Journal of the Arkansas Academy of Science

Volume 32 Article 25

1978

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ABSTRACT

Photogeologic and field mapping of a 530 mi² area in southeastern Washington and southern Madison Counties, Arkansas, indicates that post-Atoka structural deformation occurred primarily through differential uplift of basement fault blocks. Northeast and east trending basement faults and fracture systems are present. Northeast trending features are related to the major fracture systems of the stable continental interior. They were initiated by shearing during Pre-Cambrian time and have subsequently acted as crustal zones of weakness along which mostly vertical movement has occurred. East trending basement faults may have originally developed as a result of tension between the stable Ozark uplift and the subsiding Arkoma basin during late Atokan time. Northeast and east trending faults join to form a mosaic of polygonal basement blocks. During post-Atoka uplift(s) of the Ozark region, each block behaved more or less independently. Normal faults and (more commonly) monoclinal draping occurred in the sedimentary rocks which overlie the marginal basement fault zones. Slight tilting and warping of the blocks created local homoclinal dips whose magnitude and direction may change abruptly at block margins. Structural highs occur at the most elevated margin or corner of each block.

Horizontal compression during the Ouachita orogeny possibly accounts for several gentle east trending folds in the Pettigrew area. An anomalous dome structure near Witter may be related to a local high on the Pre-Cambrian basement surface.

INTRODUCTION

The northern Boston Mountain area of northwest Arkansas has undergone mild structural deformation. Broad expanses of nearly flat-lying beds are broken by small-displacement faults and monoclines. Low amplitude anticlines and shallow synclines occur locally. Mapping of these structural features has been hindered previously by a lack of large-scale topographic base maps and by an apparent lack of mappable stratigraphic units in the widespread Atoka Formation. Recent publication of 7½-minute topographic quadrangles, in combination with the recognition of three widely mappable sandstone units in the lower Atoka, now permit detailed geologic mapping (Hoover, 1976; Kelley, 1977; Shinn, 1977).

This study is a description of the magnitude, orientation and spatial relationships of structures occurring within a relatively large area in the northern Boston Mountains. These features form a pattern which suggests that regional tectonic deformation has occurred primarily through differential uplift and tilting of large crustal blocks. Horizontal compression has played a relatively minor role in the development of this regional pattern.

LOCATION

The name Brentwood-St. Paul area is applied to a 530 mi² area in northwest Arkansas which includes all or most of T. 13-15 N., R. 25-29 W. The area lies primarily within southeastern Washington and southern Madison Counties. Small portions of northern Crawford, Franklin and Johnson Counties are also included. Topographic relief within this area is moderate to rugged. Elevations range from about 1000 feet to over 2500 feet. Differential erosion of nearly horizontal sandstone and shale units has created a characteristic bench and bluff topography.

PREVIOUS INVESTIGATIONS

The westernmost portion of the study area was originally mapped by Simonds (1891) and Purdue (1907) who each reported minor structural deformation. In master's thesis investigations by Kimbro (1960), Bishop (1961), McEntire (1964) and Phifer (1967), elements of the northeast and east trending fold series described by Quinn (1959) were reported in the Brentwood-St. Paul area. No evidence supporting the existence of these structures was found in the present investigation.

Middle Bloyd stratigraphy and structure of the Witter area (Madison County) has been described recently by Berry (1978). Kelley mapped lower Atoka units in southeastern Washington County (1977).

METHODS

The Brentwood-St. Paul area was mapped primarily through photogeologic techniques. These techniques are similar to those employed by Desjardins and Hower (1939) and Nugent (1947) in mapping areas of gently dipping strata, and were used recently in a study of the structure of southern Washington and northern Crawford Counties (Shinn, 1977).

Three ledge-forming sandstone units in the lower Atoka Formation were identified and traced throughout the area on stereoscopic aerial photography. The positions of the units were then transferred to 1:24,000 scale topographic quadrangles. Systematic changes in elevations of mapping units result from subtle structural deformation. Structural features were described through the preparation of structure contour maps of the tops of the first and third Atoka sandstones, employing a 40 foot contour interval.

