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Geologic map of parts of the Gaither, Hasty, Harrison, Jasper, and Ponca Quadrangles, Boone and Newton Counties, Northern Arkansas

By

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Introduction

This report summarizes the geology of parts of five 7.5-minute quadrangles (Fig. 1) in the Ozark Mountains region of northern Arkansas. The study area spans the transition from Boston Mountains to Springfield Plateau physiographic provinces and has the Buffalo River as its southern boundary. The bedrock of this region comprises an approximately 500-m-thick sequence of Ordovician, Mississippian, and Pennsylvanian carbonate and clastic sedimentary rocks (Fig. 2) that were deposited mostly in shelf environments on what is now the southern margin of North America. These rocks are generally flat lying but they were mildly deformed by a series of faults and folds, probably during Pennsylvanian time. Plentiful rainfall in past and present climates has enhanced karst processes and has promoted development of abundant caves and sink holes within carbonate formations of the region.

This project was funded through the National Cooperative Geologic Mapping program of the U.S. Geological Survey and was initiated in response to a proposal from the National Park Service to obtain geologic information to aid resource management at Buffalo National River. The study area coincides with a region of high hydrogeologic interest within and adjacent to a part of the western headwaters of Buffalo National River.

Previous Work

The area was first mapped as part of a larger region by Purdue and Miser (1916) at 1:125,000 scale. Later, in the late 1960's and early 1970's, the Gaither, Ponca, and Jasper quadrangles were mapped at 1:24,000 scale as master's theses by University of Arkansas students (McMoran, 1968; Morrison, 1971; Henderson, 1972, respectively). This map and report confirm many stratigraphic and structural features of these previous studies, but they also identify new features, employ an updated stratigraphy, provide new fault interpretations, and consider potential geologic controls on ground-water flow.

Mapping Methods

Mapping for this study was conducted on a 1:24,000 scale topographic base. A hand-held altimeter with 20 ft (6 m) resolution was employed in the field to constrain elevation of contacts or other sites. With frequent calibration, the altimeter was estimated to yield a 20 to 30 ft (6 to 9 m) accuracy based on relocation of common points. A hand-held global positioning satellite receiver with horizontal accuracy of about 328 ft (100 m) was used to supplement map locations, although the topography and altimeter readings generally permitted a more precise map location. Aerial photos and orthophotos were used to help trace ledge-forming units between field traverses within the upper clastic Mississippian and Pennsylvanian part of the stratigraphic sequence; this technique was most effective for the cliff-forming middle sandstone of the Bloyd Formation capping the stratigraphic sequence. Strike and dip of beds were typically measured along stream drainages or at well-exposed ledges to avoid loose rock affected by slope creep. Beds dipping 2° or less are shown as horizontal.

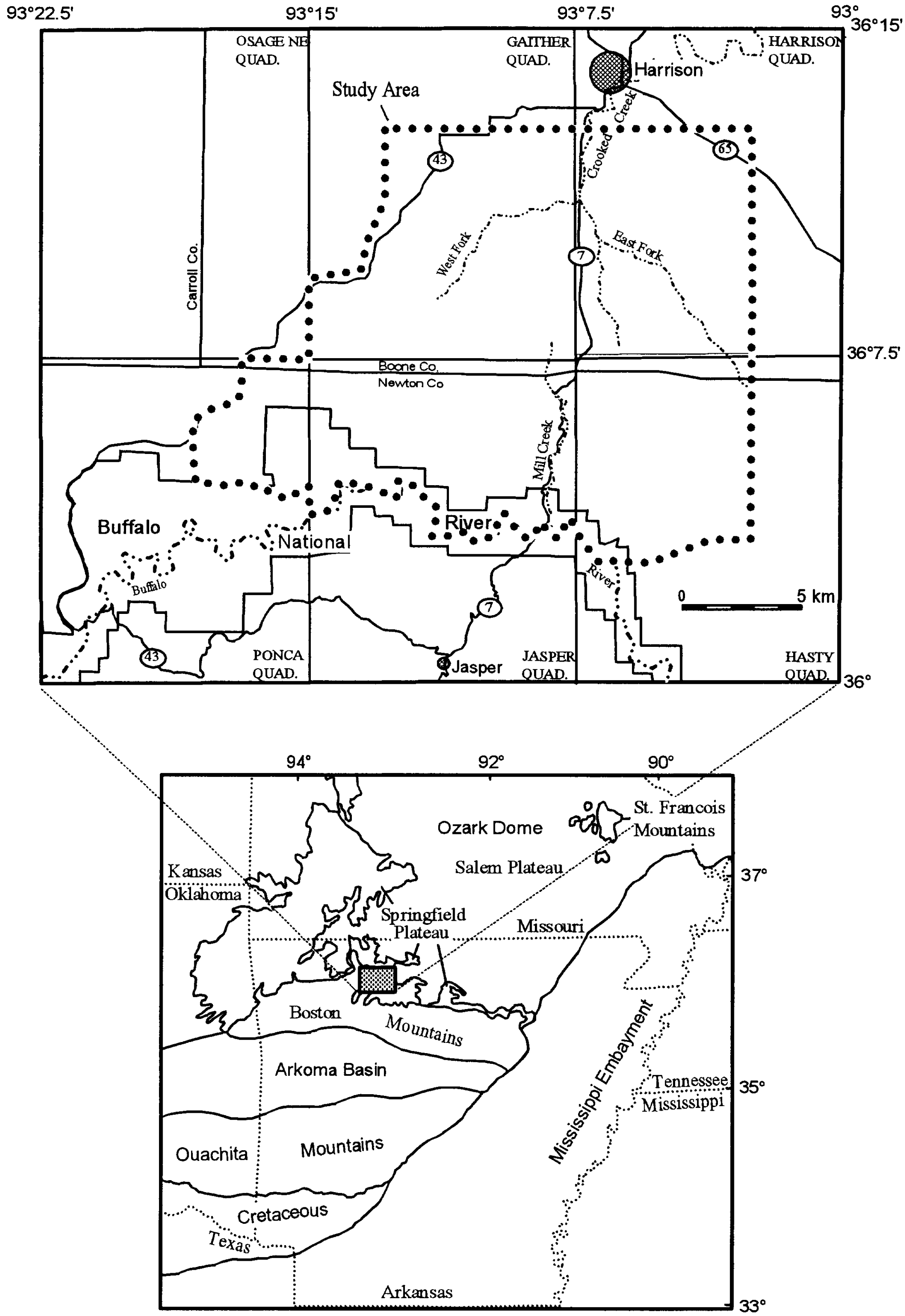

Figure 1. Location of study area within northern Arkansas, adjacent to the western part of Buffalo National River. Study area overlaps parts of five 7.5' quadrangles. Lower regional map illustrates geological and selected physiographic provinces of Arkansas and adjacent areas.

