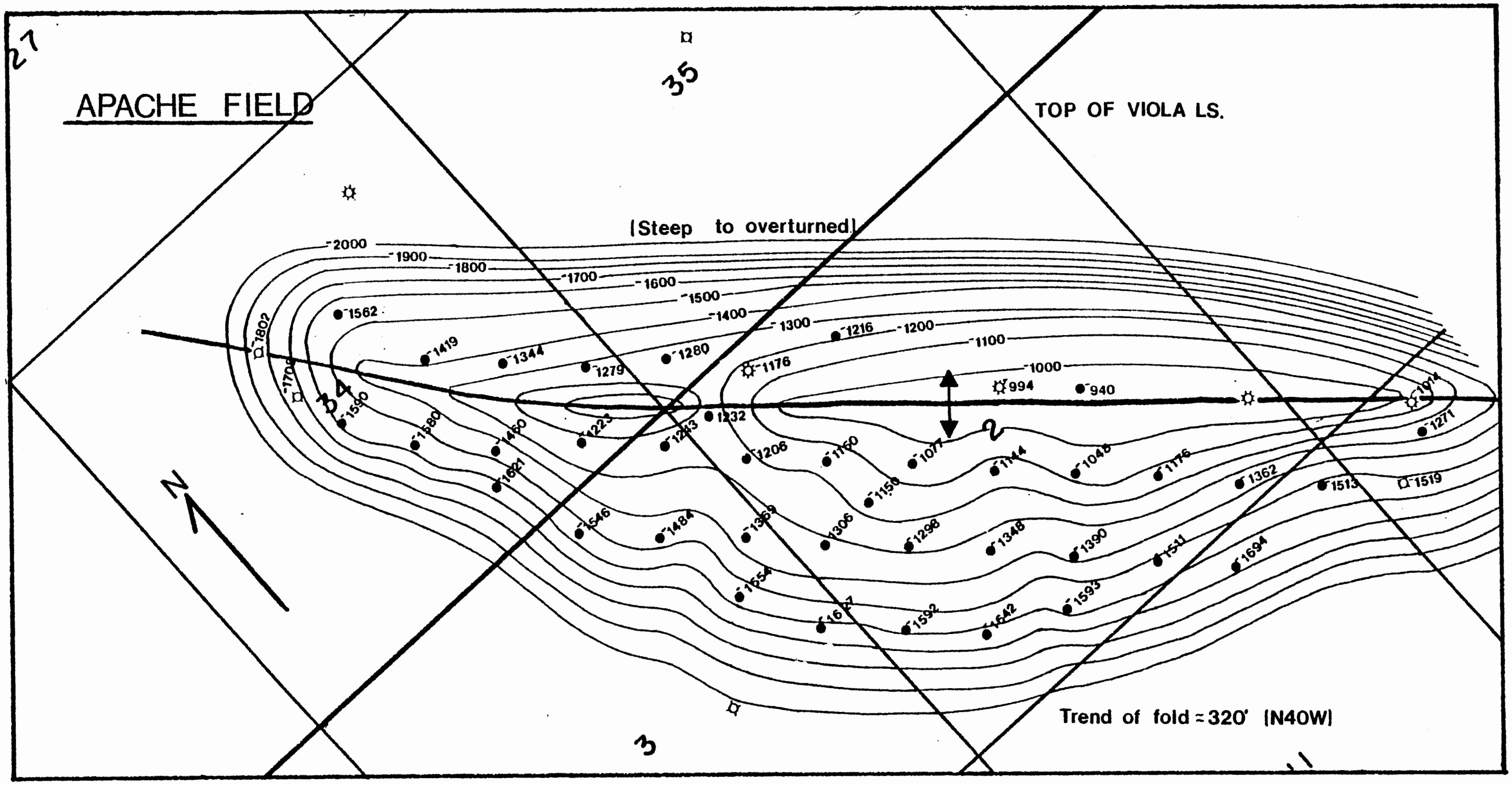


Figure 45. Structural Contour Map of the Apache Field. Contoured on the Top of the Viola Limestone

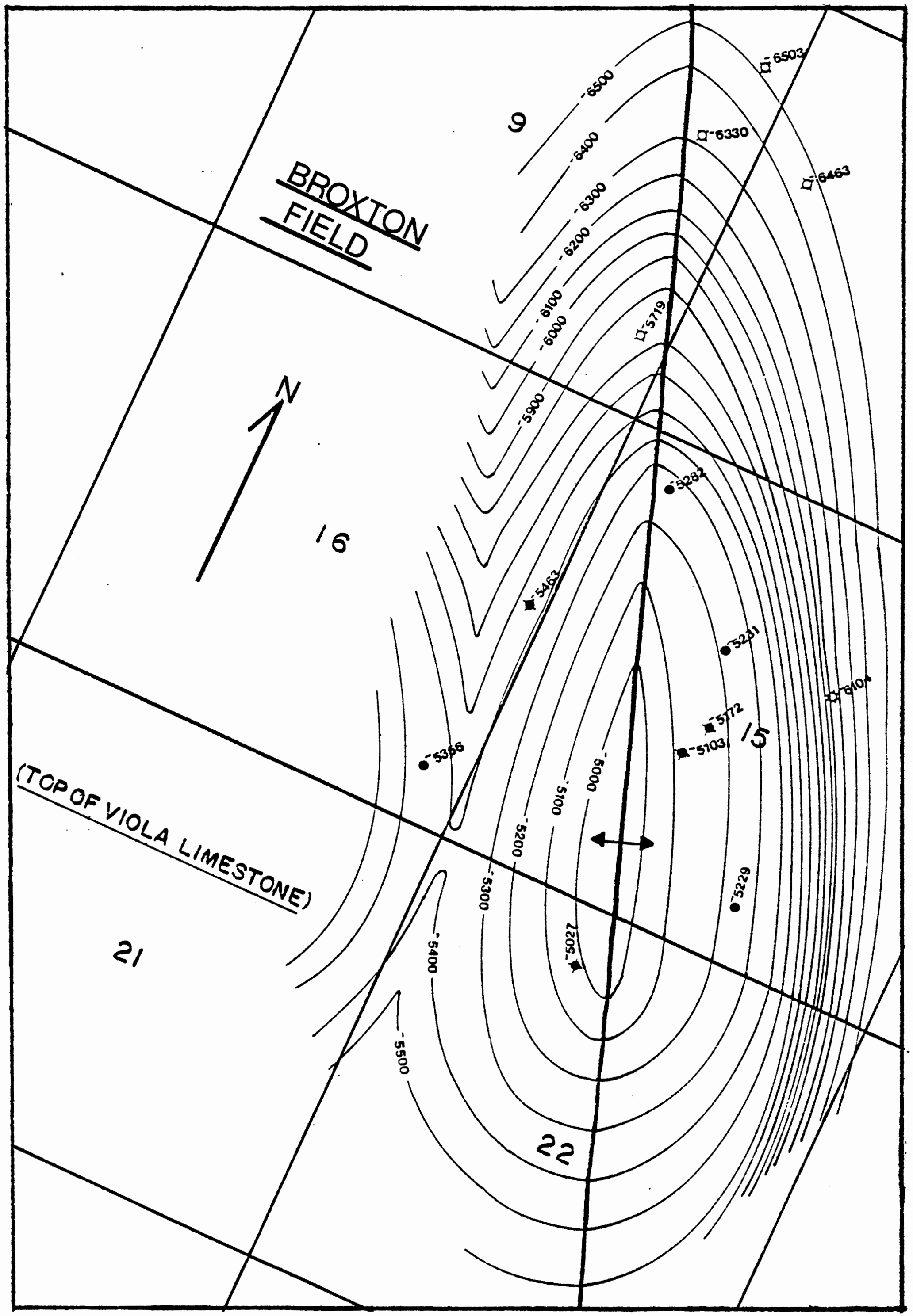


Figure 46. Structural Contour Map of the Broxton Field. Contoured on Top of the Viola Limestone

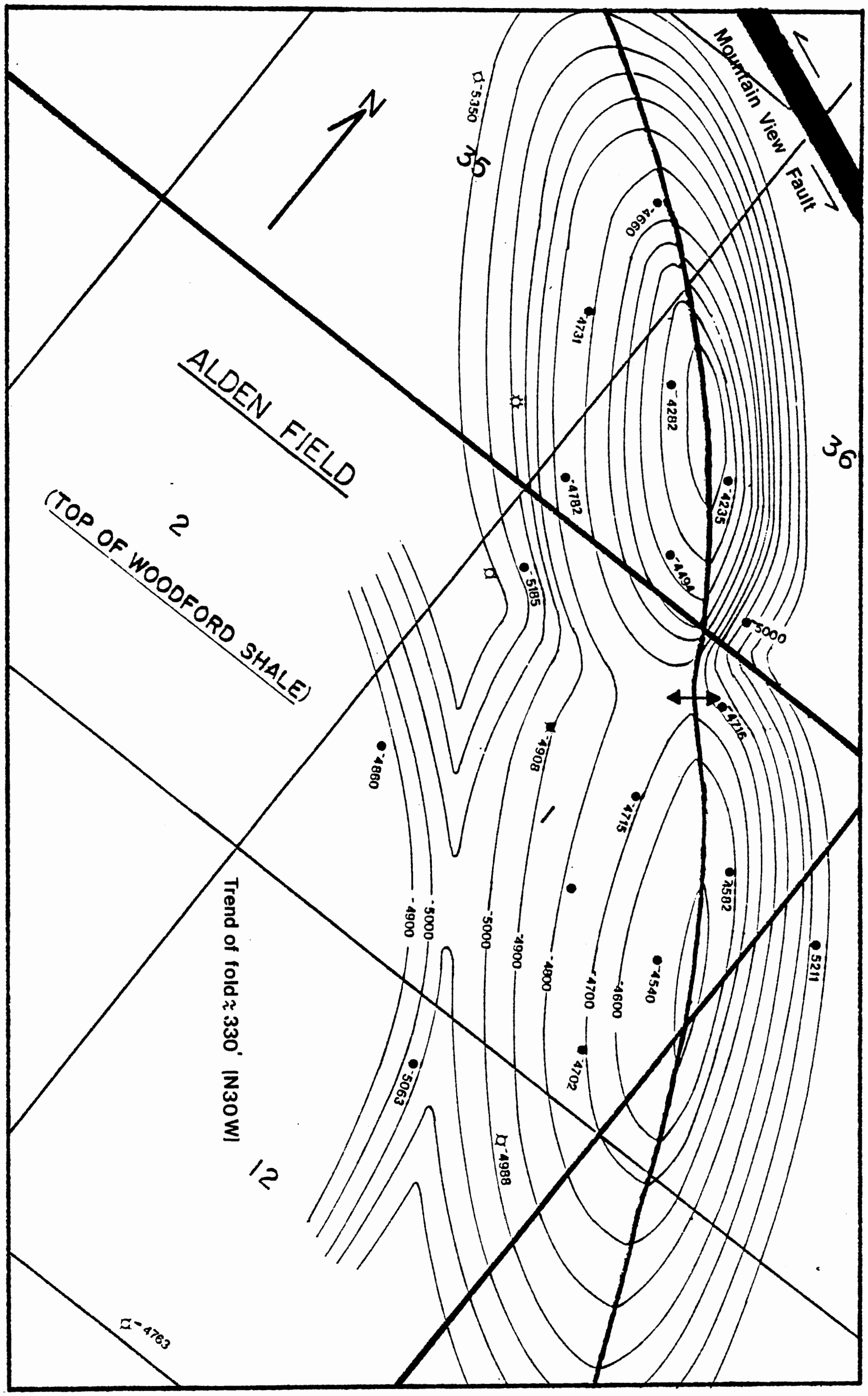


Figure 47. Asymmetrical Anticline (Alden Field) Fold Appears to be Slightly Rotated and Sheared in Left-Lateral Sense by Transpression. Contoured on Top of the Woodford Shale

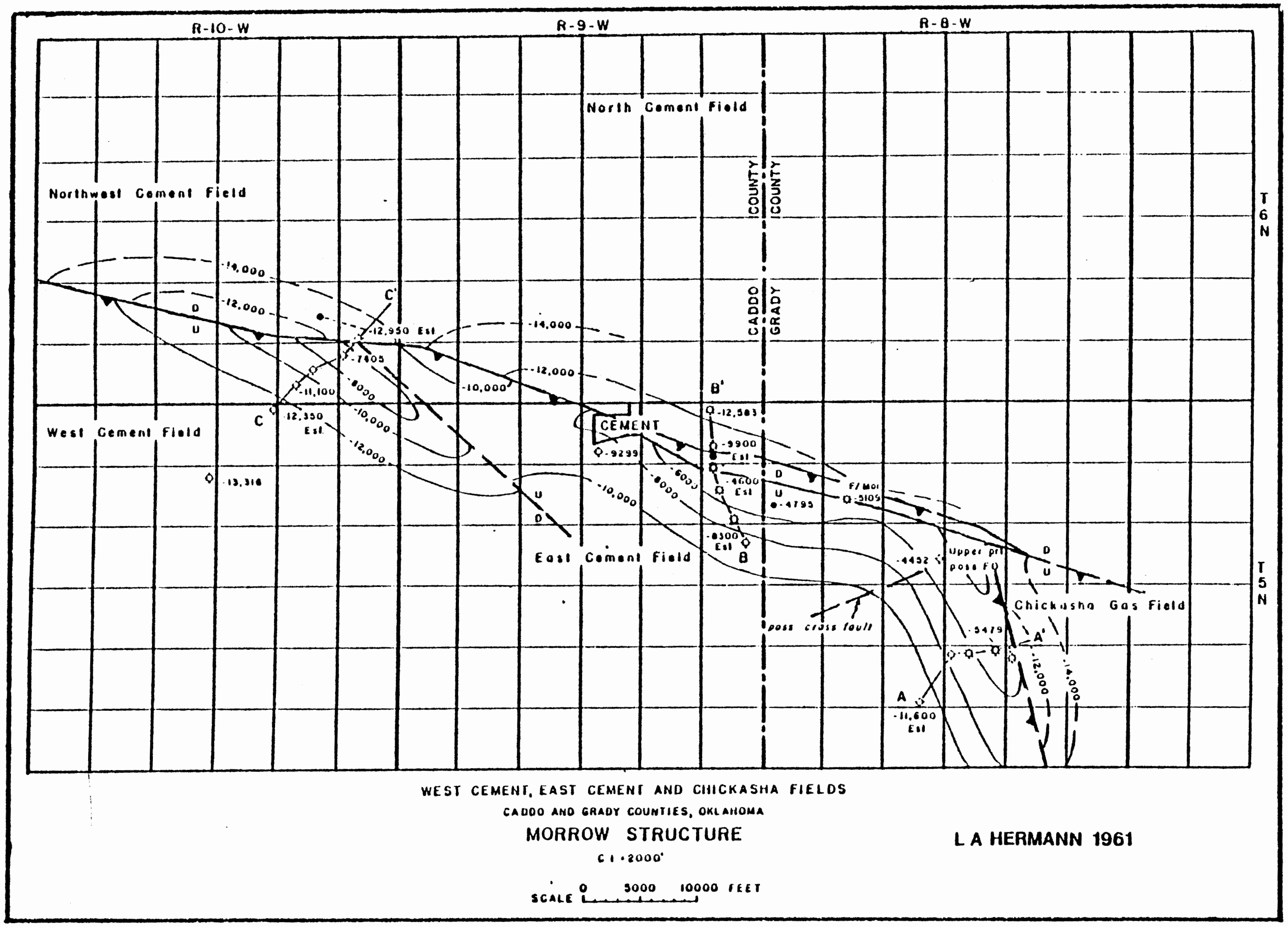
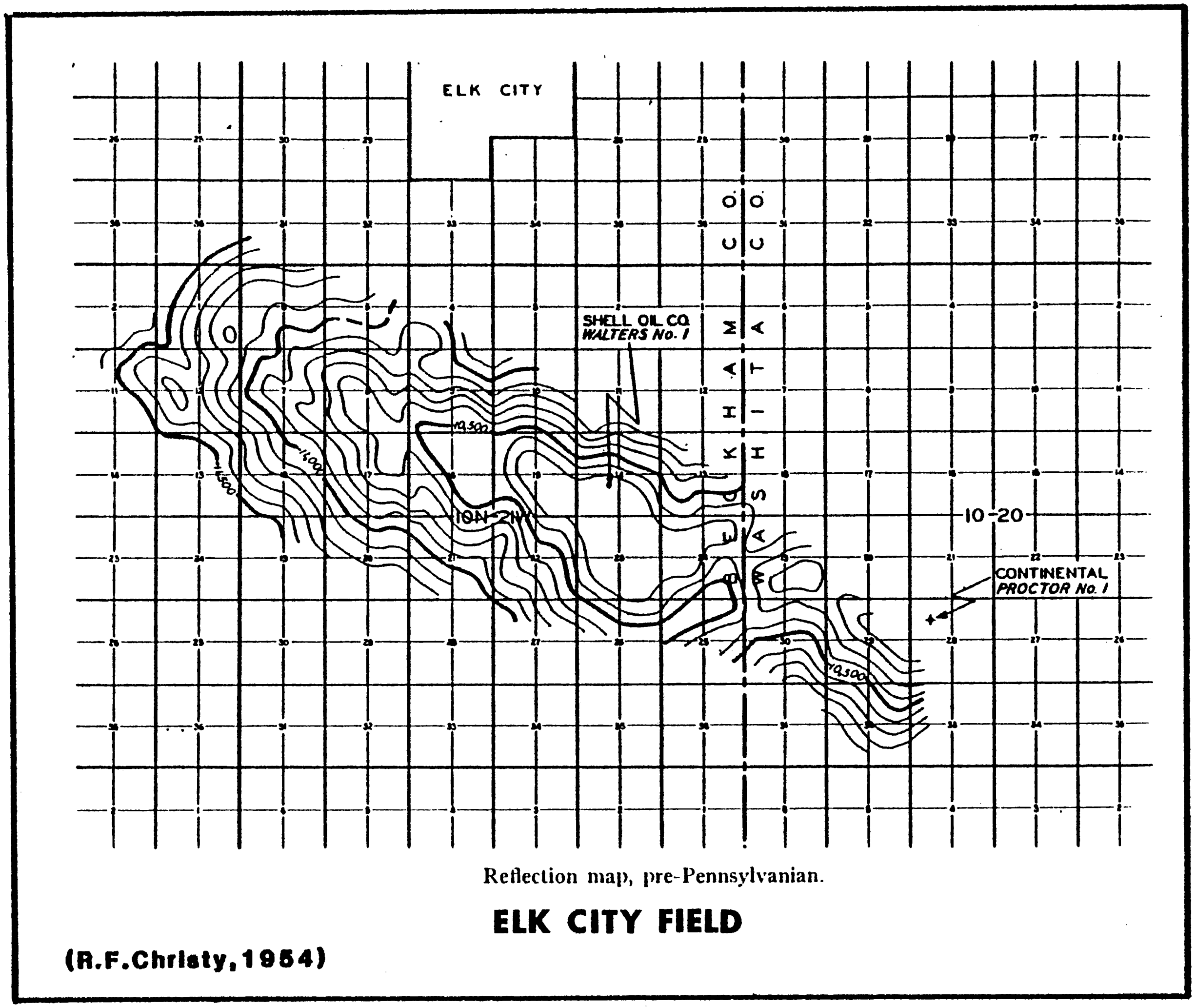


Figure 48. Anticlinal Structure cut by a High Angle Fault (Cement Field). Contoured on the Top of the Morrow Formation

To the west of the Slick Hills and the Cement Field lies a large anticline which is known as the Elk City Field. This field, like the Apache Field, was found in the subsurface by the use of seismic exploration. A pre-Pennsylvanian reflection map (Christy, 1954) interprets the structure as a large northwest trending anticline (Figure 49). Other such fields in this area, along the same trend, appear to have similar characteristics (e.g., Gotebo Field, Gageby Creek [TX.]). They are here interpreted as having been due to similar stresses as those responsible for deformation in the Slick Hills.