Field investigations were used to aid and confirm photographic interpretation. Fifteen measured sections were made of the upper Bloyd and lower Atoka Formations, using an altimeter and hand level. Additional field studies were concentrated in areas of relative structural complexity, particularly along the Drakes Creek structural lineament.

STRATIGRAPHY

The Pre-Cambrian igneous basement of the Brentwood-St. Paul area is overlain by a maximum of approximately 4000 feet of Paleozoic sedimentary rocks. Most pre-Pennsylvanian rocks are carbonates. The Pennsylvanian Hale, Bloyd and Atoka Formations are predominantly composed of sandstone and shale. In this study, structural fea-

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tures were delineated by observing elevation changes of the tops of three sandstone units in the lower Atoka Formation. The units are blanket deposits of thin- to thick-bedded, very fine- to fine-grained quartzarenite which probably formed through seaward progradation of beach-barrier island complexes (Hoover, 1976). The sandstone units are separated by shale intervals which record episodes of marine transgression. Figure 1 is a stratigraphic section which illustrates the lateral persistence of the Atoka sandstone and shale units within the northern portion of the study area. In southeastern Washington County, the underlying Trace Creek Member of the upper Bloyd Formation is composed entirely of black shale and siltstone. In Madison County one or more prominent sandstone units occur within the Trace Creek. These upper Bloyd sandstones apparently extend into Franklin and Johnson Counties where, in the subsurface, they have hitherto been recognized as lower Atoka units (Corbin, thesis in preparation).

STRUCTURAL GEOLOGY

The Brentwood-St. Paul area lies on the southern margin of the east trending northern Arkansas structural platform (Chinn and Konig, 1973). Regional southerly dip is nearly zero across the platform. The north flank of the Arkoma basin begins along a series of down-to-the-south faulted monoclines a few miles south of the present study area.

Structural Features

Structural features within the Brentwood-St. Paul area exhibit two preferred orientations. Most folds and faults trend either approximately N30E or due east (Figure 2).

Extensive northeast trending lineaments are evident on satellite imagery of the Arkansas and Oklahoma Ozarks. Most of these topographic features are directly related to lines of tectonic disturbance and thus may accurately be called "structural lineaments" (Hodgson, 1965). At least three such lineaments are present in the Brentwood-St. Paul area. From west to east, these features are designated the Drakes Creek, Combs and Venus structural lineaments.

The surface expression of the structural lineaments is related to closely-spaced fractures, normal faults, monoclines, synclines or a combination of these features. Fault displacement and overall structural relief may vary markedly along the lineaments. This variation is commonly due to the presence of discontinuous synclines on the downthrown sides of faults and monoclines. Structural relief varies in a more systematic fashion where east trending faulted monoclines meet with the northeast lineaments. For example, fault displacement on the Drakes Creek lineament decreases from over 300 feet just east of Durham (T15N, R28W) to zero in T13N, R29W, south of Brentwood. Between these two areas the east trending, down-to-the south Brentwood faulted monocline joins the Drakes Creek lineament from the west. A similar down-to-the-south tensional zone (Dutton faulted monocline) extends east between the Combs and Venus lineaments. North of this zone, the Combs lineament is expressed as a monocline which dips northwest at approximately one degree. South of the Dutton structure, the sense of displacement along the Combs lineament is reversed and is to the southeast. Deformation along the Venus lineament takes the form of a syncline and a down-to-the-northwest monocline to the north and south of the Dutton structure, respectively. Dips on the monocline range from 1 to 3 degrees.

Synclines along the northeast trending lineaments are usually associated with faults and monoclines, but may occur alone, locally. These features are most prominently developed along the Drakes Creek structural lineament. A structural low which occurs on this trend in T13N, R29W is accompanied by secondary faulting. Another broad downwarp occurs along the Drakes Creek lineament in T15N, R27W.