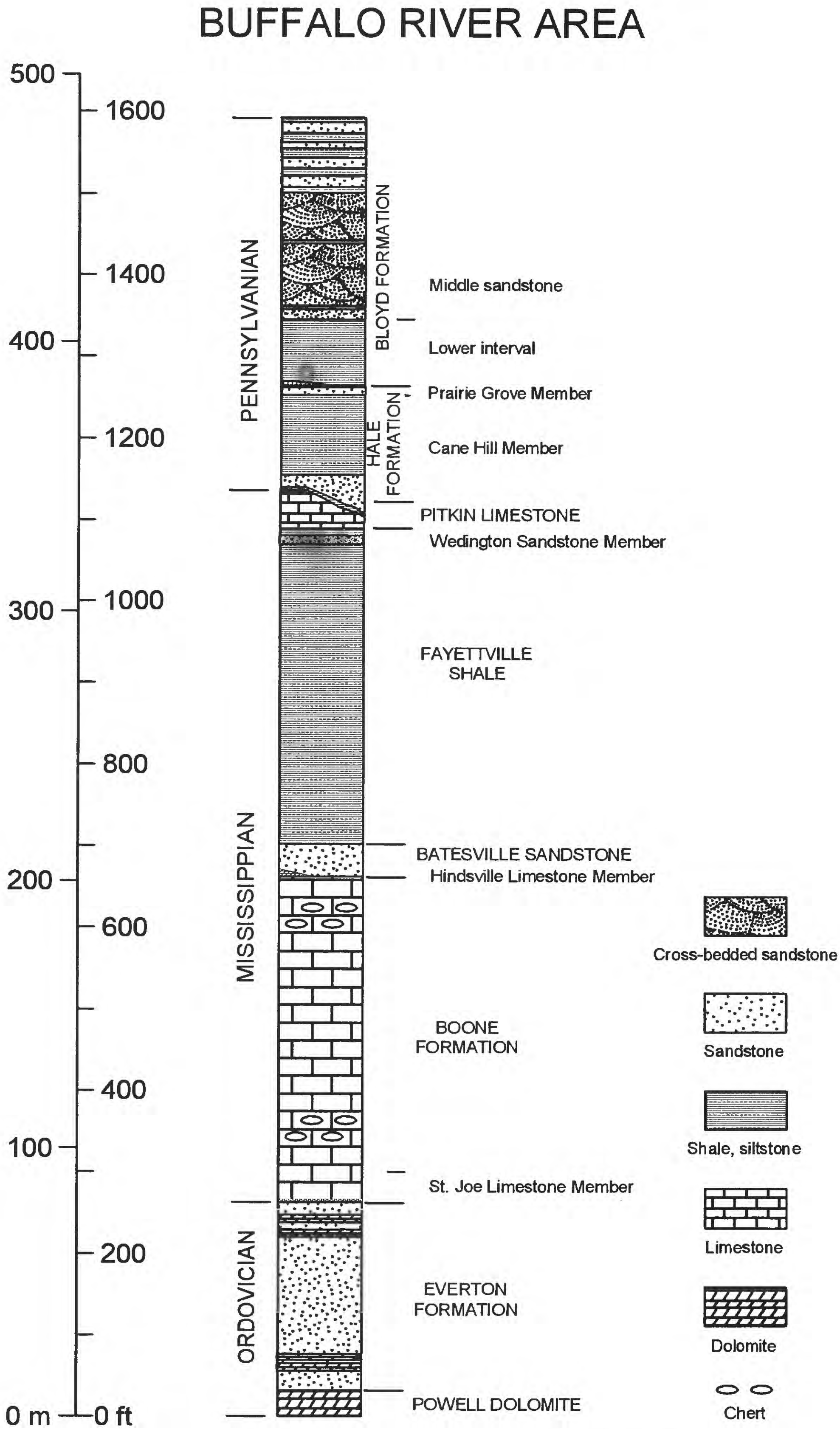

Figure 2. Stratigraphic column for Paleozoic rocks of the map area.

Description of Map Units

Qta **Terrace and alluvium deposits (Quaternary)** -- Unconsolidated sand and gravel of the Buffalo River and its major stream tributaries. Terrace deposits are principally composed of fine sand and they have smooth upper surfaces about 20 ft (6 m) above the Buffalo River base-flow level. Gravel deposits mostly line recent drainages and are composed of subrounded to rounded clasts of mixed lithology.

Qls **Landslides (Quaternary)** -- Large jumbled slide blocks of limestone, sandstone, and shale of the Wedington Sandstone Member of the Fayetteville Shale and Pitkin Formation back tilted into the hillside on the north side of Sulfur Mountain. Blocks moved over middle and lower parts of the Fayetteville Shale.

Bloyd Formation (Lower Pennsylvanian) -- Interbedded sequence of sandstone, siltstone, shale and thin limestone separated into lower and middle intervals. Up to 380 ft (116 m) thickness of formation is present in area.

ℙbm **Middle sandstone of Bloyd Formation (Morrowan)** -- Prominent cross-bedded sandstone that forms 30 to 60 ft (9 to 18 m) cliffs that rim the high plateaus of the study area. As much as 280 ft (85 m) thickness of the sequence is preserved within the area. Thin shale horizons are present within upper part of unit and form topographic flats between sandstone ledges. McMoran (1968) reported local coal seams within unit. Basal massive sandstone is a white to light brown, fine- to medium-grained quartz arenite with local concentrations of white quartz pebbles. The sandstone has a sharp erosional base and is commonly a composite of several 1 to 3 ft (0.3 to 1 m) thick tabular and trough cross-bed sets. Large blocks of sandstone are distributed as much as 500 ft (150 m) in elevation downslope from their outcrop by mass wasting processes, completely clogging some drainages.