In the Arbuckle Mountains to the southeast of the Slick Hills there are several faults approximately parallel to the Meers and Mountain View Fault which have been documented as having left-lateral movement (e.g., the Washita and Reagan Faults; Wickham and others, 1978). These faults have been recognized as extending into the subsurface and parallel known subsurface faults (Figure 50). Similarly, en echelon folds at the surface in the Arbuckle Mountains (Figure 51 A) extend into the subsurface and have the same trend as subsurface structures (Figure 51 B). Early exploration for oil in southern Oklahoma resulted in the recognition of these folds as hydrocarbon reservoirs, and many of the largest oil fields in southern Oklahoma are contained in these ($310-340^{\circ}$ trending) "en echelon" anticlinal structures.

The Crinerville Anticline in Carter County (Figure 52 B) discovered by surface mapping, is an asymmetrical anticline in which beds dip steeply on the northeast limb into a fault along the same limb (Powers, 1929). The Cumberland Anticline (T5S, R7E), which was discovered in the subsurface, has the same characteristics as the Crinerville Anticline, i.e., a faulted or overturned northeast limb (Figure 52). Within the



Reflection map, pre-Pennsylvanian.

ELK CITY FIELD

(R.F.Christy, 1954)

Figure 49. Northwest Trending Anticline (Elk City Field). A Seismic Reflection Map on Top of pre-Pennsylvanian Rocks

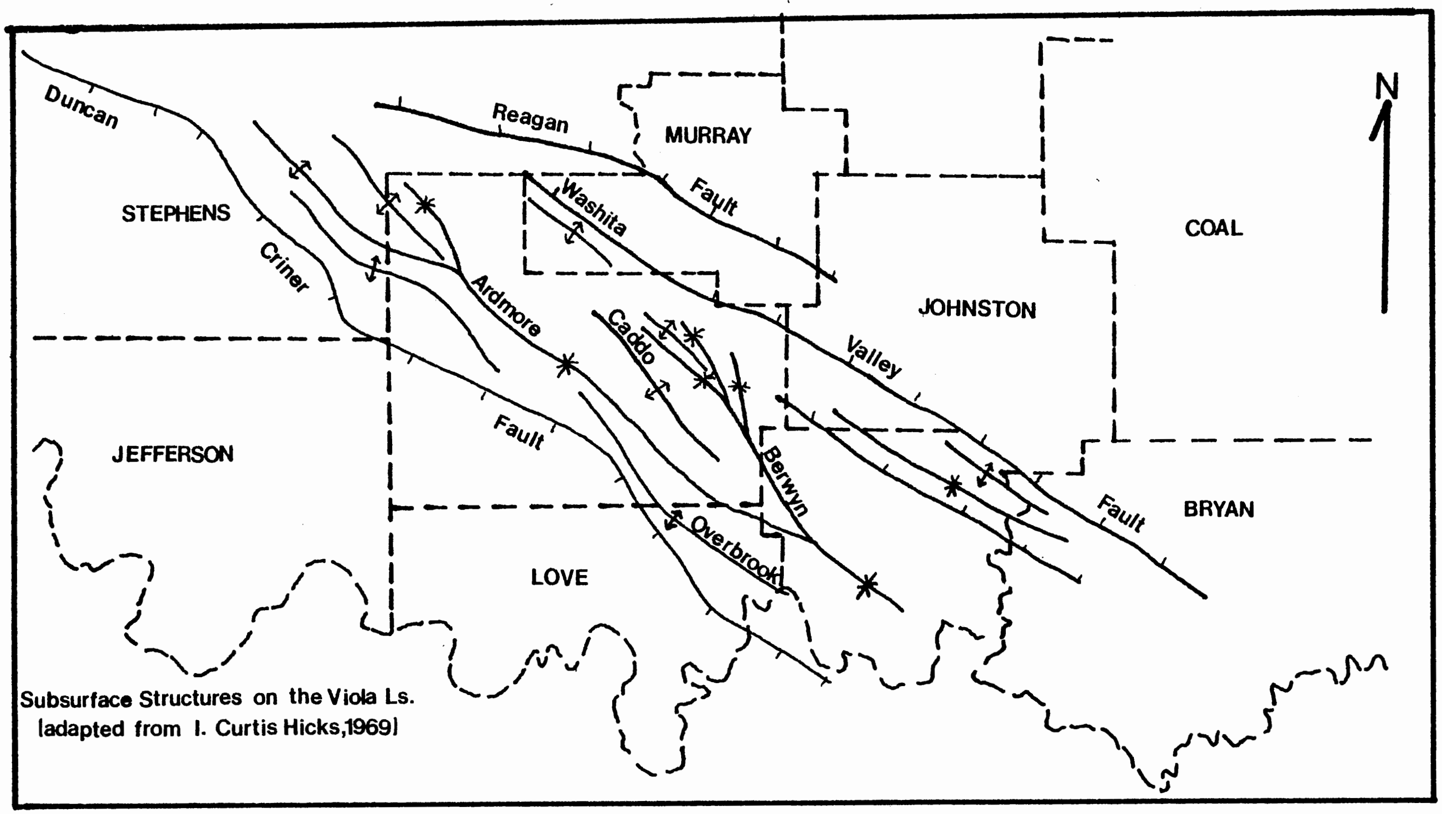


Figure 50. Map of Subsurface Structures in Southern Oklahoma

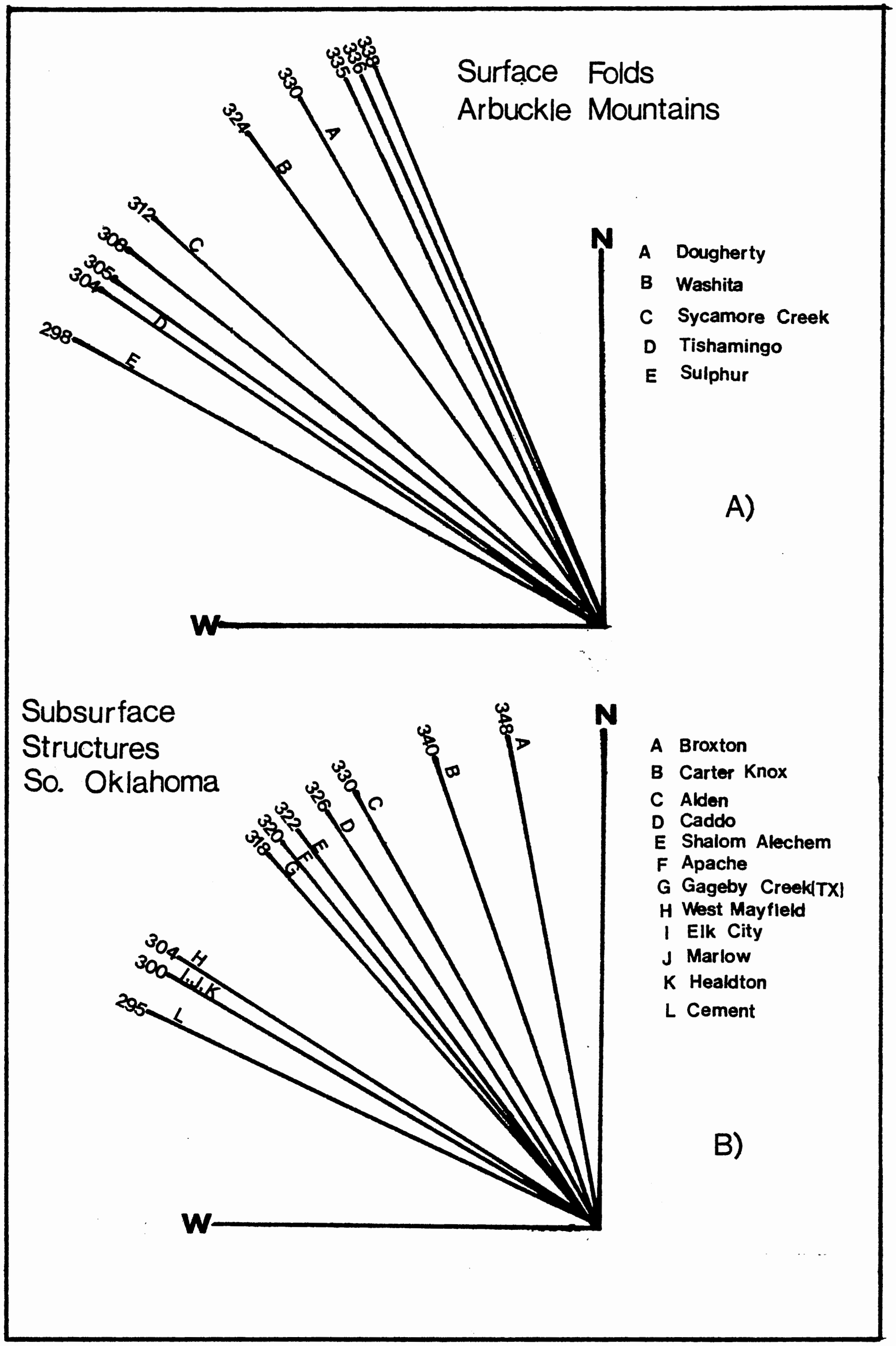
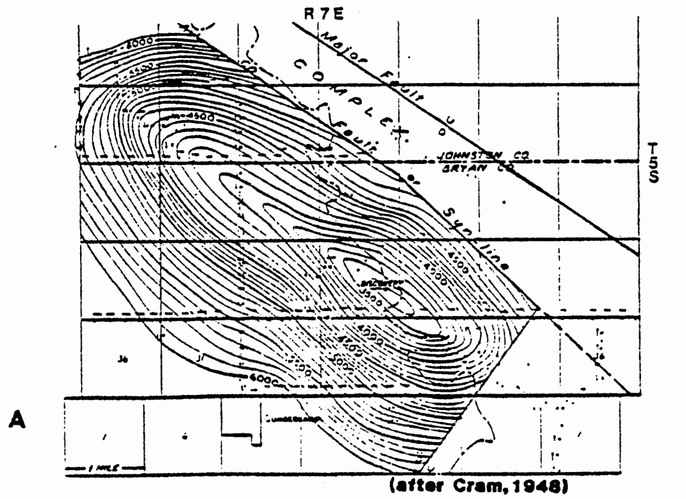
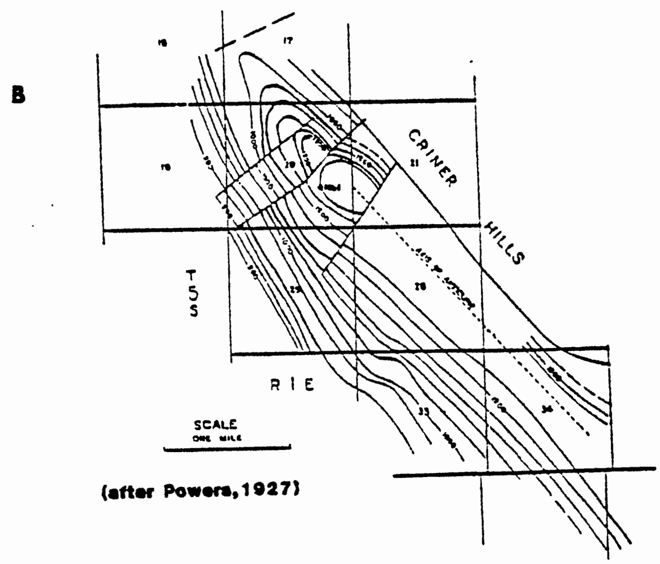


Figure 51. Rose Diagrams of Surface and Subsurface Folds in Southern Oklahoma. A) Trends of Anticlinal Structures in the Arbuckle Mountains; B) Trends of Subsurface Structures



Reflection seismograph map contoured on a dominant reflection believed to be the Hunton limestone. Velocity assumed. Records obtained by The Geotechnical Corporation. Interpretation by Myron C. Kiess.



—Structure contours, above sea-level, of the surface geology, Crinerville anticline. Contour interval, 100 feet. Datum, sea-level. The location of the discovery well is shown. (Geology by R. A. Birk and C. J. Wohlford, for the Amerada.)

Figure 52. Northwest Trending Anticlines in Southern Oklahoma (Cumberland and Crinerville Anticlines). A) Reflection Map of the Cumberland Anticline; B) Structure Map of the Crinerville Anticline

same area, two more fields occur which have the same trend, the Shalom Alechem Field and the Caddo Field (Figure 53). Both of these fields are slightly asymmetric anticlines. The Caddo Anticline has both surface and subsurface expression. The Caddo Anticline was mapped by Dionisio and Ghazal (1975) and found to be a non-cylindrical anticline with a slight inclination of the axial plane northward. Normal faults crossing the axis of the anticline in the subsurface suggest extension along the axial trend of the anticline (Figure 53).

The Healdton Field in the Ardmore Basin comprises two complexly deformed anticlines. Subsurface mapping of the Healdton Field by Latham (1965) on top of the Brown Zone (Kindblade Fm. of the Arbuckle Group) showed the anticlines trend northwest and that both are faulted along their northeast limbs by a high angle reverse or thrust fault (Figure 54). This fault places lower Paleozoic rocks against Pennsylvanian rocks with an estimated throw of 2,000 feet (Figure 55). Similar faults in the area may have at least 10,000 feet of throw, juxtaposing Pennsylvanian Springer age rocks against the Arbuckle Group (Latham, 1965).