Anticlines with northeast trends occur intermittently along the major lineaments. These features are most strongly developed on both sides of the Venus lineament in T14N, R25W (Ogden Creek and Boston anticlines). Flank dips on these two structures average 1.5 degrees. The highest structural elevation in the area occurs along the axis of the Boston anticline.

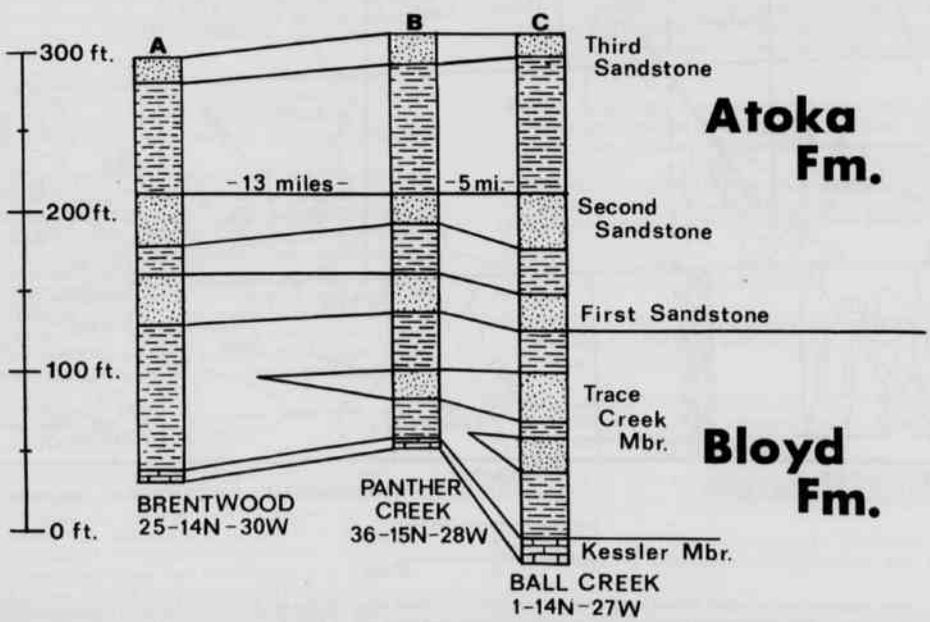

Figure 1. Correlation of selected measured sections in the upper Bloyd and lower Atoka Formations (Pennsylvanian), southeastern Washington and southwestern Madison Counties, Arkansas. Datum is top of second Atoka sandstone. Locations of sections are shown on Figure 2.

Two anticlines which lie just east of the Combs lineament in T14-15N, R26W have a northeasterly alignment, but are not clearly related to other features associated with that trend. Precise delineation of the structure near Witter (T15N, R26W) is hampered by the absence of the lower Atoka in most of the area. This feature is apparently a broad northeast trending arch upon which a small, well defined dome is superimposed. Total structural relief is approximately 100 feet. The structure in T14N, R26W is an isolated dome with a structural closure on the third Atoka sandstone of less than 50 feet.

The major east trending structures of the area are the Brentwood and Dutton faulted monoclines. Both features are at least 7 miles long and lower strata to the south about 150 to 200 feet. Although each structure is basically a monoclinal flexure, both are locally broken by normal faults having displacements of 40 to 160 feet. Individual faults, which do not exceed 2 miles in length, succeed each other along strike. A westward plunging syncline and accompanying structural nose occur at the west end of the Brentwood faulted monocline in the west half of T14N, R29W. The faulted monoclines terminate against the major northeast trending structural lineaments. Strike directions on the monoclines shift to the northeast in proximity to the major lineaments.