ℙbl **Lower part of Bloyd Formation (Morrowan)** -- Sequence of predominantly dark-gray to black shale and siltstone with thin interbedded sandstone and limestone beds. Sequence is 90 to 120 ft (27 to 37 m) thick and holds up moderate to steep topographic slopes, but it is commonly poorly exposed. Fine-grained, planar-bedded, olive-brown sandstone beds, 5 to 10 ft (1.5 to 3 m) thick, are locally exposed as topographic ledges in upper part of sequence. Goniatite-bearing, brownish-gray limestone beds are interbedded with shale near top of sequence in roadside exposures on the east face of Gaither Mountain (McMoran, 1968). The Brentwood Limestone Member at the base of the formation was only observed in the southwestern part of the study area where it formed a 5 to 10 ft (1.5 to 3 m) thick reddish-gray bioclastic limestone with local basal chert-pebble conglomerate.

Hale Formation (Lower Pennsylvanian) -- Interbedded sequence of sandstone, siltstone, shale and thin limestone that includes Cane Hill and Prairie Grove Members. Formation is 110 to 150 ft (35 to 46 m) thick.

IPhg **Prairie Grove Member (Morrowan)** -- Brown to reddish-brown, fine- to medium-grained, thick-bedded, calcite-cemented sandstone, 5 to 20 ft (1.5 to 6 m) thick. Locally contains quartz pebbles and marine fossil fragments. Beds are planar or cross bedded and cross-beds may have opposing dips. Weathering leaves elliptical cavities up to 8 in (20 cm) long in some sandstone exposures. The sandstone forms steep slopes but it is often covered by float from overlying units.

IPhc **Cane Hill Member (Morrowan)** -- Interbedded sequence of shale, siltstone, and sandstone having a thickness of about 110 to 140 ft (33.5 to 43 m), but thickening to as much as 200 ft (61 m) on northern Gaither Mountain. The upper part of the Cane Hill Member is generally poorly exposed and composed of dark-gray shale and thin-bedded siltstone that underlie low to moderate topographic slopes. Lower part of interval contains shale as well as an interval of reddish-brown- to light-brown, fine- to medium-grained sandstone of variable character. The lower sandstone is poorly to well cemented, planar to trough cross-bedded and locally contains casts of wood fragments, thin angular mudstone rip-up clasts, and red, rounded, oblate chert fragments. Sandstone forms a ledge and is 10 to 15 ft (3 to 4.5 m) thick but locally greater than 30 ft (9 m) in areas such as Broadwater Hollow where it forms spires adjacent to stream. A 3 ft (1 m) thick conglomerate containing chert, sandstone, and crinoid-bearing limestone clasts as large as 6 cm is exposed at the base of the sandstone in Hideout Hollow (SW quarter, SE quarter, NE quarter, Sec. 36, T17N, R22W).

Mp **Pitkin Limestone (Upper Mississippian, Chesterian)** -- Generally medium- to dark-gray, fetid limestone. Limestone varies from micritic to coarse grained and is locally oolitic. The limestone is locally sandy in its upper part. Many limestone beds are strongly fossilferous with abundant crinoids, brachipods, corals, and the bryzoan *Archimedes*. The basal contact with the Fayetteville Shale is conformable. The Pitkin Limestone generally forms a prominent topographic ledge or cliffs. Its thickness is generally 40 to 80 ft (12 to 24 m), but it is absent on northern Gaither Mountain, probably due to erosion at the base of the Pennsylvanian sequence.

Mf, Mfw **Fayetteville Shale (Upper Mississippian, Chesterian)** -- Black, slope-forming shale that grades upward to siltstone and fine sandstone of Wedington Sandstone Member (Mfw). Total thickness of the formation is 350 to 420 ft (107 to 128 m). Change from shale to sandstone at formation top is gradational and consists of a coarsening upward sequence that culminates in the Wedington Sandstone Member, a 5 to 20 ft (1.5 to 6 m) thick interval of brown, well-indurated, calcite-cemented siltstone and sandstone. The Wedington Sandstone Member caps a steep topographic slope and is separated from overlying Pitkin Limestone by a thin black shale that commonly forms a topographic bench; this shale was only directly observed in Broadwater Hollow. The upper Wedington sandstone is very-fine- to fine-grained and is present in thin to thick planar beds with internal parallel laminations and locally developed low-angle cross beds. The sandstone is thickest in the northern part of the Cecil Creek drainage in the southwestern part of the map area. Lowest siltstone beds of Wedington are typically ripple cross-laminated and strongly bioturbated. The middle part of Fayetteville Shale is rarely exposed but local topographic flats developed within this interval suggests that thin sandstone or limestone interbeds are present within a shale sequence. Black fissle shale at the base of the Fayetteville Shale is exposed along many stream gullies where it may contain medium- to light-gray, fetid septarian concretions as large as 2 ft (0.6 m) in diameter. Fayetteville Shale is susceptible to landslides.

Mbv **Batesville Sandstone (Upper Mississippian, Chesterian) --** Fine- to very-fine-grained, light- to medium-brown, calcite-cemented sandstone with interbedded limestone and shale. Thin to medium beds are commonly parallel laminated with low-angle cross beds common in upper part of unit. Sandstone commonly contain burrows on bedding plane surfaces, and breaks into flaggy blocks. One or more discontinuous, 1 to 3 ft (0.3 to 1 m) thick, medium- to dark-gray, fetid, fossiliferous limestone beds are locally interbedded with sandstone; these limestone beds are more abundant in western part of study area. The Hindsville Limestone Member (Purdue and Miser, 1916) is present in the western part of the study area at base of formation and is as much as 5 ft (1.5 m) thick in the Cecil Creek drainage. It is distinguished by the presense of subangular clasts of white chert that range in size up to 2 in (5 cm). A 1.5 ft (0.5 m) thick, dark gray shale is common at base of formation in eastern part of study area. Batesville limestone beds are fossilferrous and contain common crinoids and brachiopods. Both sandstones and limestones are pocked by 2- to 10-mm-diameter oxidized pyrite framboids that form ubiquitous reddish-brown spheres. The Batesville forms a topographic ledge and is the site of small waterfalls where crossed by streams. Where stripped of overlying Fayetteville Shale, the top of the Batesville typically forms a topographic flat that is the common host of sinkholes formed by collapse into dissolution cavities in underlying Boone limestones. Tabular blocks of sandstone are commonly used as decorative building stone in the region. Thickness is 40 to 70 ft (12 to 21 m).