Conclusion

This study of the structure of the Slick Hills has resulted in a better understanding of the structural styles and stratigraphic relationships in the area. My principal conclusion is that the structural relationships evolved through deformation by transpression. This conclusion is similar to that of McConnell, Donovan, Sanderson, and Marchini. After the amalgamation of field data with that of McConnell (Plate 3), a geologic map has been produced which represents the structural and

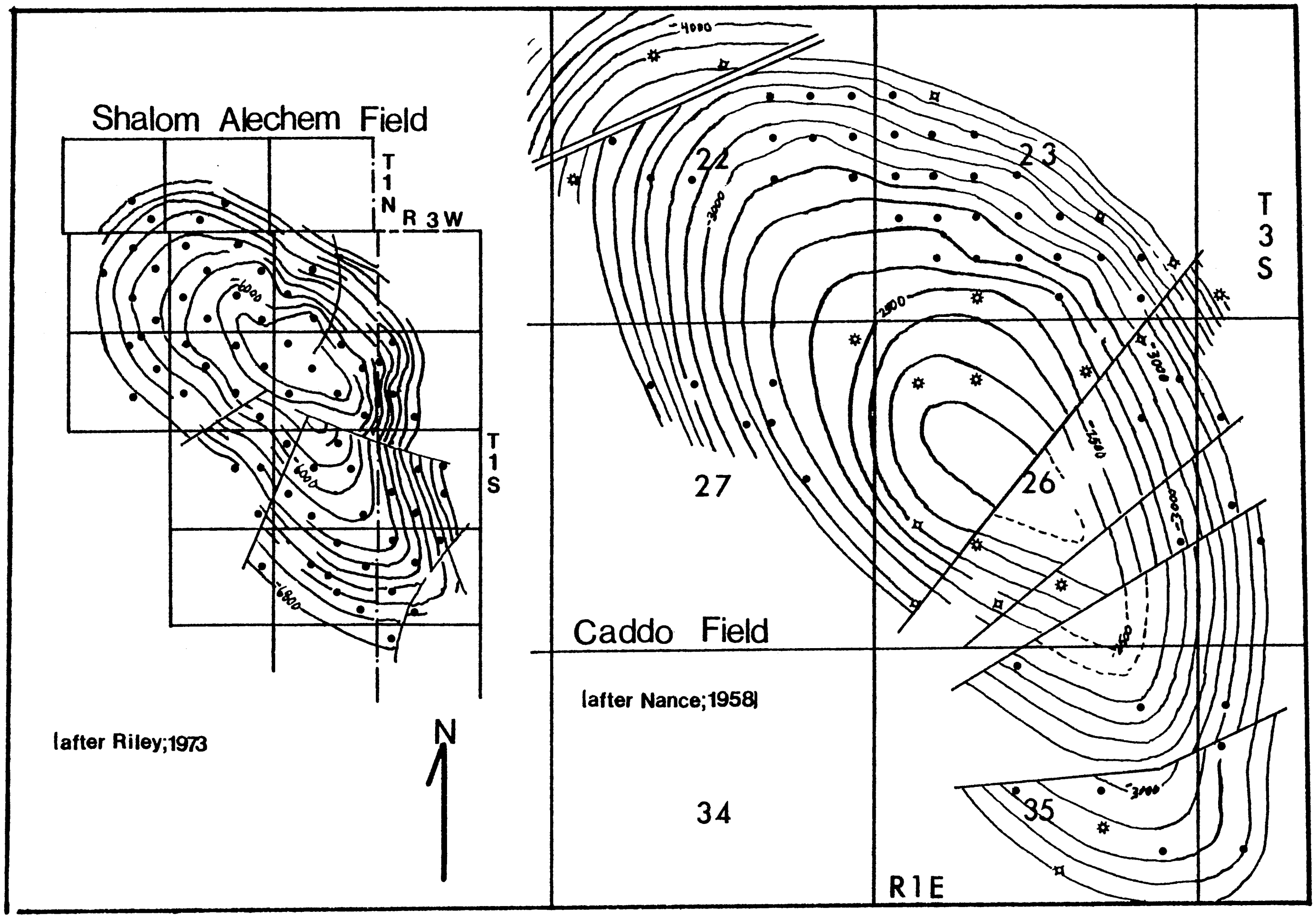


Figure 53. Northwest Trending Subsurface Anticlines (Caddo and Shalom Alechem Fields). Slighty Asymmetrical Folds With Normal Faults Occurring Across the Axial Trend

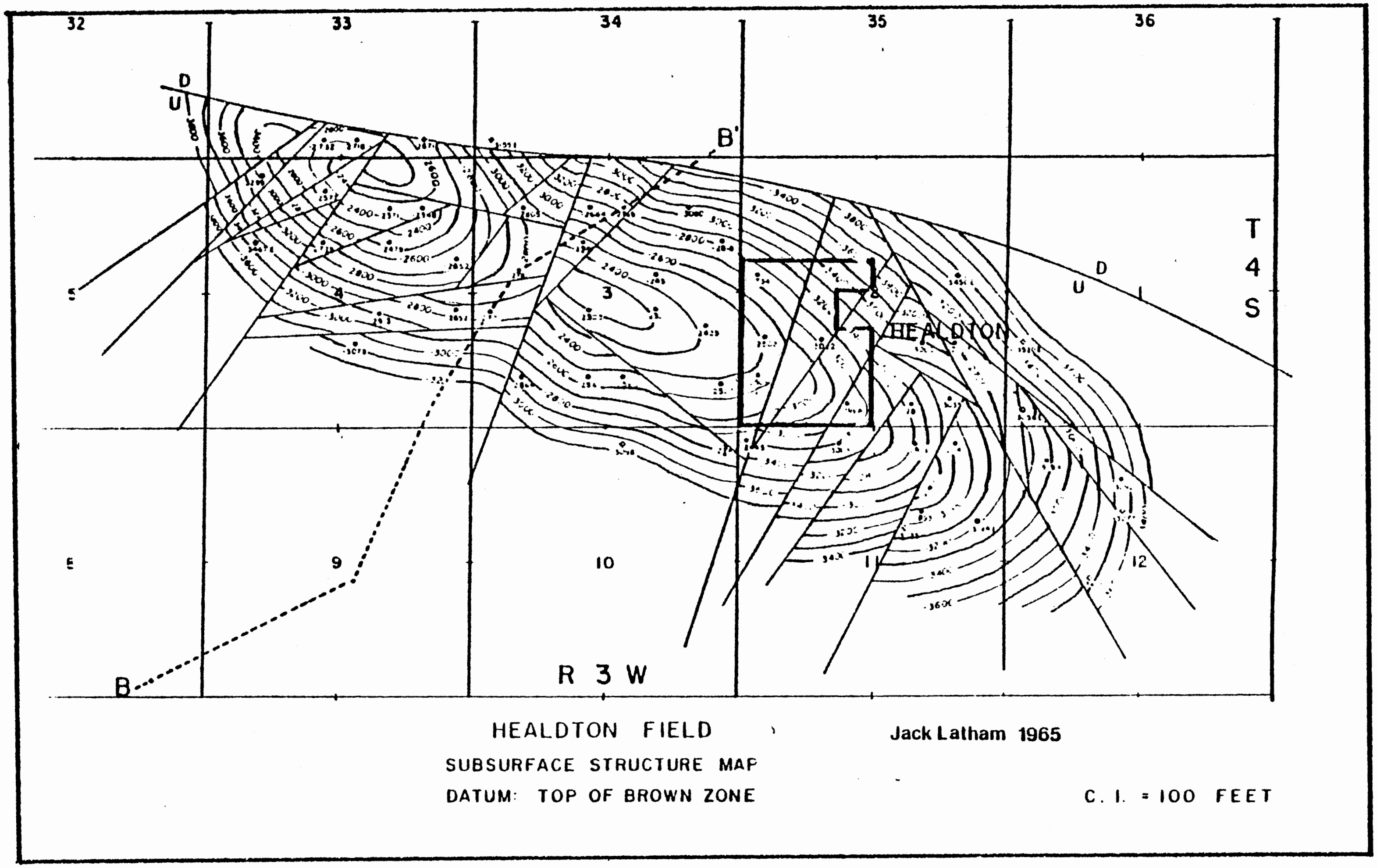


Figure 54. Subsurface Structure Map of the Healdton Field. Asymmetrical Anticline is Faulted Along the Northeast Limb

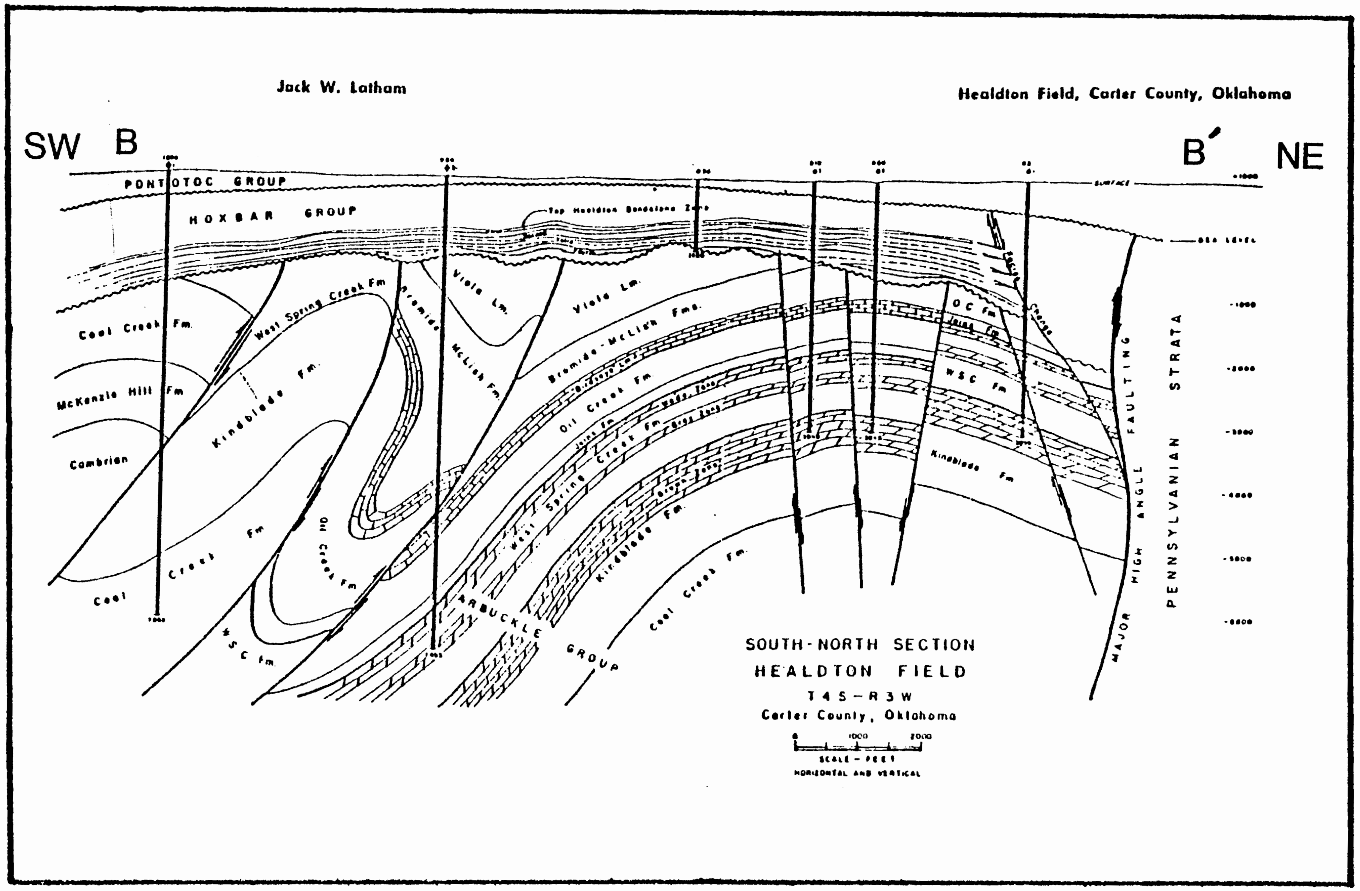


Figure 55. Subsurface Cross-Section in the Healdton Field. A High Angle Reverse Fault is Apparent Along the NE Side of the Field. Reverse or Thrust Faults to the SW Parallel the Axis of the Major Anticlinal Structure

stratigraphic relationships present in the Slick Hills (Plate 1).

I conclude that many other areas in southern Oklahoma may also have been influenced by transpressional deformation. While the structural geology of the Slick Hills may not be identical with that seen elsewhere in southern Oklahoma, there exists a compelling correspondence in the trends and styles of structural entities.

As far as further work in the Slick Hills is concerned, I believe that it would be very valuable to determine horizons within the Lower Paleozoic rocks which would lead to a better understanding of the stratigraphic relationships. It is also important that more stratigraphic marker beds be recognized for field mapping, so that minor fold styles and faulting can be recognized and understood more clearly. Considering the excellent quality of exposure (20-50%) as well as the total cooperation from land owners, the Slick Hills is an ideal region for the study of structure, stratigraphy and sedimentation in carbonate rocks.

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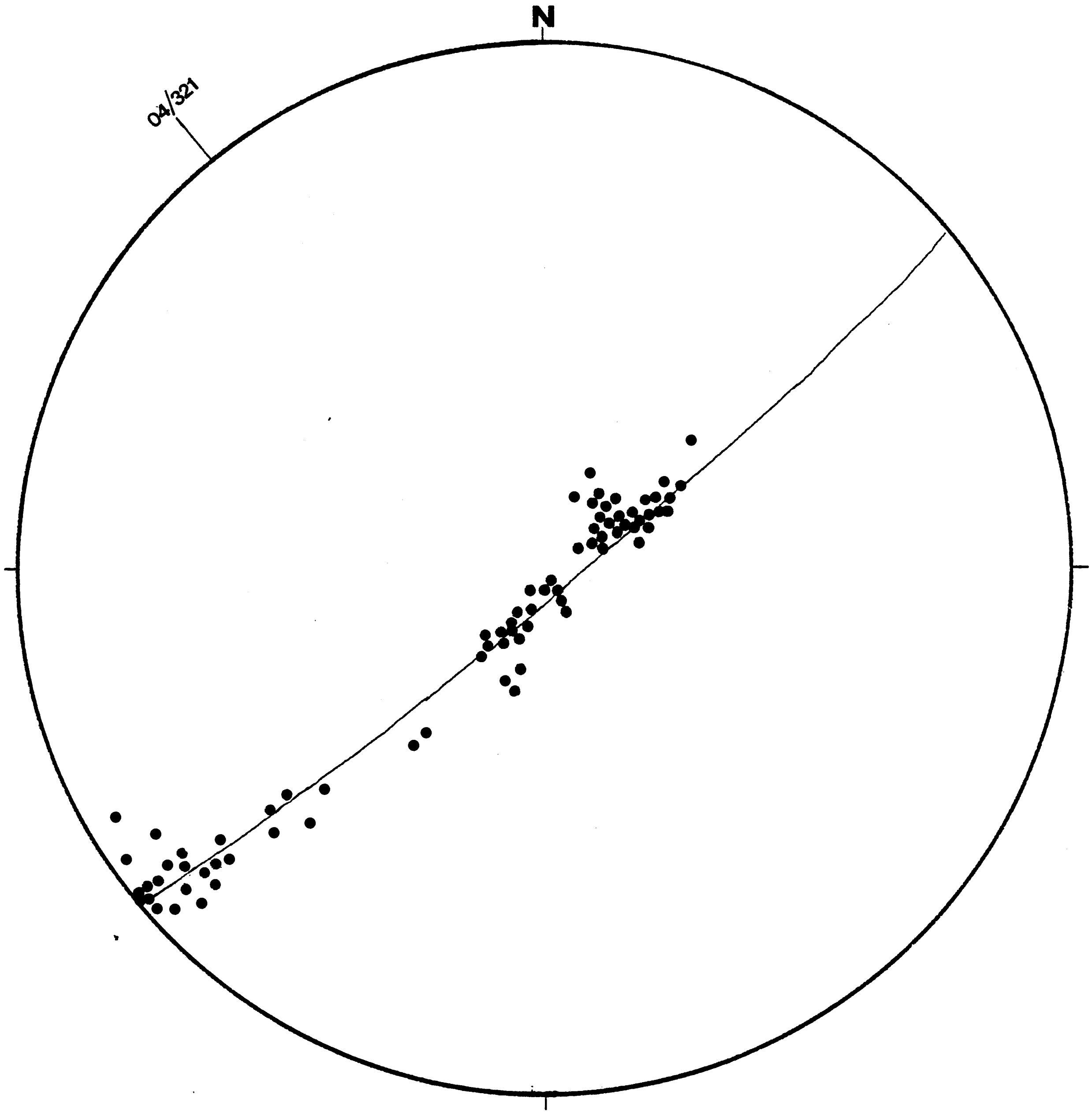
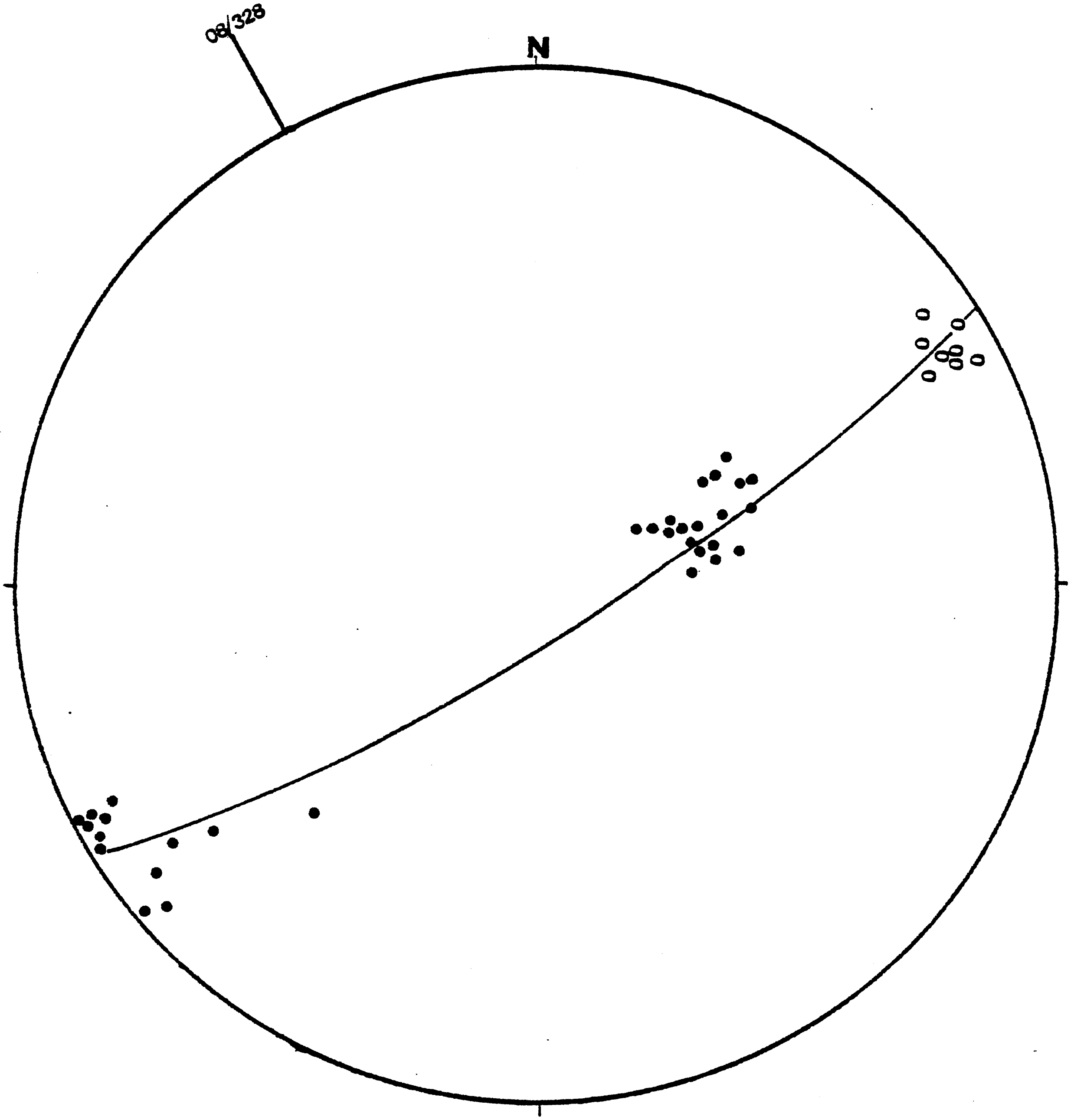
APPENDIX