A series of east trending folds occurs in T13N, R25-26W. The folds are symmetrical, with flank dips of from 0.5 to 1.5 degrees. The structures cross a down-to-the-northwest monocline on the Venus structural lineament. Dip magnitudes along the monocline are great enough to largely obscure the east trending folds within the zone of intersection. Distinct domes and basins have thus formed along the anticlinal and synclinal trends on opposite sides of the Venus lineament. These folds do not extend west of the Combs lineament.

Persistent dips of less than 0.5 degrees prevail across large portions of the Brentwood-St. Paul area. The direction and magnitude of these homoclinal dips tend to change at the major structural lineaments and east trending faulted monoclines. On the upthrown sides of the Drakes Creek fault and Brentwood faulted monocline, beds dip slightly to the west-northwest. South of the Brentwood structure, beds dip generally to the southwest. Except for prominent local downwarps near the Drakes Creek structure, strata are nearly horizontal across the large area between the Drakes Creek and Combs lineaments. Between the Combs and Venus lineaments, beds again dip generally to the west-northwest.

Origins of Structural Features

Northeast trending structural lineaments are the dominant elements of the regional structural pattern in the Brentwood-St. Paul area and throughout the northern Boston Mountains. The orientation of these features suggests that they originated through shearing as a result of northward directed stresses. Smith (1977) presented geophysical evidence of a basement shear zone (without normal faulting) along the Ponca lineament in Newton County. Northward directed stresses associated with the Ouachita orogeny would presumably account for the creation of the lineaments. McKnight (1935, p. 91) showed, however, that vertical movement occurred along at least one of the major northeast lineaments as early as Devonian time, thus demonstrating their existence prior to the Ouachita orogeny. A source for tectonic stresses capable of creating such structures is not known in earlier Paleozoic time. Thus a Pre-Cambrian time of origin for the features is indicated.

The northeast trending structural lineaments probably originated through shearing of the igneous basement rocks during late Pre-Cambrian time. Later, these features acted as zones of crustal weak-

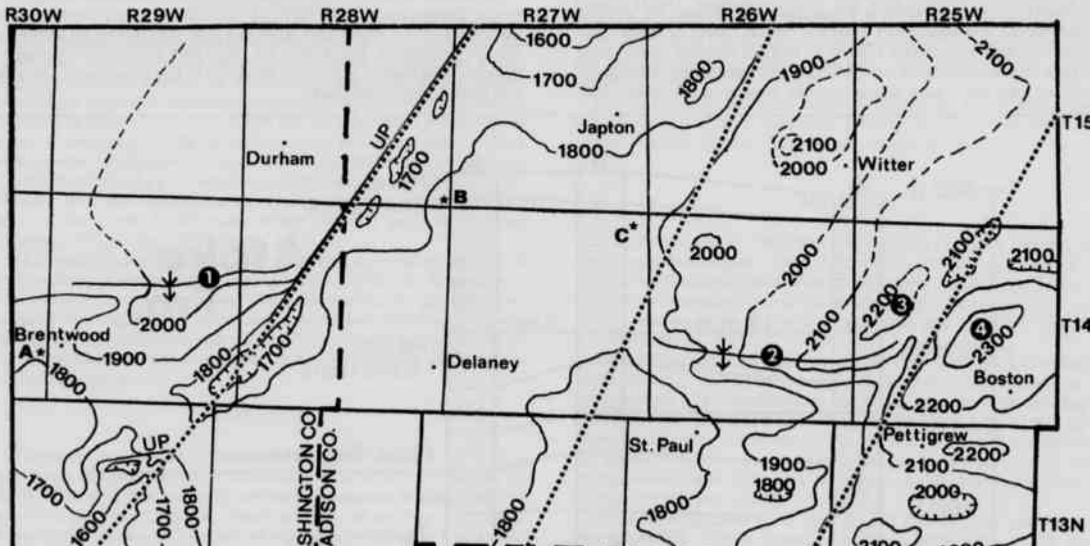

Figure 2. Structure contour map of third Atoka sandstone in Brentwood-St. Paul area, northwest Arkansas. Contour interval is 100 feet. Where contour lines are dashed, third Atoka sand is absent and mapping is projected from top of first Atoka sandstone. Asterisks designate locations of measured sections A, B and C (Figure 1). Encircled numbers designate the following structural features: 1 - Brentwood faulted monocline; 2 - Dutton faulted monocline; 3 - Ogden Creek anticline; 4 - Boston anticline.