Boone Formation (Lower to Middle Mississippian) -- Formation consists of basal St. Joe Limestone Member and a thicker unnamed upper part. The total thickness of the formation is 380 to 405 ft (116 to 122 m). In northeastern part of the area, fresh outcrops of Boone Formation are sparse and mostly restricted to stream drainages that dissect the Springfield Plateau; elsewhere in this area the Boone Formation is mantled by residual porous chert fragments within red clay matrix.

Mb **Upper unnamed member (Osagean-Meramecian) --** Medium- to thick-bedded, chert-bearing bioclastic limestone. Limestone is light to medium gray on fresh surfaces and coarsely crystalline with large interspersed crinoid ossicles. A 1 to 3 ft (0.3 to 1 m) thick bed of oolitic limestone is common at the top of the Boone Formation in the southeastern part of the study area. Dense, fine-grained beds of limestone are present in the upper third of the unit. Beds are typically parallel planar to wavy, but channels fills are locally present in the lower part of the unit. Chert forms lenticular to anastomosing lenses. Chert-rich horizons are generally poorly exposed and form slopes littered with float block concentrations of white weathered chert. The uppermost chert-rich part of unit contains prominent brachiopods that are commonly preserved as casts in chert nodules. The chert content varies vertically and laterally within the Boone Formation in the study area and significant intervals are chert-free. Thickness is 330 to 375 ft (101 to 114 m).

Mbs **St. Joe Limestone Member (Kinderhookian to Osagean) --** Thin-bedded coarse crystalline bioclastic limestone with ubiquitous 3 to 6 mm crinoid fragments. Limestone is commonly pink to red on fresh surfaces due to hematite staining, but its color and hematite concentrations vary with location. Thin beds are typically wavy in form. Chert nodules are uncommon, but, where present, they are tabular and may be reddish colored. The contact with the overlying part of Boone Formation is gradational. The middle part of the St. Joe Limestone Member forms a local topographic flat within a slightly shaley limestone interval that commonly passes downward to a low limestone ledge above its basal unconformity. Base of unit is an about 1.5 to 3 ft (0.5 to 1 m) thick sequence of phosphate-pebble-bearing tan sandstone and overlying greenish-gray shale that, although thin, is laterally persistent throughout much of northwestern Arkansas (McKnight, 1935). The member is approximately 30 to 50 (9 to 15 m) feet thick.

Oe **Everton Formation (Middle Ordovician) --** Interbedded sandstone, dolomite, and limestone sequence, about 230 ft (70 m) thick in its only full exposure along Harp Creek. The unit is predominantly quartz arenite. Quartz grains are well-sorted, well rounded, and fine- to medium-grained. Sandstones are light tan to white and variably cemented by dolomite or calcite that may form large crystals that envelop sand grains in a poikilitic texture. Poorly cemented sandstone breaks with sugary texture. The sandstone generally has medium to thick planar beds. The top part of Everton Formation contains 3 to 6 ft (1 to 2 m) thick light to dark gray dolomite beds interbedded with sandstone. The middle part of the unit is a massive sandstone that may form bluffs and that correlates in part with the Newton Sandstone Member of McKnight (1935). The lower part of unit contains 3 to 6 ft (1 to 2 m) thick limestone and dolomite beds interbedded with sandstone. Carbonate beds in both upper and lower parts of unit are typically finely crystalline, sparsely fossiliferous, and commonly display crinkly laminations. The lower limestone-rich part of the Everton is a common host of paleokarst features that consist of vertical columns or walls of highly fractured or brecciated Everton Formation sandstone that collapsed from overlying horizons.

Op **Powell Dolomite (Lower Ordovician) --** Argillaceous brownish-gray dolomite. Only the upper few feet of the formation are exposed along Harp Creek drainage (Purdue and Miser, 1916). Its contact with overlying Everton Formation is disconformable and marked by irregular topography and sand-filled cracks that penetrate into the Powell Dolomite. Regionally the formation thickness varies from 40 to 200 ft (12 to 60 m) near the map region (McFarland, 1988).

Stratigraphy

The study area preserves a 1600 ft (490 m) thick record of early and late Paleozoic deposition in dominantly marine environments on what is now the southern margin of the North American continent. Stages for Pennsylvanian and Mississippian units are from McFarland (1988). The sandstone and overlying shales at the top of the Paleozoic sequence were originally called Winslow Formation by Purdue and Miser (1916), with the basal Greensprings Sandstone Member representing the prominent cliff-forming cross-bedded sandstone. This convention was followed by McMoran (1968), Morrison (1971), and Henderson (1972). Zachry (1977), however, concluded the cliff-forming sandstone was a time-equivalent unit with the Woolsey Member of the Bloyd Formation farther west and designated it with the informal term "middle Bloyd sandstone". This use is followed here.

The greatest stratigraphic uncertainty within the area is the eastern extent of sandstone of the Prairie Grove Member at the top of the Hale Formation. The study area lies at the eastern margin of the distribution of thick Prairie Grove Member (Sutherland, 1988) and farther east Glick and Frezon (1964) abandoned the use of Prairie Grove Member, defining instead the Witt Springs Formation to include a sandstone and shale sequence that is age equivalent to both the Prairie Grove Member and lower part of the Bloyd Formation. The Prairie Grove Member is thickest (20 ft, 6 m) and best established in the headwaters of Cecil Creek (Broadwater Hollow, Tiggs Springs Hollow) where it is overlain by the Brentwood Limestone Member of the Bloyd Formation. Farther east the sandstone is typically only 10 ft (3 m) thick and its natural exposures are poor because of float from the overlying middle Bloyd sandstone. On the east face of Gaither Mountain the Prairie Grove Member is interpreted as a sandstone-rich interval that underlies the goniatite-bearing thin limestone and shale interval (McMoran, 1968) of the Bloyd Formation. Farther east, in the Sulfur Mountain-Pinnacle Mountain area, the Prairie Grove Member is mapped as an indistinctive planar- or cross-bedded sandstone ledge that forms ledge above the Cane Hill Member and below the capping cliff-former of the middle sandstone of the Bloyd Formation.