EQUAL AREA NET REPRESENTATIONS OF SELECTED FOLDS IN THE SLICK HILLS



Oliver Syncline (OS)



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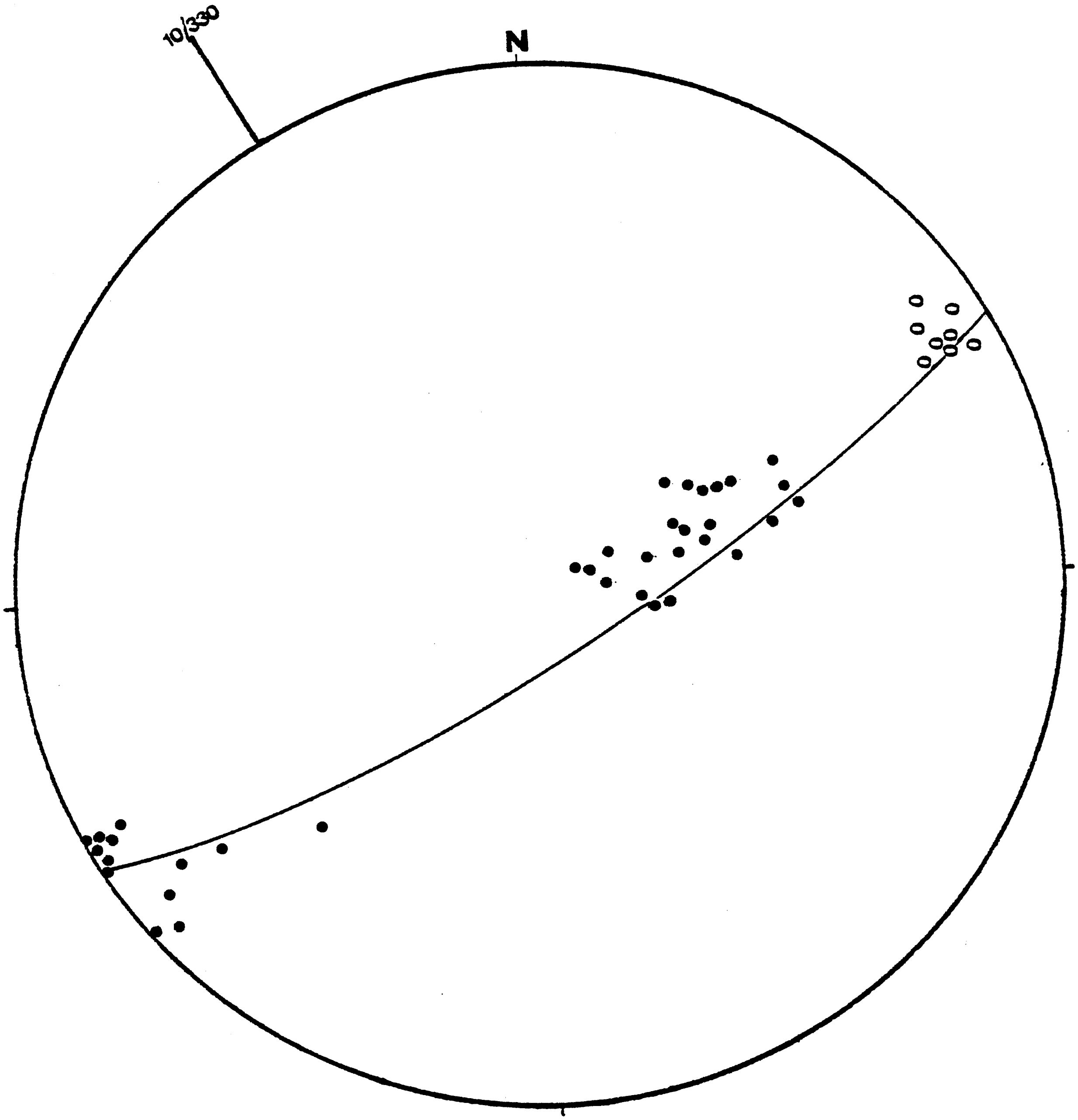
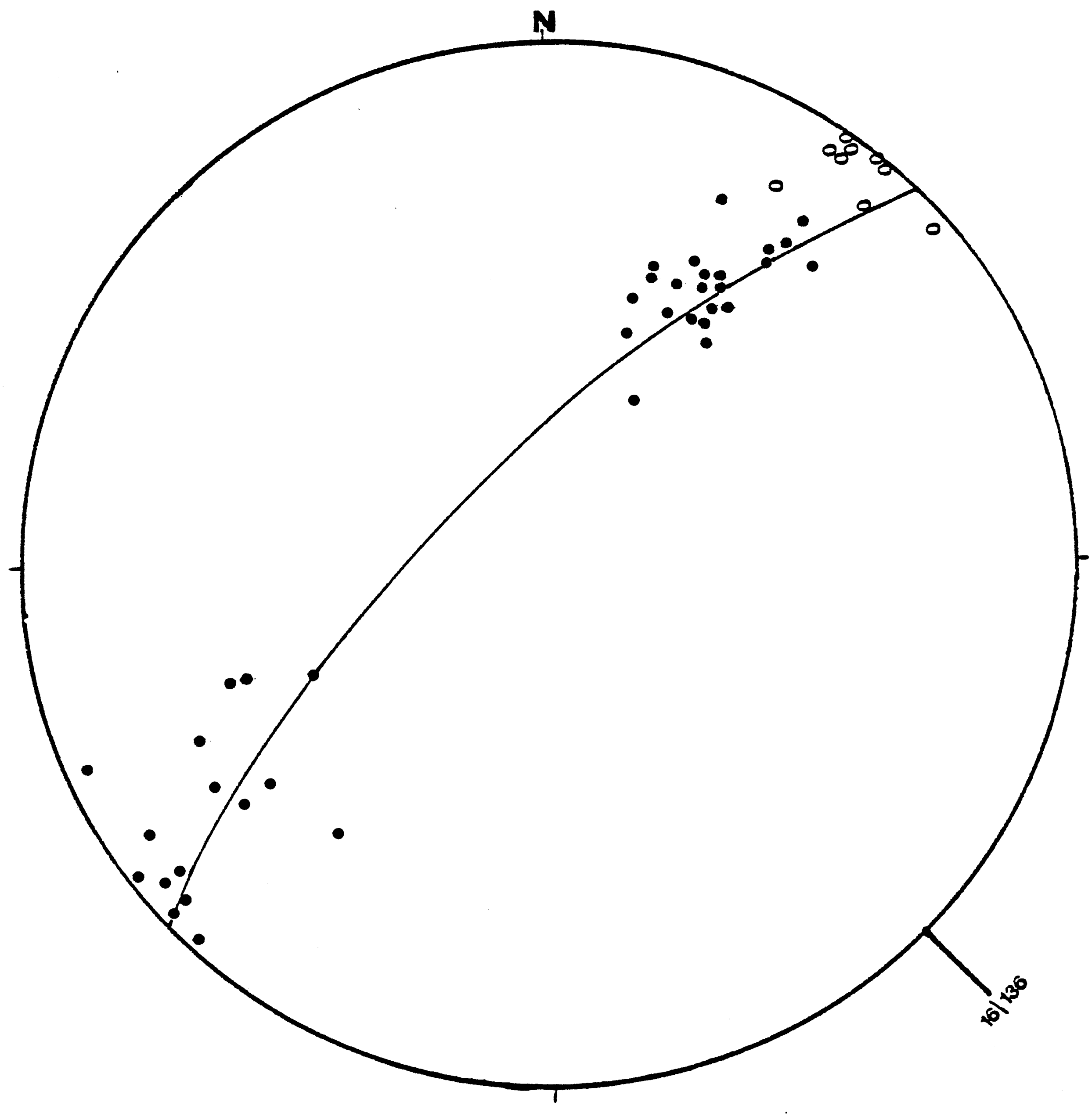
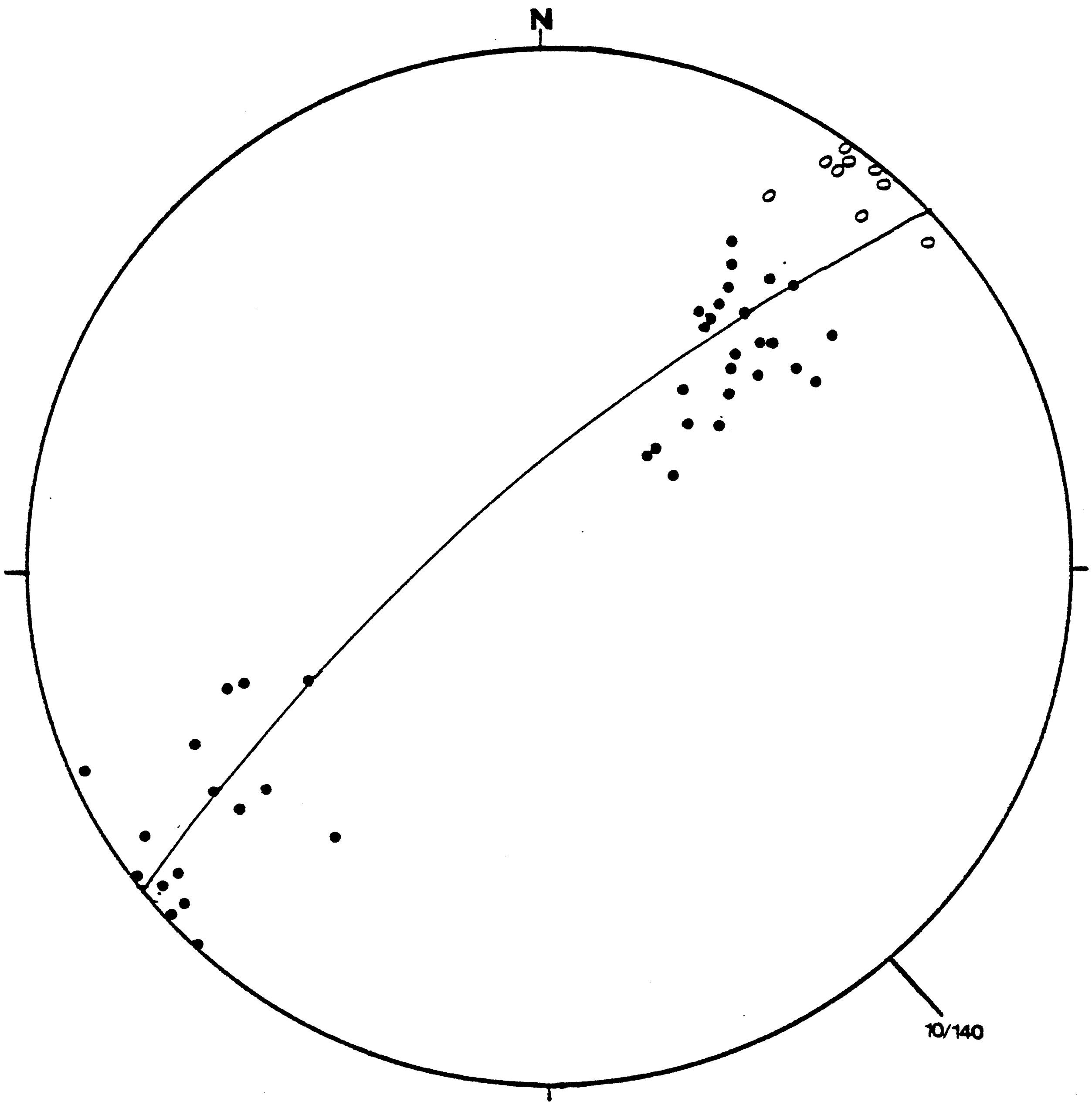