ness along which the effects of deforming stresses were concentrated. During periods of uplift related to the formation of the Ozark dome, normal faulting probably occurred along these ancient basement fracture zones. In most areas, differential uplift along the basement faults resulted only in monoclinal flexing of the overlying sedimentary beds. Where extension was excessive, however, high angle normal faults formed in the overlying sedimentary rocks. The Drakes Creek fault may be a good example of this relationship.

The northeast trending basement fracture zones controlled the extent of the younger, east trending Brentwood and Dutton faulted monoclines. At the level of the Pre-Cambrian basement these structures probably occur as one or more well-defined faults. Monoclinal draping and intermittent faulting in the overlying sedimentary rocks are reflections of the more pronounced underlying features. The Brentwood and Dutton structures are similar to other east trending faulted monoclines on the north flank of the Arkoma basin. They probably originated as a result of extension between the stable Ozark uplift and the subsiding basin during late Atokan time. Additional relative movement may have occurred during periods of post-Atoka uplift.

The northeast and east trending basement fault zones join to form a mosaic of polygonal crustal blocks. Each major basement fault block behaved more or less independently during post-Atoka regional uplifting. The direction and magnitude of dip on the broad homoclines, which occur between structural lineaments, reflect slight tilting of the individual blocks. Northeast trending structural highs occur at the most elevated margin or corner of each block. Previously, the origin of northeast trending structural lows developed along the trace of the lineaments has been ascribed to subsurface solutioning and removal of carbonate rocks, with subsequent subsidence (Quinn, 1963). Another possible explanation, which may account for the broader synclinal nature of these features, is that slight local divergence of fault blocks has occurred along the northeast trending lineaments. Such divergence might arise through stretching of the crust during regional vertical uplift. Downwarping and secondary normal faulting would presumably occur along the block margins in response to tensional stresses created by the divergence. The net result of this structural adjustment would be the formation of a gentle structural "sag" overlying the join between the two adjacent fault blocks. More recent solutioning of subjacent carbonate rocks, as proposed by Quinn (1963) would account for the more local features (subsidence structures) that occur within the earlier formed syncline.

The east trending folds in the Pettigrew area (T13N, R25-26W) possibly formed in response to northward directed stresses of the Ouachita orogeny. The extent of the fold belt appears to have been controlled on the west by the presense of the Combs structural lineament.

The origin of the dome structures east of the Combs lineament in T14-15N, R26W cannot be explained easily in terms of basement block faulting, nor can they be readily related to compressive stresses associated with the Ouachita orogeny. Croneis (1930, p. 189) noted that a well on the east flank of the high near Witter penetrated basement rocks at an unexpectedly shallow depth. A local topographic high on the Pre-Cambrian surface is thus indicated. Such buried hills often underlie surface anticlines in the sedimentary rocks elsewhere in the Mid-Continent area. The mechanism whereby upward reflection of the buried hills occurs is not well understood, although differential compaction of sediments across the hills has been suggested (Blackwelder, 1920).

ACKNOWLEDGMENTS

Appreciation is extended to R. H. Konig, who supervised the mapping project and critically reviewed this paper. Thanks are also due to D. L. Zachry, H. C. MacDonald, W. L. Manger, K. C. Jackson, R. A. Berry, M. Corbin and M. Borengasser. Roger Taylor, Arkansas Highway Department, and Boyd Haley, U. S. Geological Survey, loaned or donated aerial photography. Financial assistance and additional photographs were provided by the Arkansas Geological Commission, Norman F. Williams, Director.

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