The onset of Morrowan deposition reflects sea-level rise following a terminal Mississippian sea-level drop (Sutherland, 1988). The variable nature of the basal sandstone interval of the Cane Hill Member of the Hale Formation as well as its content of conglomerate and wood fragments suggests that this interval contains non-marine valley-fill fluvial deposits. The truncation of the Pitkin Limestone and Wedington Sandstone Member of the Fayetteville Shale progressively northward along the face of Gaither Mountain may reflect erosion beneath this unconformity.

The chert content of the upper part of the Boone Formation in the study area is not as pervasive as described elsewhere in the region and as a consequence its contact with underlying St. Joe Limestone Member, which elsewhere is based on a marked increase in chert, is indistinct. At the base of the St. Joe Limestone Member, McKnight (1935) called attention to the persistent phosphate-nodule bearing sandstone and overlying thin shale. Based on petrography, Horner and Craig (1984) supported a correlation of the basal sandstone with Sylamore Sandstone (Penrose, 1891) and endorsed the model of Swanson and Landis (1962) that the sandstone represents a transgressive lag deposited during sea level rise in late Devonian to early Mississippian time. The absence of upper Ordovician through Devonian strata below the Mississippian unconformity in the study region may be related to erosion along a north-trending arch centered on the area (Quinn, 1959), inasmuch as strata of these ages are preserved both to the east and west of the study area. Suhm (1974) interpreted the mixed sandstone and carbonate interval of the Ordovician Everton Formation as barrier islands and adjacent tidal-flat environments.

Structural Geology

General characteristics

Rocks within the map area have been mildly deformed by a system of normal and strike-slip faults and related folds. These structural features are principally identified by elevation changes of marker contacts. Consequently the structures are well illustrated for the region by a structure contour map on the base of the Boone Formation (Fig. 3). No horizontal offsets could be estimated across structural features due to the lack of appropriate markers, but kinematic information described below suggests that a strike-slip component was important during deformation. The structure contour map was constructed from sites on both lower and upper contacts of the Boone Formation as well as other limiting information on their maximum or minimum elevations. A 390 ft (119 m) thickness for the Boone Formation (including the St. Joe Limestone Member) was used to project the elevation of the basal contact from sites on the upper contact. This thickness was averaged from five traverses, selected away from recognized structures (Fig. 3), yielding individual thicknesses from 380 to 405 ft (116 to 123.5 m).

Within the map area, the maximum vertical offset of strata by structures is about 400 ft (122 m) within the eastern Braden Mountain graben, but most structures have vertical offsets less than 150 ft (46 m). Tectonic offsets less than about 40 ft (12 m) could not be confidently resolved at the scale of mapping due to the cloaking effects of vegetation and colluvium and the competing effects of subsidence caused by local carbonate dissolution. Distinguishing between faults and folds was subjective if marker contacts could not be fully traced through structures. Faults were interpreted where contact elevations changed as much as 100 ft over short horizontal distances along azimuths similar to better-established faults. Folds were interpreted where elevation differences were less or changed more gradually. In general, folds and faults are probably related, with folds representing drape of strata adjacent to or above faults. Location of structures was augmented by their coincidence with topographic lineaments and by any field observations of tectonic rock fabrics.

Fault surfaces are only sparsely exposed within the region. Most of the faults observed in the map area have small offset. A total of forty three fault planes were observed in the map area and thirty four preserved slip lineations (Fig. 4A). Slip sense was inferred for striated faults either from offset of bedding or from secondary fault plane features such as calcite fibers or en echelon shears (Petit, 1987). Faults observed in the areas are either dominantly normal or strike-slip (Fig. 4B). Strike-slip faults are mostly northeast-striking dextral faults but west-northwest-striking sinistral faults are also present. Most strike-slip faults also have a small component of normal slip. Normal faults generally strike east-west and dip north or south. Most faults in the map area dip steeply;