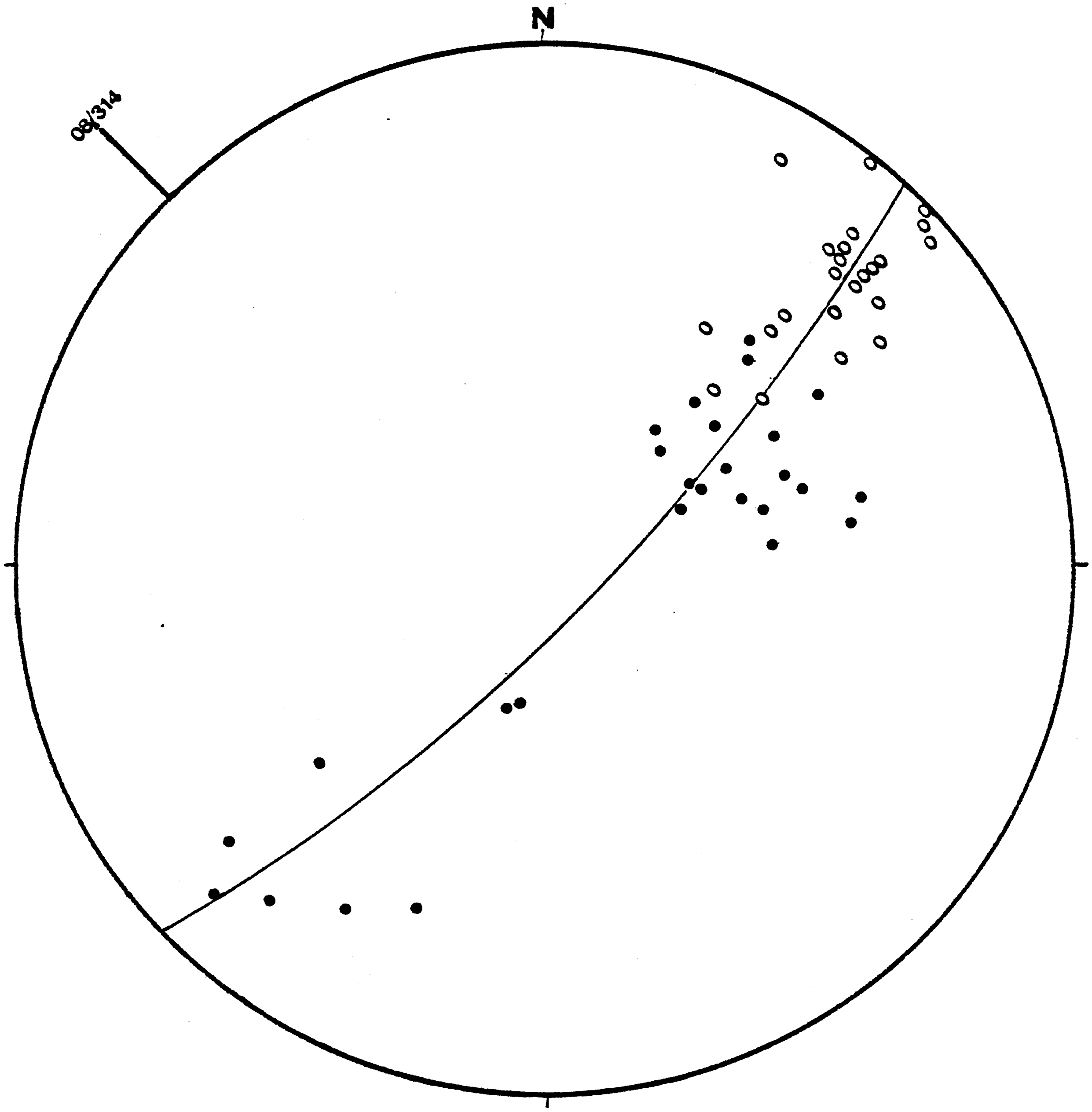
OSns8



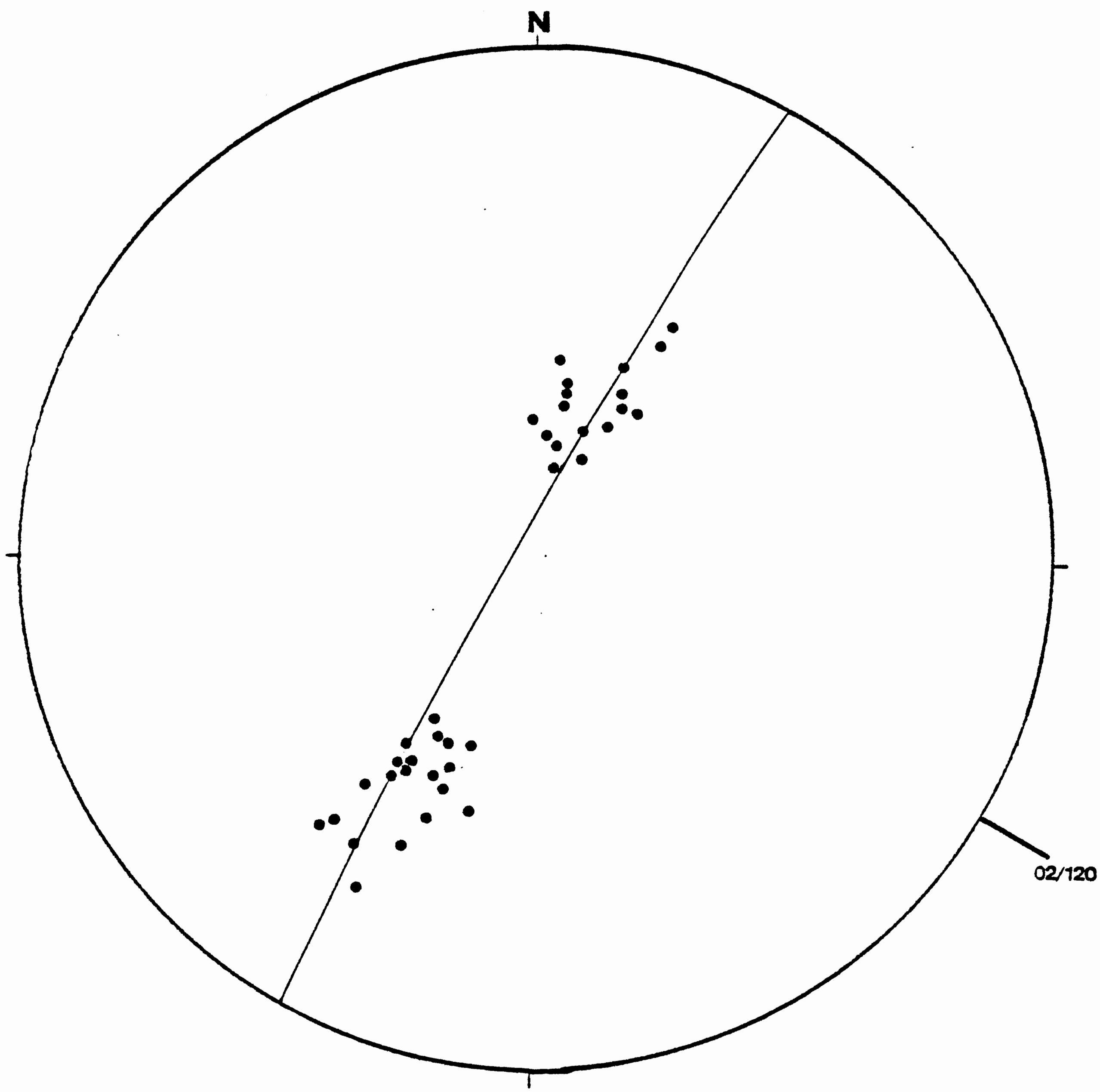
FAsa2



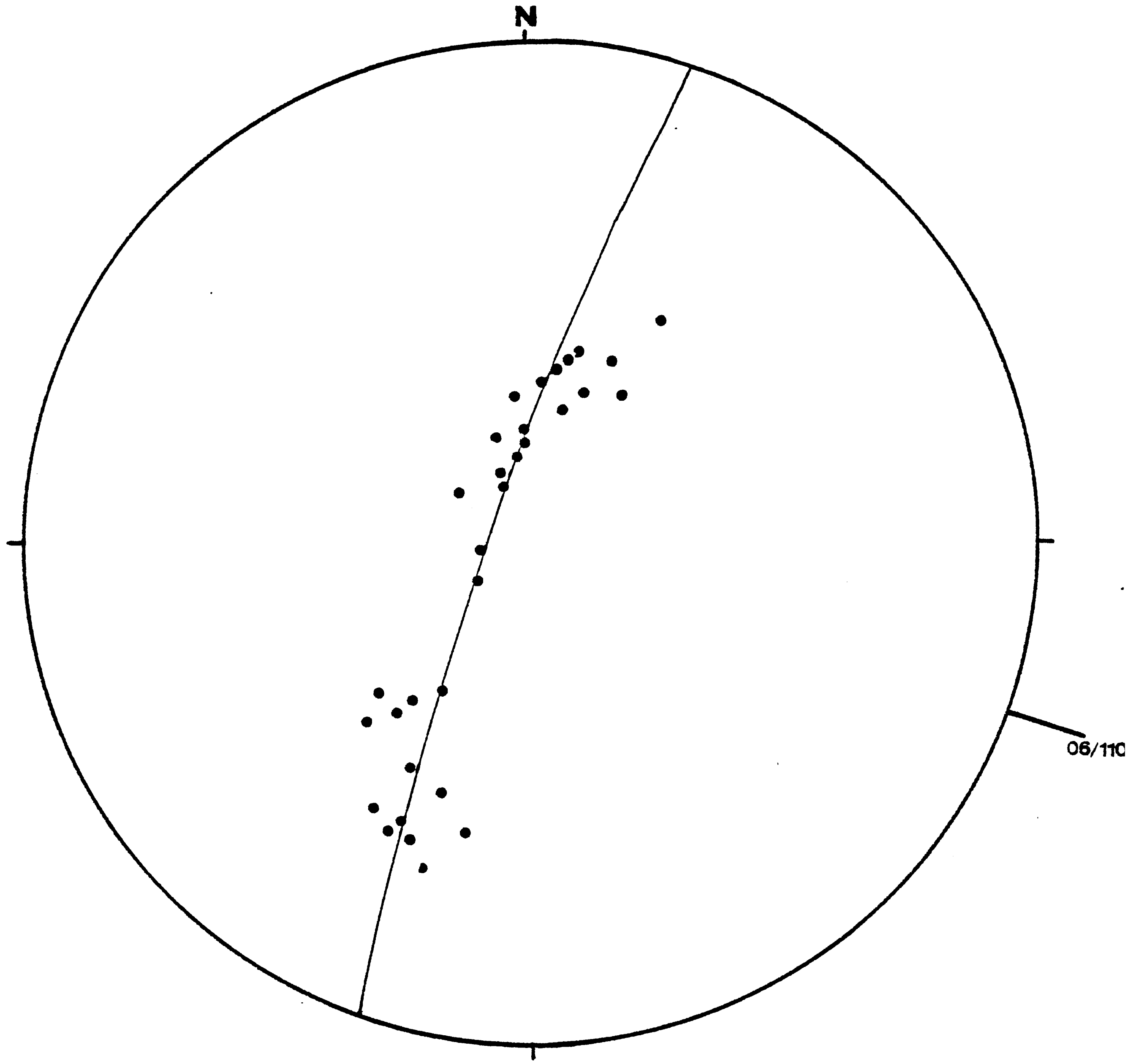
FAss1



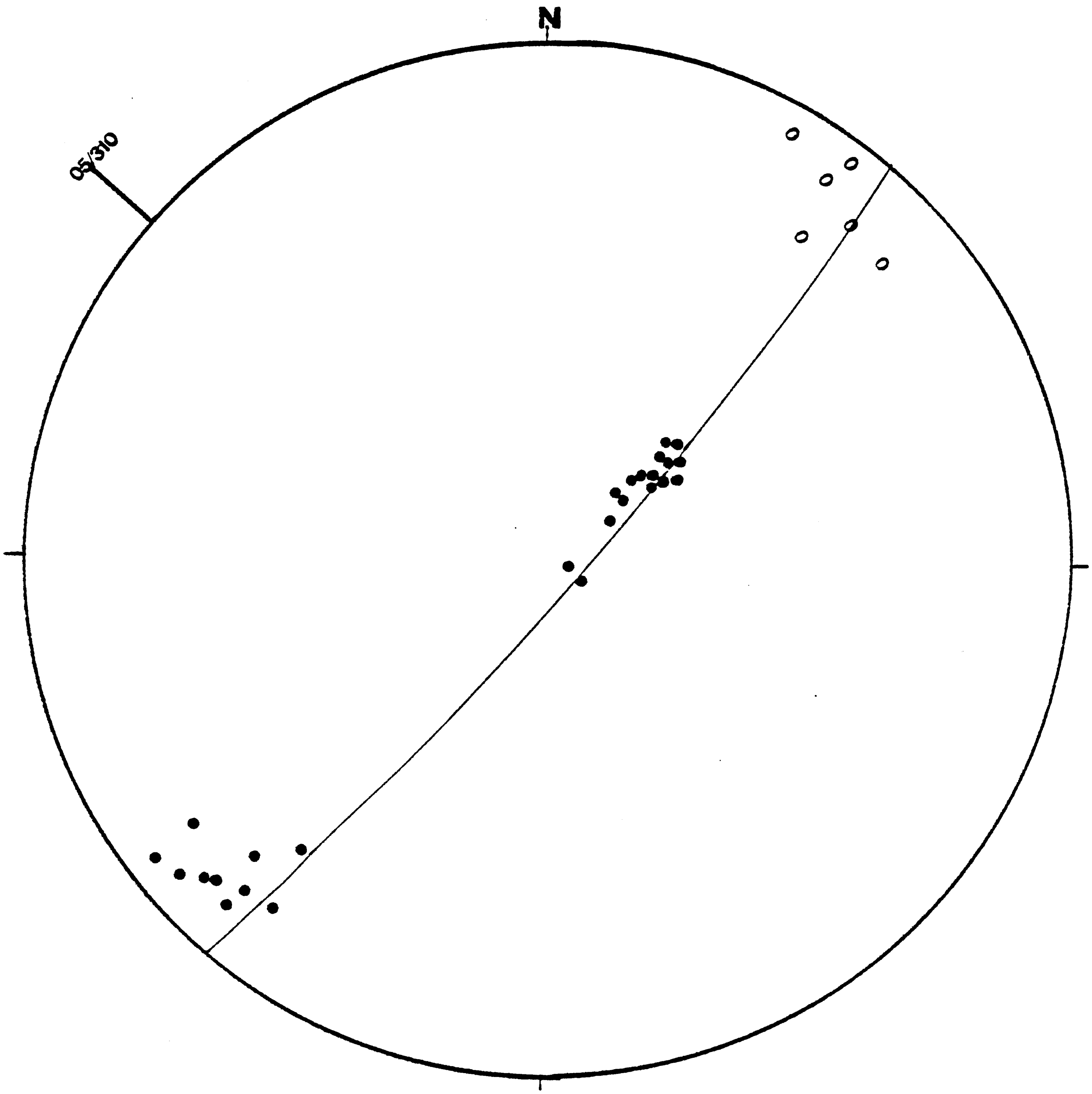
CAss1



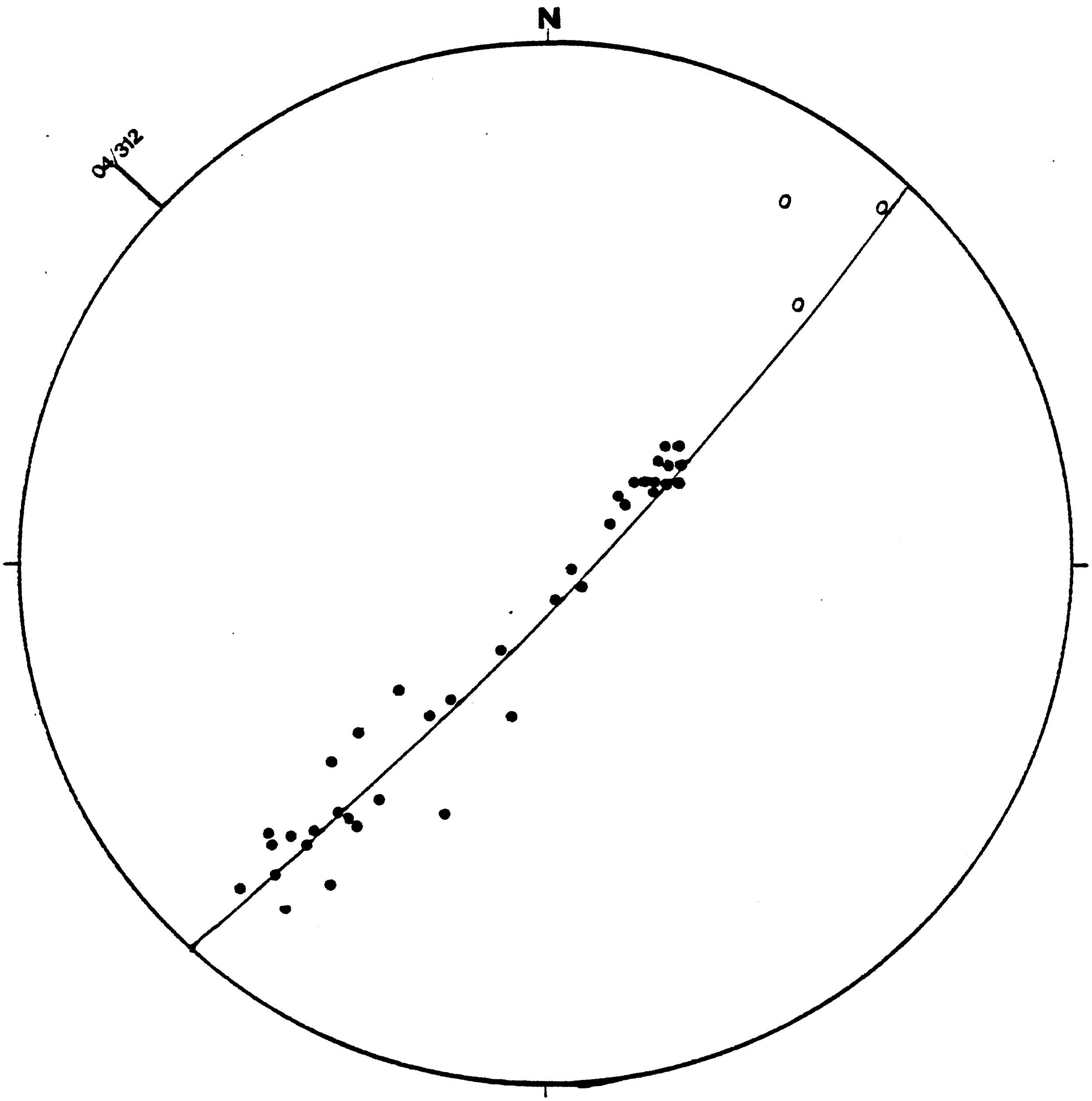
White Tail Anticline (WA)



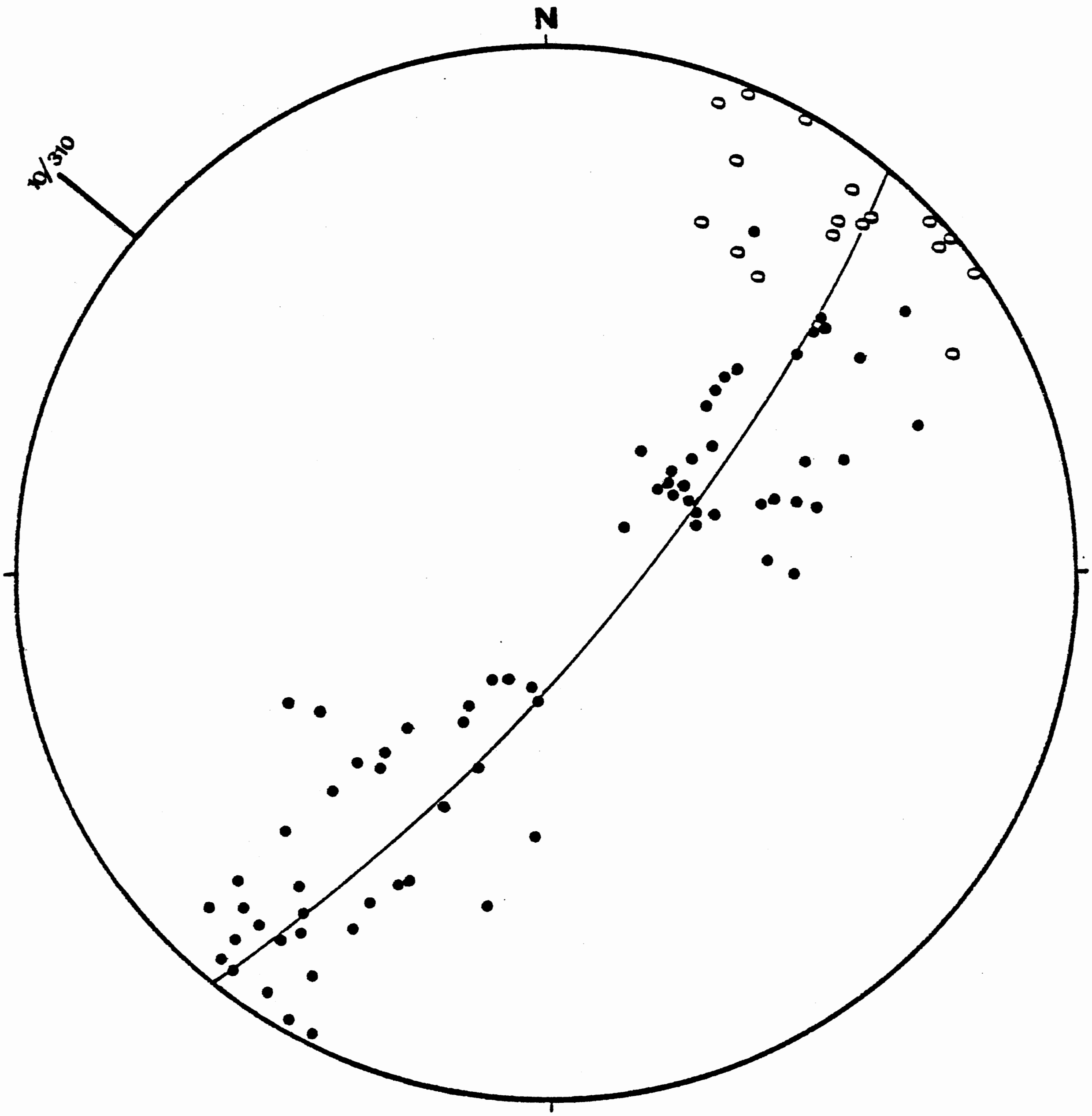
WAss1



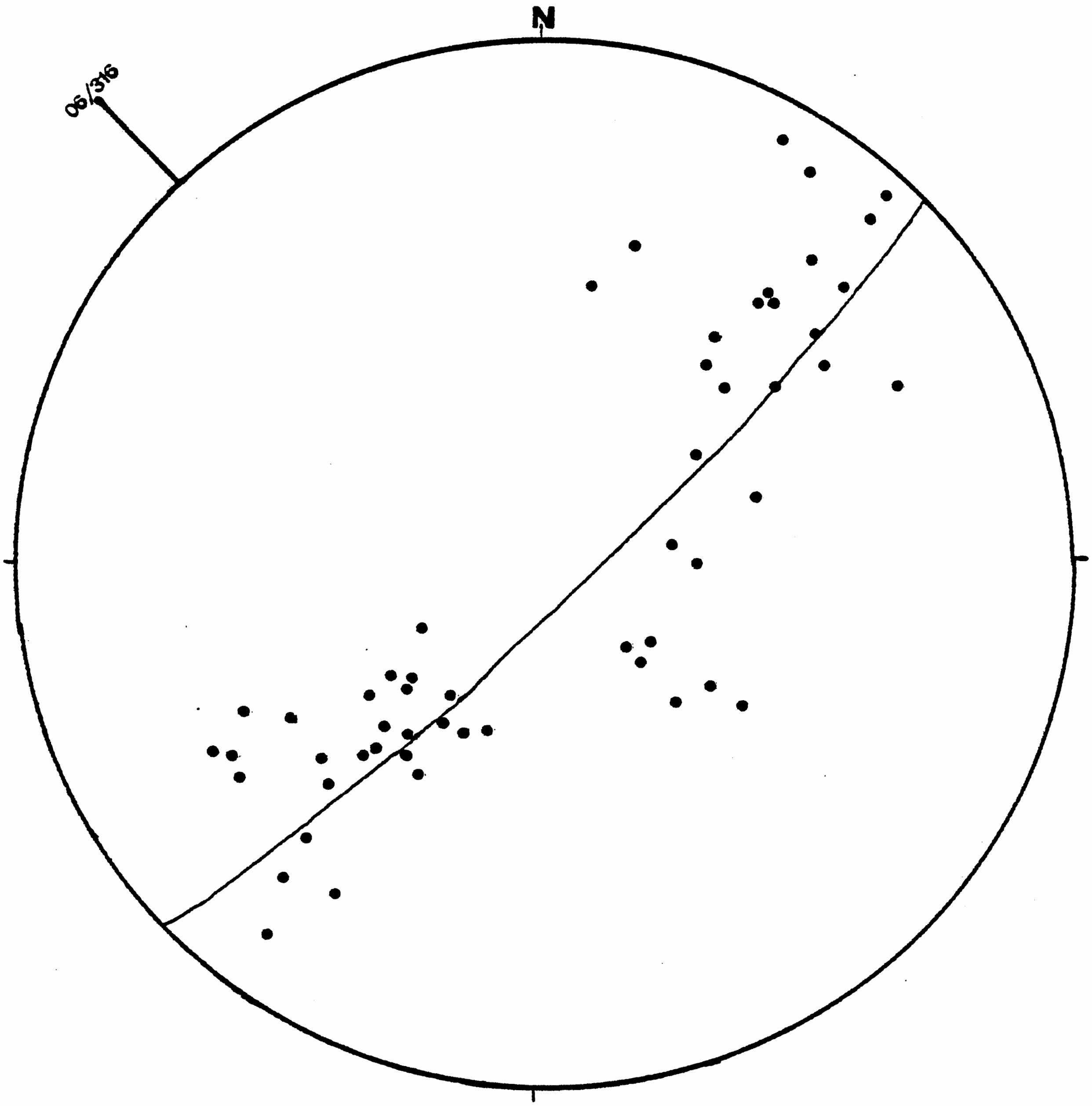
WAns1



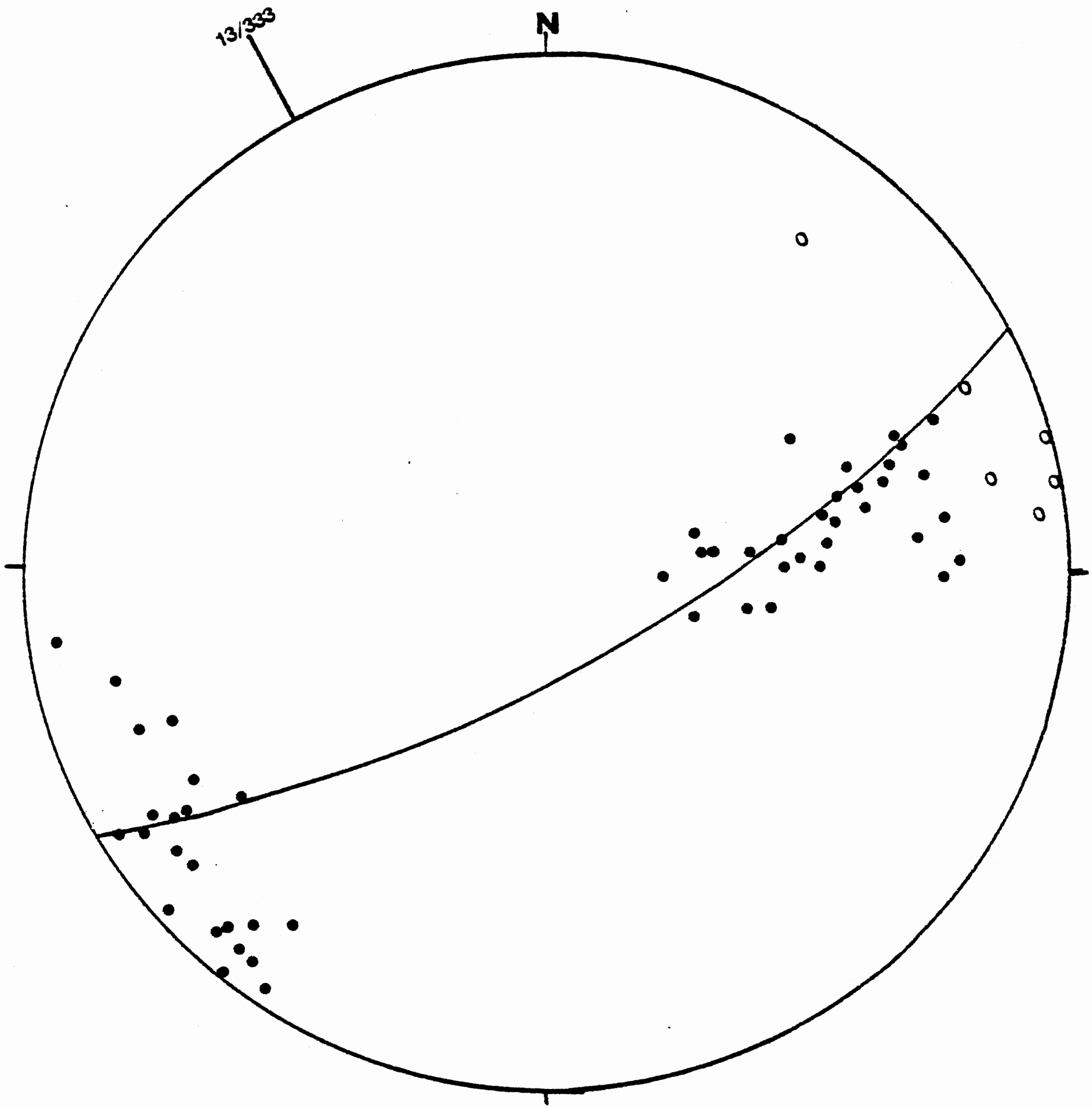
WAna2



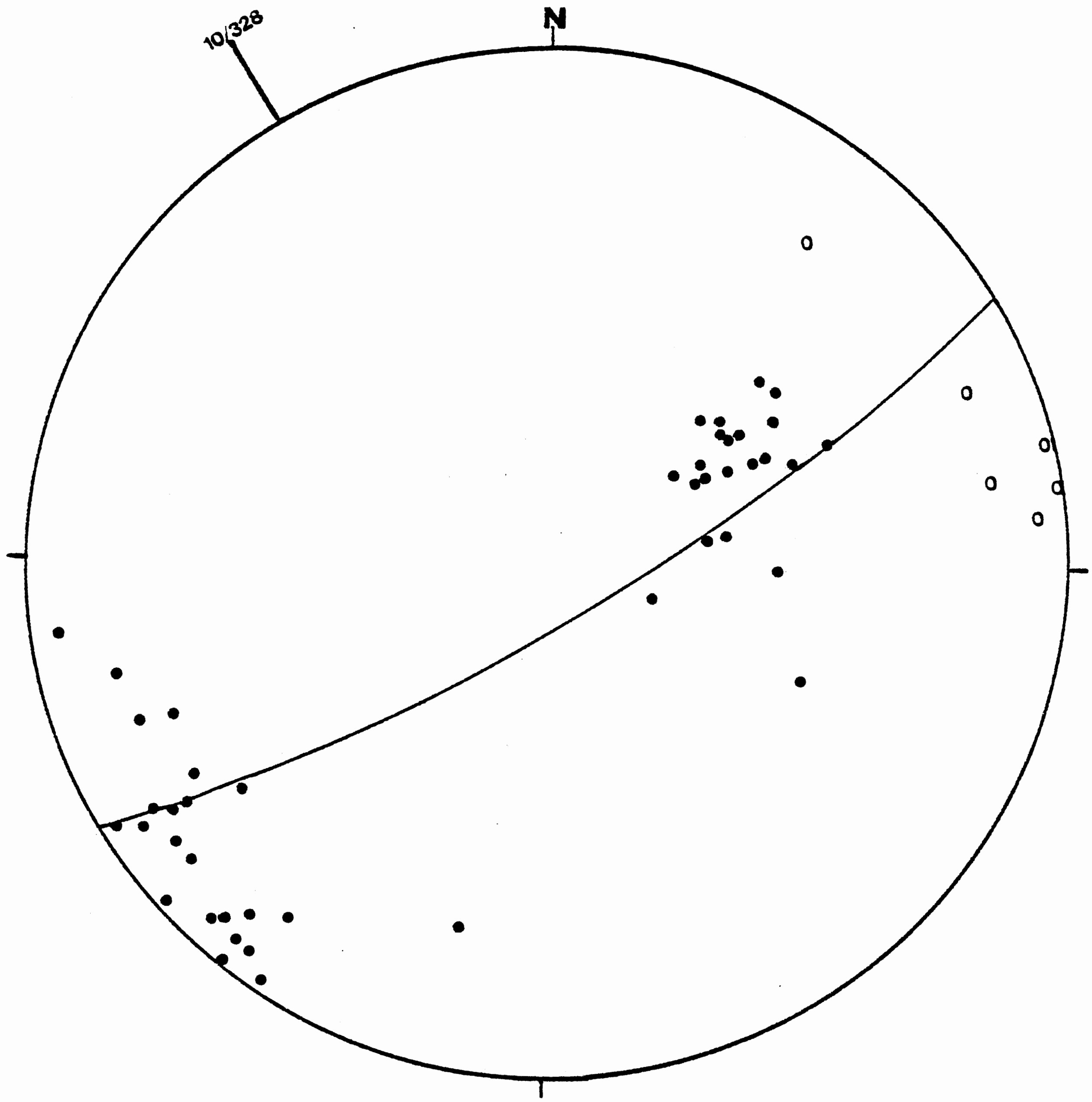
Kiowa Syncline (KS)



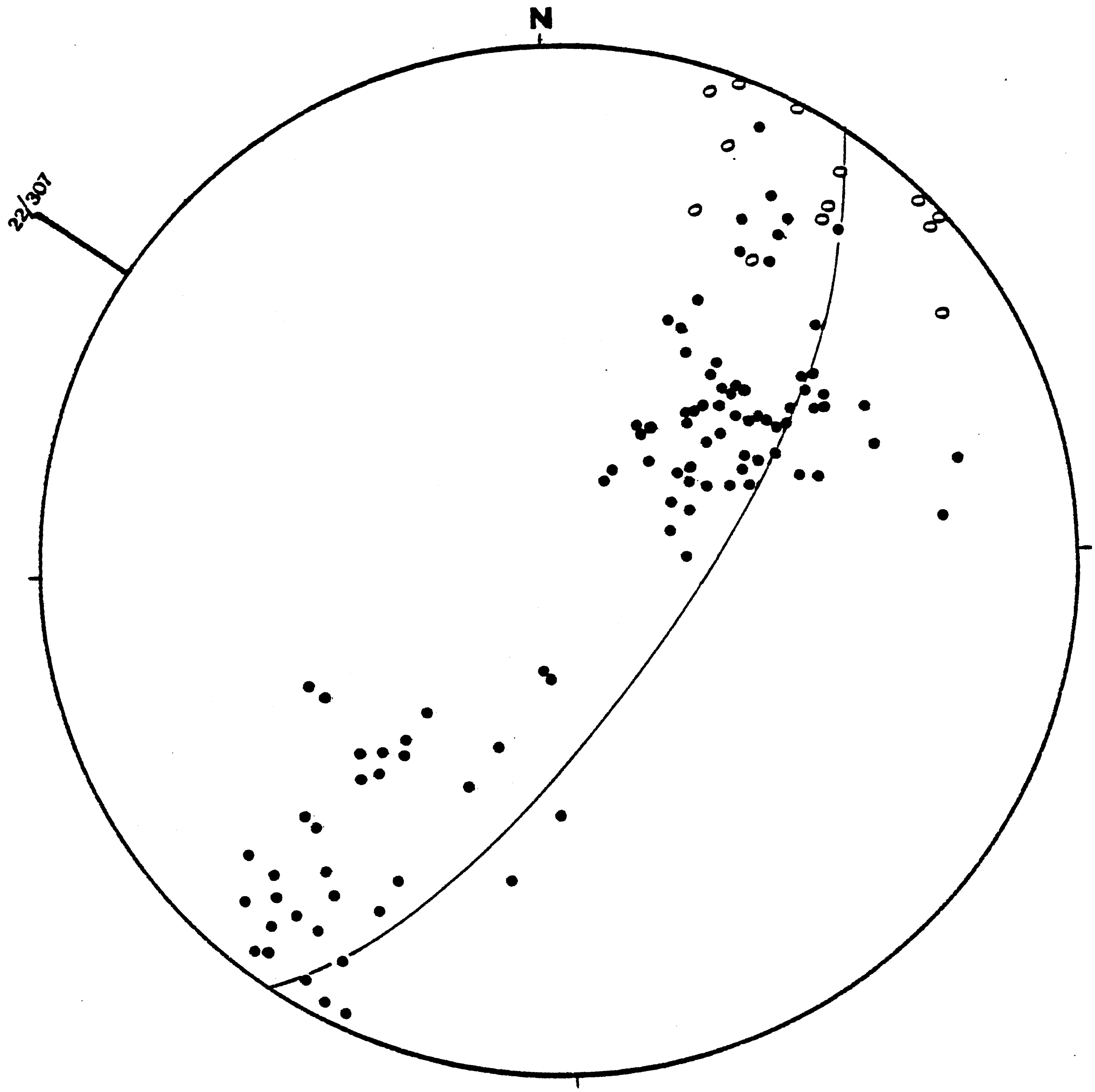
Indian Mission Anticline (IA)



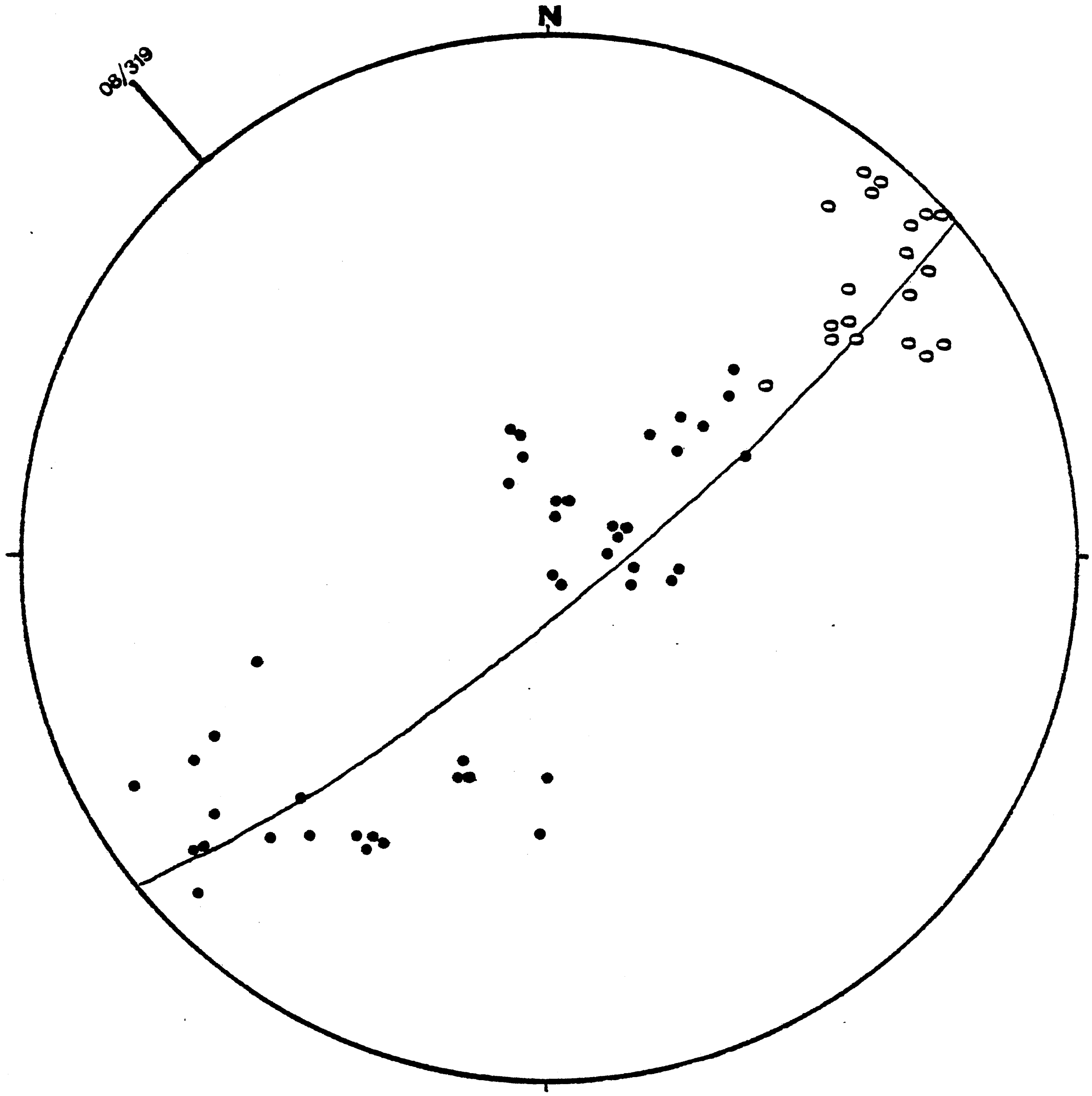
Bull Run Anticline (BA)