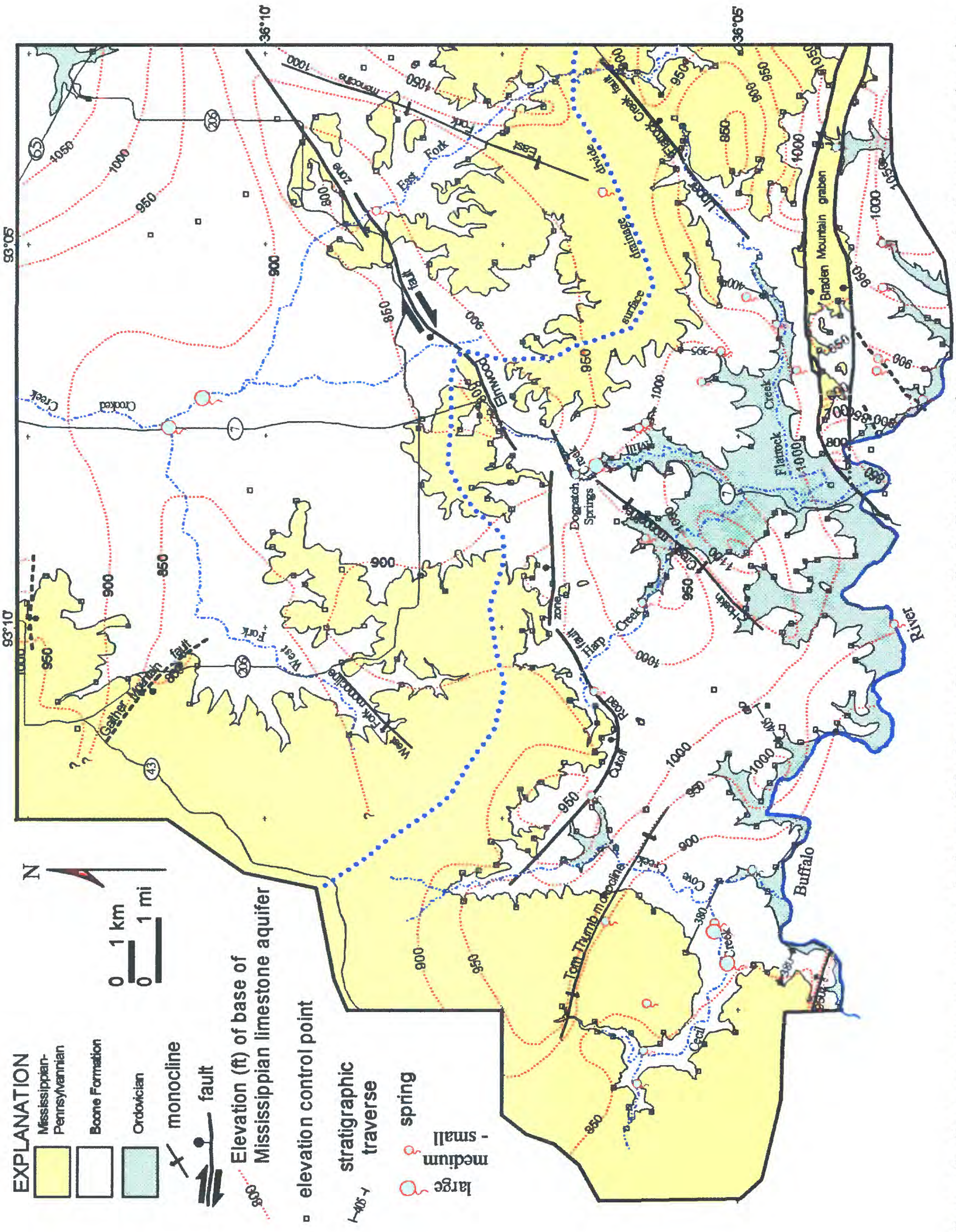

Figure 3. Structure contour map on the base of the Boone Formation (including St. Joe Limestone Member). Squares are locations of control points on the bottom and top of the formation. For sites on the top of the Boone Formation, elevation was obtained by subtracting the average thickness of the Boone Formation as determined at five traverses through the formation.

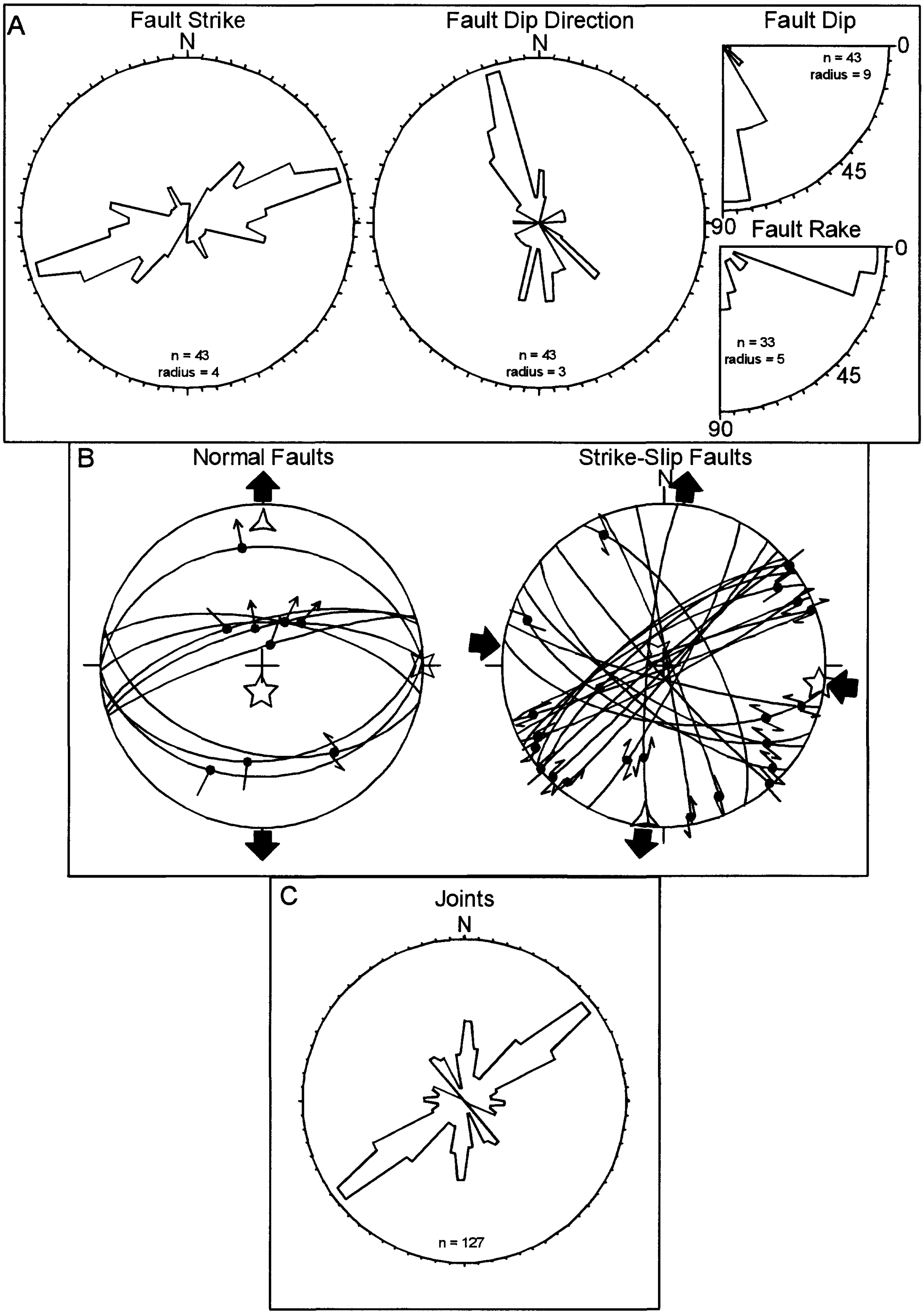

Figure 4. Fracture data for the map area. (A) Rose diagrams for a population of mostly small faults. (B) Stereographic projections of striated faults separated into normal and strike-slip types. Arcs and dots are lower hemisphere projections of fault planes and their slip lines, respectively. Small arrows show movement sense, with greater head ornamentation indicating higher confidence on slip determination. Open five-, four-, and three-pointed stars represent orientation of maximum, intermediate, and least principal paleostress axes, respectively, estimated from analysis of Angelier (1991). (C) Rose diagram of strike frequency of joints recorded within the map area.

65-80° for normal faults and 80-90° for strike-slip faults. Reduced paleostress tensors calculated from the population of striated faults (Angelier, 1990) indicate that both normal and strike-slip faults were active under a north-south directed least principal stress (Fig. 4B).