Bull Run Syncline (BS)



Comanche Anticline (CA)



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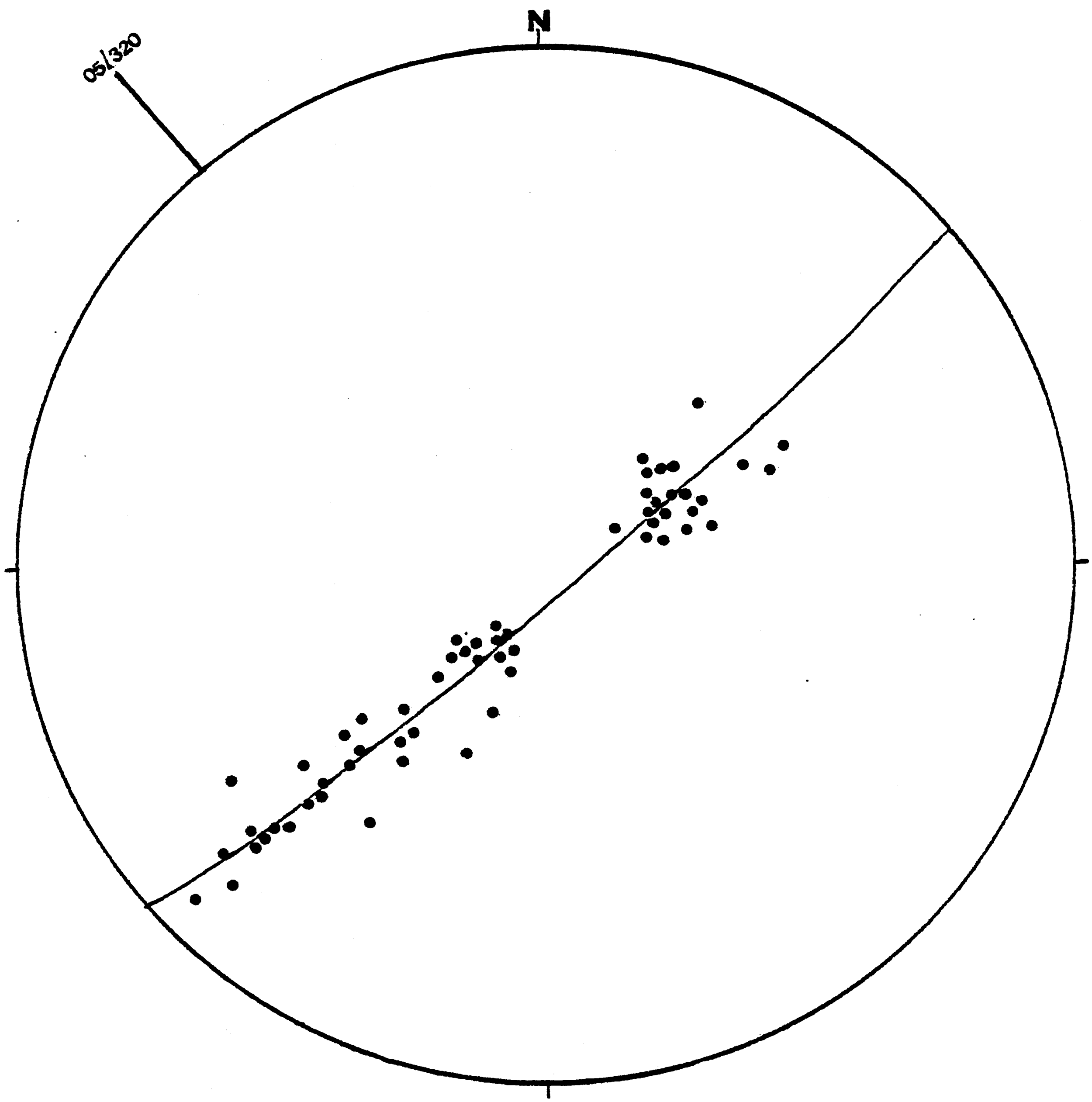
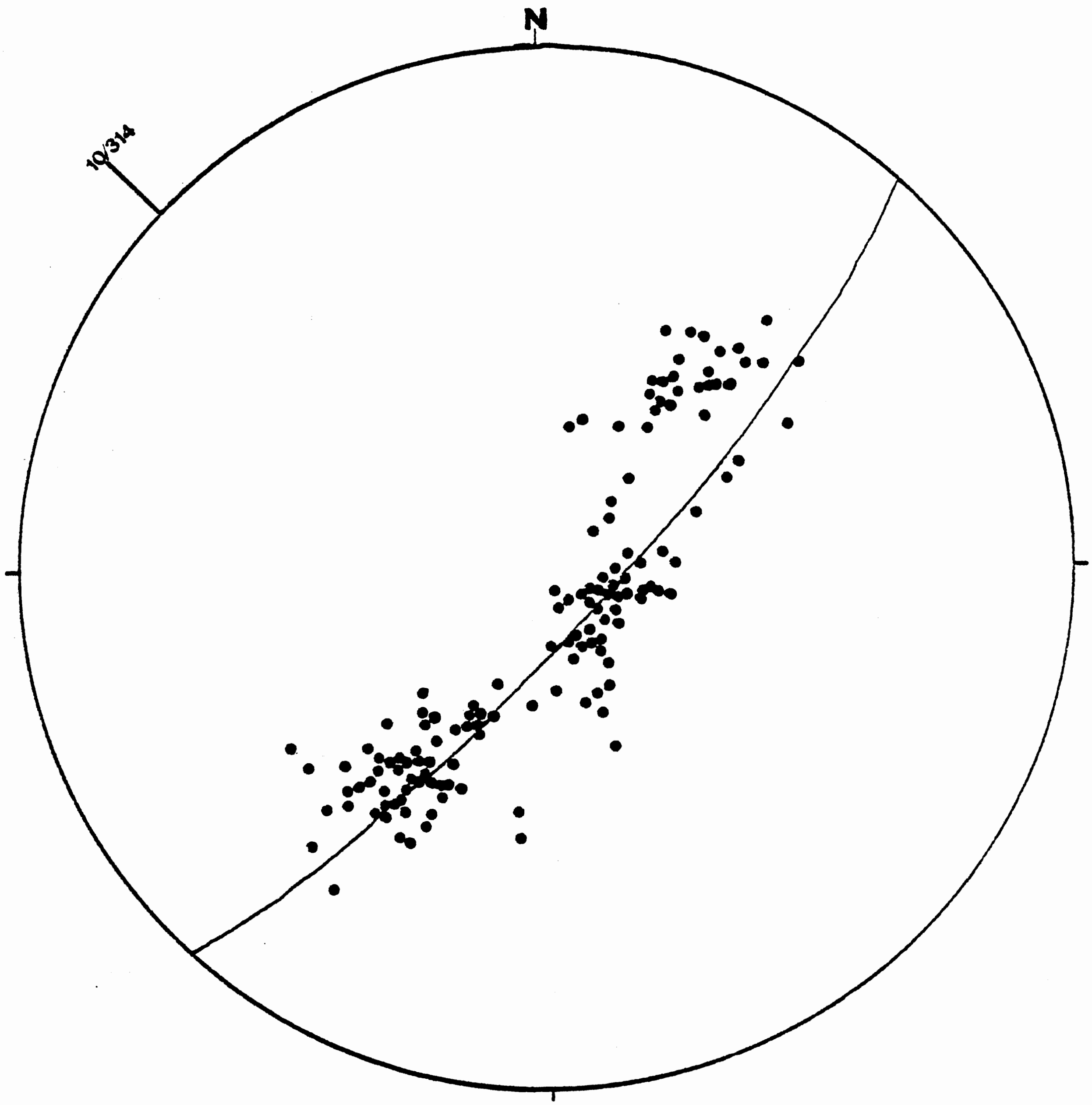
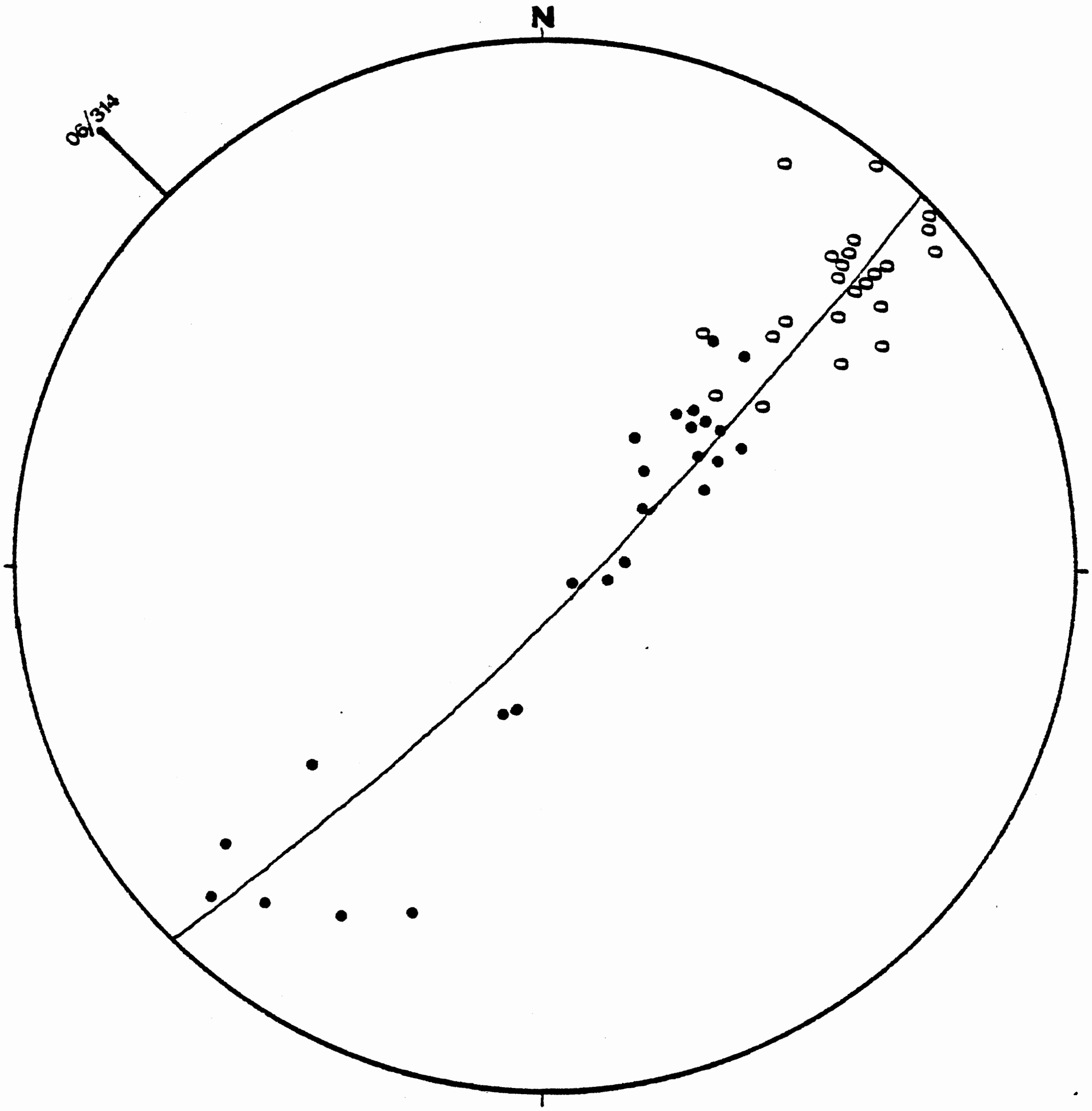


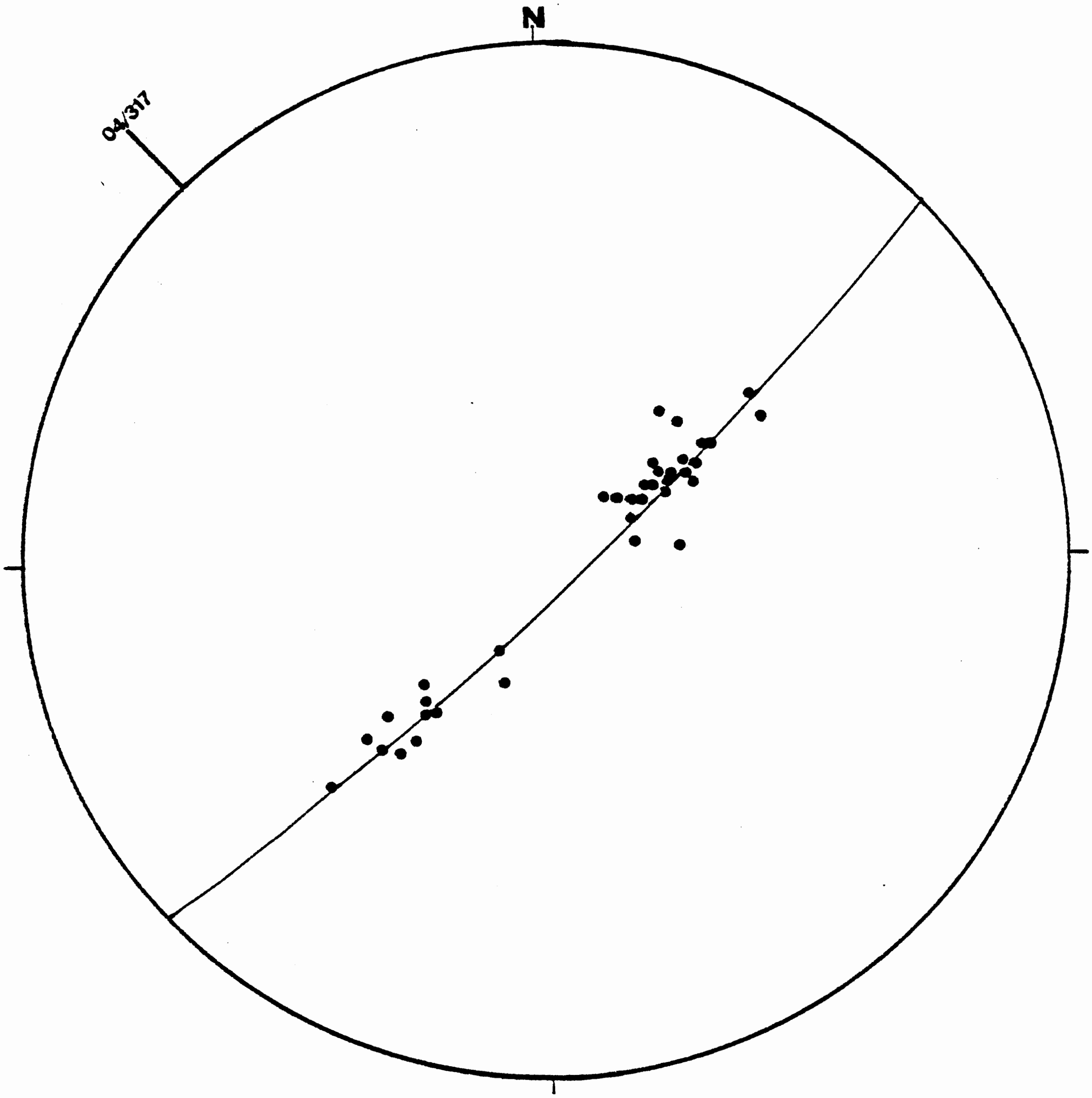
Diamondback Anticline (DA)



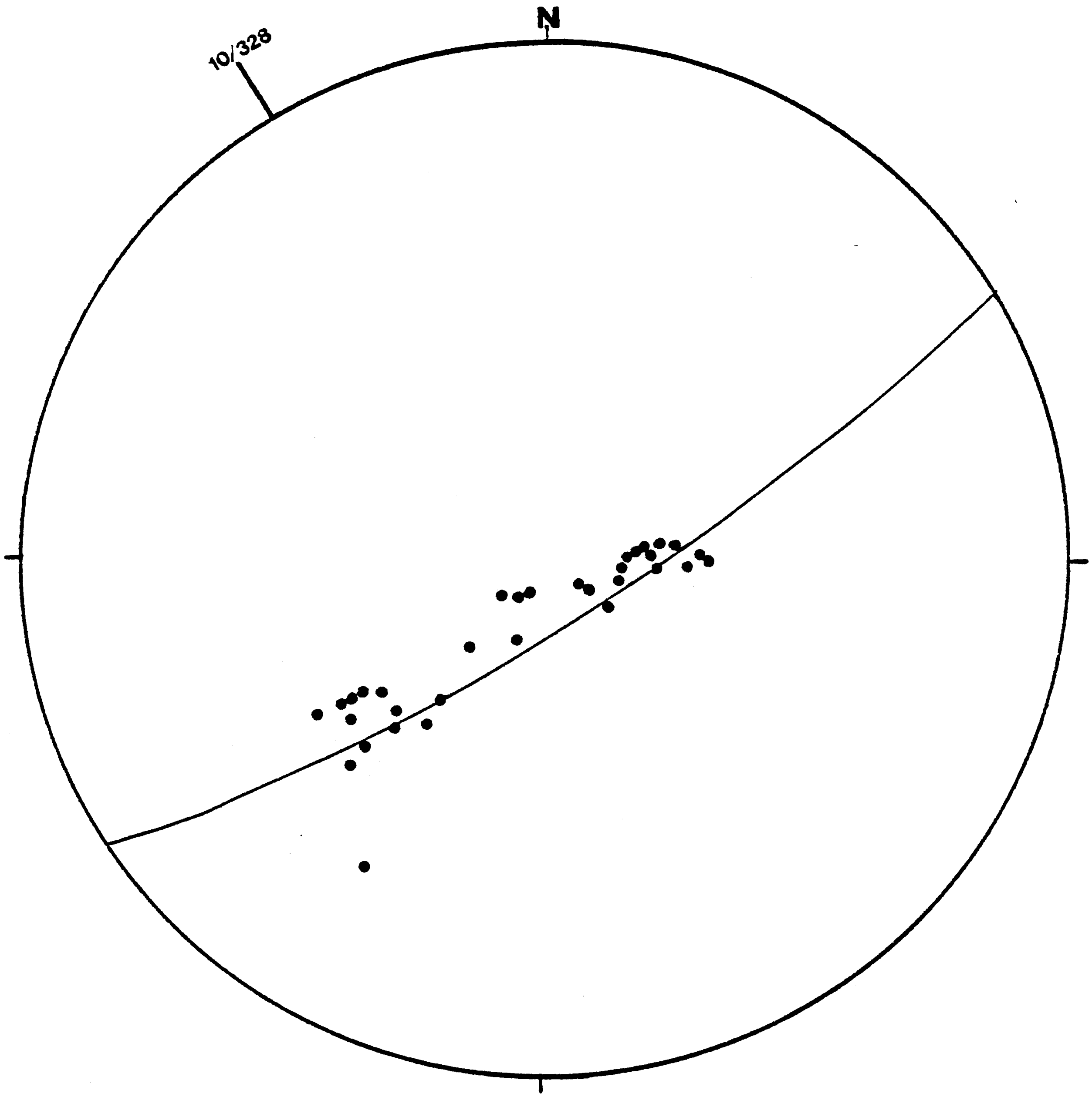
Saddle Mountain Syncline (SS)



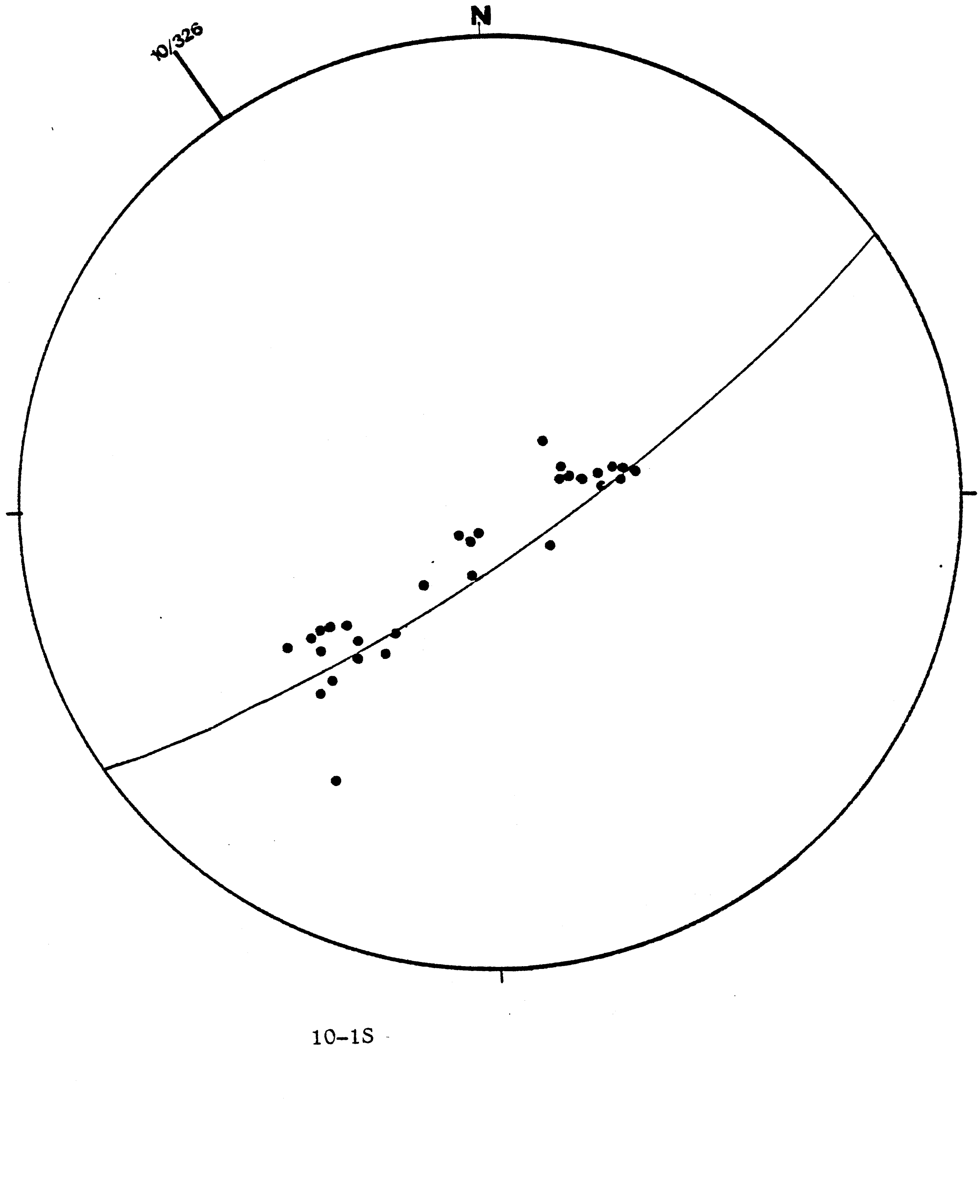
Forte Anticline (FA)



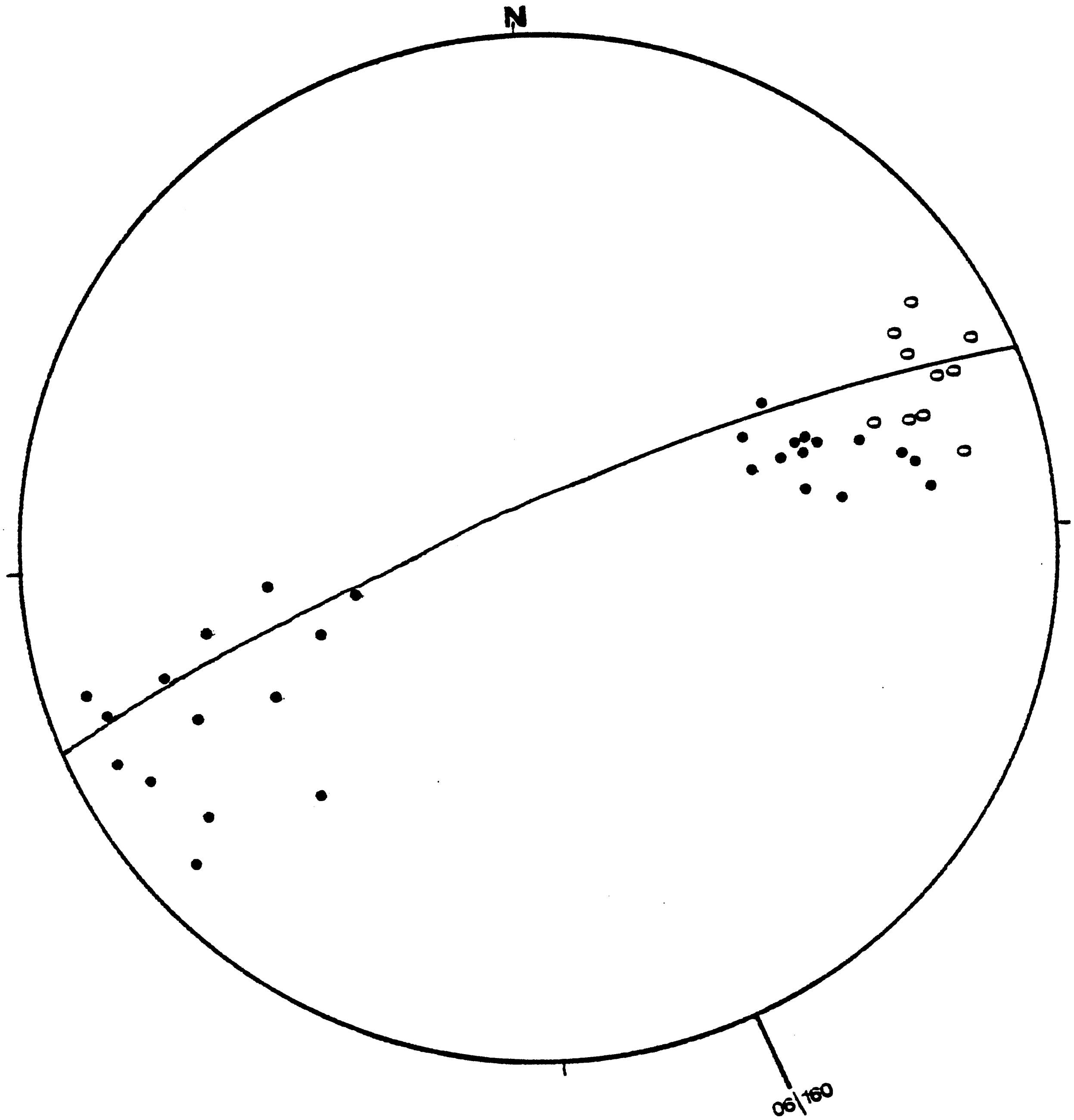
Prickly Pear Anticline (PA)



10–1A



10-1S



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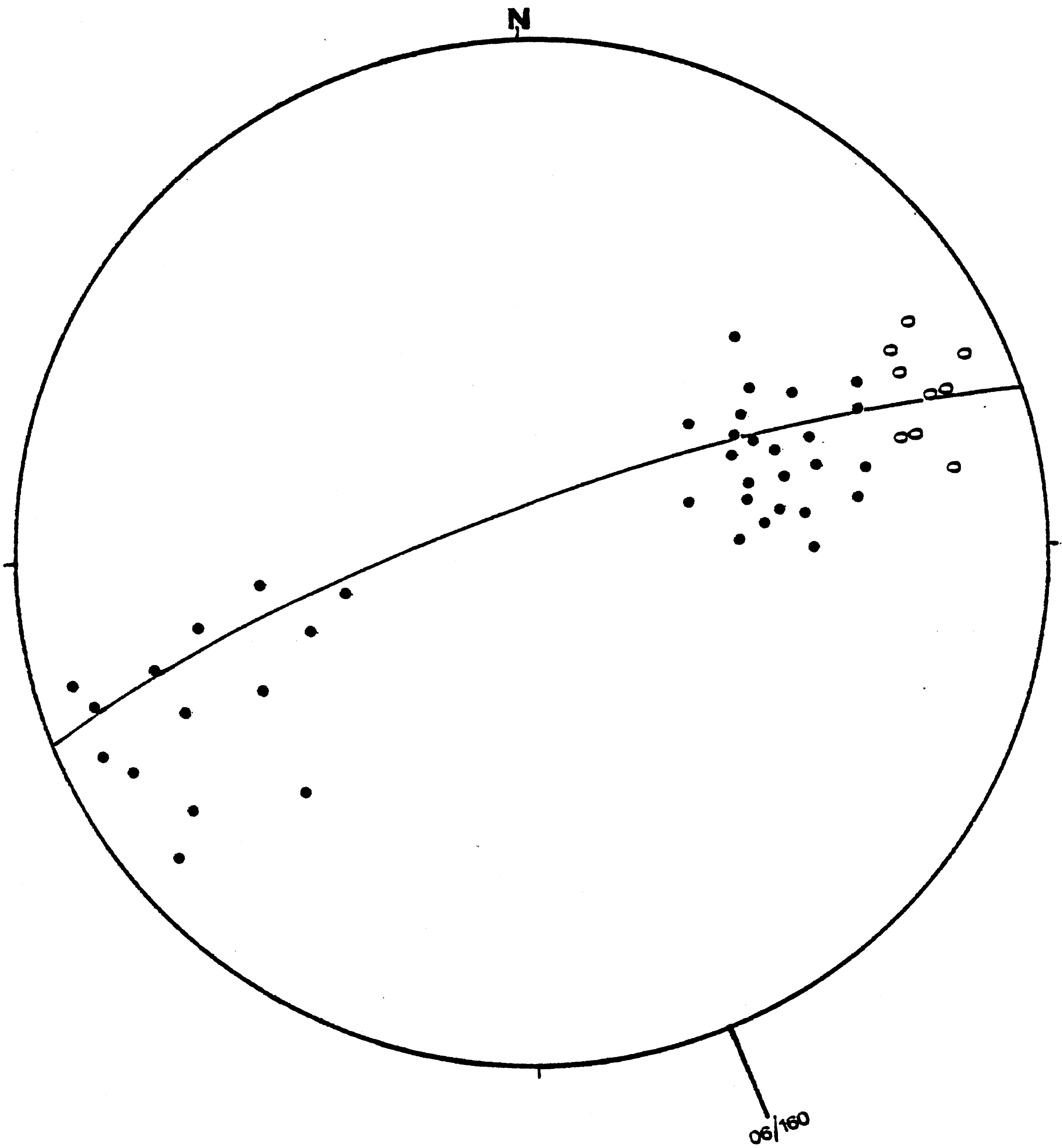

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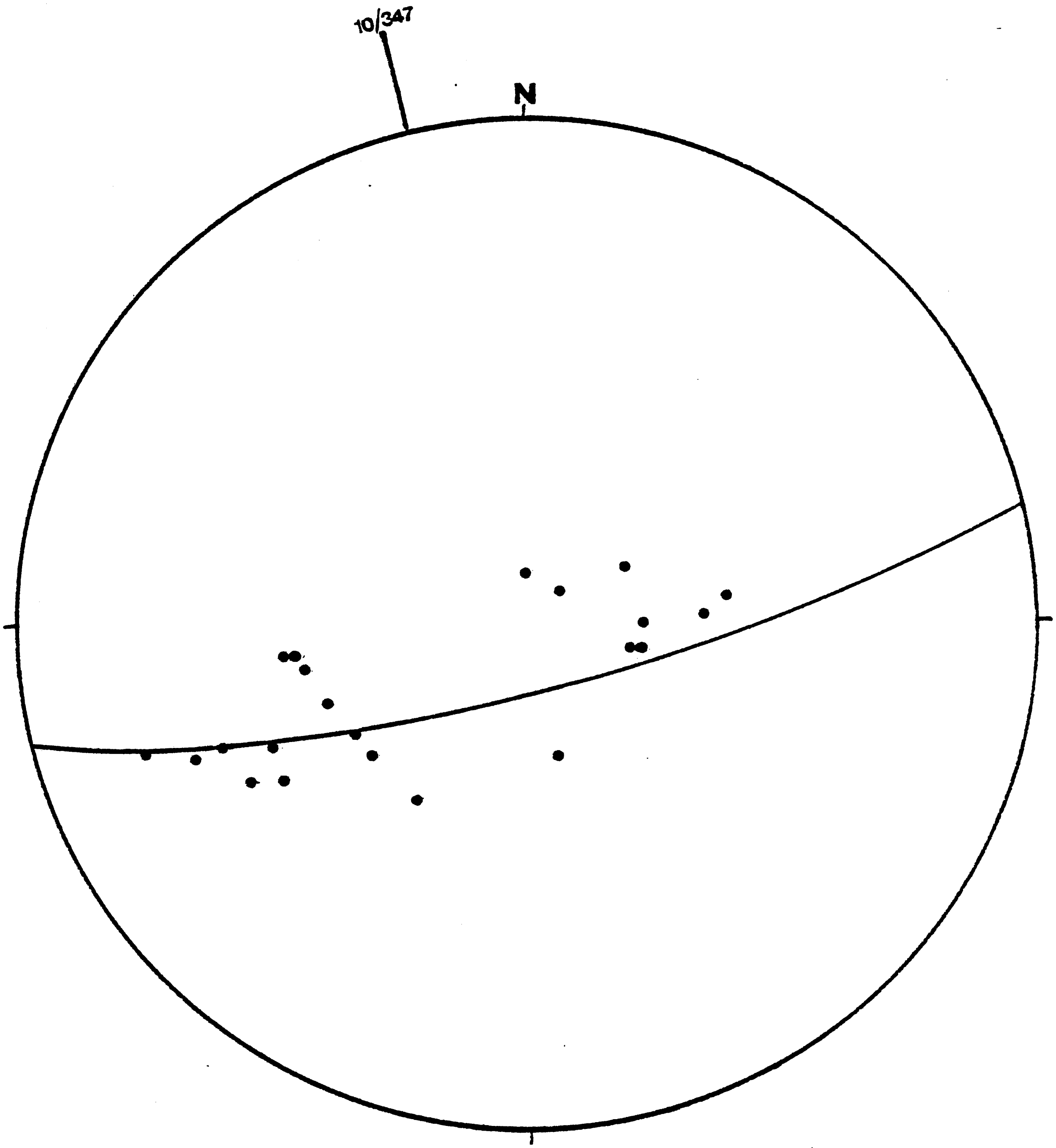

25–2A

VITA 2

Weldon Harold Beauchamp

Candidate for the Degree of

Master of Science

Thesis: THE STRUCTURAL GEOLOGY OF THE SOUTHERN SLICK HILLS, OKLAHOMA

Major Field: Geology

Biographical:

Personal Data: Born in Duncan, Oklahoma, March 2, 1959, the son of Edward and Barbara Fitkin.

Education: Graduated from Casady School, Oklahoma City, Oklahoma, in May, 1977; received Bachelor of Arts degree in Geology from New England College, Henniker, New Hampshire, in May, 1982; completed requirements for the Master of Science degree at Oklahoma State University in July, 1983.

Professional Experience: Mud Logging Engineer, Mills Well Logging Service, 1980; Laboratory Assistant, New England College, 1980-1981; Consulting Geology, Energy Resources Institute, 1981-1982; Teaching Assistant, Oklahoma State University, Department of Geology, 1982-1983; Summer Project Geologist, Sun Gas Company, 1982; Associate Production Geologist, Sun Production Company, 1983; member of American Association of Petroleum Geologists, 1982-1983; member of the Oklahoma City Geological Society, 1982-1983.