Rock fabrics associated with deformation were observed within and adjacent to some faults and their presense helps constrain the location of other more poorly located faults. Sandstone of the Everton Formation adjacent to faults contains light colored ridge-forming bands that are interpreted as small strain-hardened faults. Such strain-hardened faults have been termed deformation bands and they are a common strain mechanism in porous sandstones (e.g., Aydin and Johnson, 1978). Deformation bands in the Everton Formation are associated with paleokarst structures as well as faults and they only rarely preserve slip lineations. Everton Formation sandstone is silica cemented adjacent to some faults and, consequently, it may break into competent rectangular blocks that contrast with the typical rounded sugary surfaces of carbonate-cemented sandstones. Within the Boone Formation, fault surfaces are rarely well exposed but are best preserved as striated or brecciated planes within chert lenses. Calcite veins, some with fibers indicating slip direction and sense, were observed at a few localities within or adjacent to faults in limestone of the Boone Formation. More commonly, faults in Boone Formation coincide with areas of poor exposure and concentrations of sinks. No secondary fractures or fabrics were typically developed within or adjacent to faults offsetting the Batesville Sandstone. Grooves attributed to frictional wear were observed on one fault antithetic to the North Braden Mountain fault and offsetting northeast-striking dextral and west-northwest-striking sinistral deformation bands are exposed within Batesville Sandstone along a wash adjacent to Highway 43 in the northeastern part of the study area. No fault planes or fabrics were observed in the Fayetteville Shale and younger strata.

For a population of 127 joints measured within the map area (Fig. 4C), the dominant set strikes northeast whereas lesser sets strike north-south, northwest, or east-west. This population constitutes a relatively small sampling of joints, but similar joint sets were reported from comparable populations by McMoran (1968), Morrison (1971), and Henderson (1972) within the Gaither, Ponca, and Jasper quadrangles, respectively. Joints within the Boone Formation are commonly enlarged due to dissolution.

Individual structures

Brief descriptions of some individual structures are given below.

Braden Mountain Graben

The Braden Mountain graben extends generally east-west about 9 km across the southeastern part of the map area. The bounding northern and southern faults have maximum throw in the central to eastern part of the graben where their throw approaches 390 ft (119 m), nearly the entire Boone Formation thickness. Both the northern and southern faults dip steeply (about 75°) where exposed at the surface and striations on the main faults or associated small faults indicate normal dip-slip displacement. Nonetheless, the downdrop of Fayetteville Shale in rhomb-shaped block adjacent to a northeast-striking segment and development of a local anticline in the footwall adjacent to a northwest-striking segment of the North Braden Mountain fault suggests that this fault may have a component of sinistral slip. Throw on the graben faults decreases westward in concert with the presense of northeast-striking faults interpreted to merge with the graben faults. These relations suggest that displacement from Braden Mountain faults is transferred to northeast-striking dextral faults at the western end of the graben. A number of sinks lie within upper Boone Formation and Batesville Sandstone on or adjacent to the North Braden Mountain fault.

Upper Flatrock Creek fault

North of the Braden Mountain graben, this poorly exposed northeast-striking fault downdrops the basal Batesville Sandstone contact on its southeast side. Throw on this fault is greatest adjacent to upper Flat Rock Creek where about 100 ft (30 m) of vertical offset occurs over a short horizontal interval and coincides with a zone of dense fractures and calcite veins in southeast-dipping Boone Formation. Farther northeast along the fault, along uppermost reaches of Davis Creek, the basal Batesville Sandstone contact is deformed in a broad syncline on the downthrown southeastern block. Several poorly preserved subhorizontal lineations on observed northeast-striking planes within Boone Formation limestones in this region suggest this fault probably has a component of dextral slip.

Elmwood fault zone

The Elmwood fault zone is at least 10 km long, strikes about N50°E, and is interpreted to contain several fault strands arranged in an en echelon manner that individually strike about N60-65°E. The structure of the zone is best constrained at its southwestern end where high topographic gradients at the head of Mill Creek and roadcuts along Highway 7 enhance exposures. Slickensides preserved on chert fragments and calcite fibers on near-vertical planes observed in outcrops adjacent to Highway 7 are subhorizontal and are interpreted to indicate a dextral sense for the fault zone. The low angle that individual fault segments within the Elmwood fault zone make to the overall trend is consistent with their function as Riedel shears (Tchalenko and Ambraseys, 1970) within a dextral fault zone. Strata on either side of the fault zone dip gently toward the zone as shown by the basal contact of Batesville Sandstone that falls from surrounding elevations of 1300 to 1400 ft (396 to 427 m) to as low as 1150 ft (351 m) within the fault zone. The Elmwood fault zone coincides with a topographic lineament defined by an alignment of stream traces and ridge saddles. Adjacent to the fault zone, the Batesville Sandstone is locally deformed by mostly northeast-trending, small-scale, open to close folds with 1 to 2 m amplitude. Similar scale folds are absent in the underlying Boone Formation suggesting that the Batesville Sandstone decouples from its substrate within the fault zone.

Hoskins Creek Monocline

The northeast-trending Hoskins Creek monocline aligns with the southwest projection of the Elmwood fault zone and it downdrops its northwestern side 60 to 80 ft (18 to 24 m) via a northwest dip of strata. The Hoskin Creek monocline is interpreted as a drape fold over a buried continuation of the Elmwood fault zone that may have lost some displacement southwest of its intersection with the Cutoff Road fault zone. Small-scale, northeast-striking dextral faults within Everton sandstone were observed within the monocline limb in the wash north of Grapevine Ridge, supporting its association with the Elmwood fault zone. The southeastern flank of the Hoskin Creek monocline forms a broad dome northeast of Grapevine Ridge in which the basal Boone contact rises to as high as 1150 ft (351 m) elevation. The single exposure of Powell Dolomite within the map area results from dissection of this dome by Harp Creek.

Cutoff Road fault zone

This 8-km-long fault zone separates an extensive area of Batesville Sandstone whose basal contact lies at about 1300 ft (396 m) elevation from an area to the south in which Batesville Sandstone is preserved as hilltop remnants at 1380 to 1420 ft (421 to 433 m) elevations. The fault zone is interpreted to consist of two nonaligned east-west striking normal fault segments connected by a northeast trending fault or ramp. Only the location of the eastern segment is well constrained where it juxtaposes Boone Formation against Batesville Sandstone along a north-trending road (NE quarter, NE quarter, Sec. 24, T17N, R21W). Location of the western fault segment is more poorly constrained because of wider spacing between Batesville Sandstone outcrops, but it is interpreted to follow a curvilinear set of drainages that rim the southern promontory of extensive Batesville Sandstone outcrop. By analogy to other east-west striking faults, the Cutoff Road fault probably has normal displacement. The western end of the Cutoff Road fault zone is interpreted to turn northwest and allow uplift of a high of Everton Formation in its footwall and then lose displacement farther to the northwest along the Cove Creek drainage. The eastern end of the zone probably truncates against the Elmwood fault zone, inasmuch as it does not affect the Batesville contact farther east.

Tom Thumb Monocline

This monocline bounds the southwest margin of the high of Everton Formation exposed along upper Cove Creek. It is interpreted as a monocline because of the southwest dip of St. Joe Limestone Member strata along Cove Creek that agrees with a coordinated elevation decrease of its basal contact. Nonetheless, the area of an abrupt 100 ft (30 m) fall of the upper Boone Formation contact just east of Tom Thumb cemetery is alluvium covered and fault offset cannot be precluded. The monocline projects westward beneath Newberry Point to separate an approximate 120 ft (37 m) difference in the elevation of the upper Boone Formation contact along Bartlett Cove. Stratigraphically higher, the Pitkin Limestone undergoes a similar elevation change across the monocline, although over greater distance, but the base of the middle Bloyd sandstone does not appear to be equally affected.

Gaither Mountain Fault

This northwest-striking fault, first recognized by McMoran (1968), locally downthrows Batesville Sandstone at least 60 ft along its southwestern side. Offset from this fault cannot be traced above the Fayetteville Shale, prompting McMoran (1968) to suggest that this structure was active before deposition of overlying lower Pennsylvanian strata.

East Fork Monocline

This 4-km-long, north-northeast-trending fold downdrops the upper Boone contact about 100 ft (30 m) on its western side and its southern continuation may be expressed by the higher elevation of the eastern versus western ends of Sulfur Mountain. Multiple sinks were observed at the upper Boone Formation contact in the area west-southwest of the East Fork Crooked Creek coinciding with the maximum dip of the contact.

West Fork Monocline (?)

This northeast-trending structure downdrops its northwest side and separates broad areas where the upper Boone Formation contact lies at about 1300 ft (396 m) and 1240 ft (378 m). Landowner access did not permit direct observation of this contact in the area of elevation change and thus it is assumed to be monocline principally because of the relatively small elevation difference.

Setting and age of deformation

The merging of normal and strike-slip faults (e.g., Cutoff Road and Elmwood fault zones or the Braden Mountain graben and its southwestern splay faults) within the map area indicates that these different structures acted together in coordinated fashion to accommodate one principal period of regional deformation. This conclusion is supported by the common north-south least principal paleostress calculated from the striated normal and strike-slip faults (Fig. 4B). These relations suggest that tectonic deformation of the area was principally a response to north-south extension. The three dimensional strain field was probably triaxial, however, with normal faults accommodating vertical shortening and with an additional component of east-west shortening indicated by the relative abundance of strike-slip faults.

The north-south extension accommodated in the map area is similar to that of south-dipping growth faults of early Atokan age within the Arkoma Basin farther to the south (Arbenz, 1988, and references therein) and they were probably formed by a common cause; loading and flexure of the southern continental margin beneath the Ouachita orogeny (Bradley and Kidd, 1991). Age constraints on deformation within the map area are broad but they are compatible with this hypothesis. All Paleozoic strata are equally offset within the Braden Mountain graben and thus this structure must postdate Morrowan deposition. The restriction of the Gaither Mountain fault and perhaps the Tom Thumb monocline to pre-Pennsylvanian rock, however, implies that these structures may have had earlier movement (e.g., McMoran, 1968). Regionally, faults in northern Arkansas were present and acted to localize Pb-Zn mineralization (McKnight, 1935) probably as a response to large scale expulsion of brines out of the Arkoma basin during Late Pennsylvanian to Early Permian time (Leach and Rowan, 1986).

Geologic controls on ground water flow

The geologic map provides a context within which to examine ground-water flow through the region. Integrating data from the geologic map with the distribution of springs within the Buffalo River and Crooked Creek drainages (D.N. Mott, unpublished data) suggests that there are both stratigraphic and structural controls on ground-water flow within the area. A strong concentration of springs at its base indicates that the Boone Formation is the predominant aquifer that discharges ground water into surface watersheds of the region. This spring concentration is illustrated both as a spatial coincidence of springs with the Boone Formation basal contact (Fig. 3) and by a tabulation of spring frequency versus stratigraphic height (Fig. 5). Rapid transit times of dye introduced into water flowing through the Boone Formation (T.J. Aley and D.N. Mott, unpublished data) are only compatible with conduit flow and this, coupled with its abundance of karst features, illustrates that the Boone Formation acts as a karst aquifer (Brahana and others, 1988). Ground water flowing through karst conduits within the Boone limestones may emit at its base either because it encounters the low permeability basal shale horizon of the St. Joe Limestone Member or less soluble dolomitic sandstone or dolomite within the upper Everton Formation.

Structural features influence ground water flow within the study area in two ways. Faults and folds control the elevation of the Boone Formation and thus are responsible for local differences of base level for ground water flow within the aquifer. An observation that large springs within the upper Mill Creek and Cecil Creek drainages of the Buffalo River watershed lie within or adjacent to large structural lows within the Boone aquifer suggests that these troughs may be gathering water from surrounding higher regions and channeling them through extensive karst networks to emit at the springs. A long-term confluence of ground water within structural lows may promote development of extensive karst networks within them.

Structural features also change the hydrologic properties of rocks. Dense fracturing associated with faults and folds enhances fracture flow of ground water and, probably more importantly in this area, increases the potential for karst dissolution along fractures within carbonate units. Within the map area, a concentration of sinks observed within the Boone Formation and overlying Batesville Sandstone associated with several structures (e.g., North Braden Mountain fault, Cutoff Road fault zone) confirms a structural enhancement of karst processes and suggests a corollary control on ground water flow. Hudson and Mott (1997) suggest that fracturing associated with the Elmwood fault zone aids a known interbasin ground water flow from Crooked Creek watershed to the upper and lower Dogpatch springs within the Buffalo River watershed. Emergence of these ground waters at the Dogpatch springs was probably forced by an upstep of the basal Boone Formation contact in the footwall of the Cutoff Road fault zone where it intersects the Elmwood fault zone. Farther west along the Cutoff Road fault

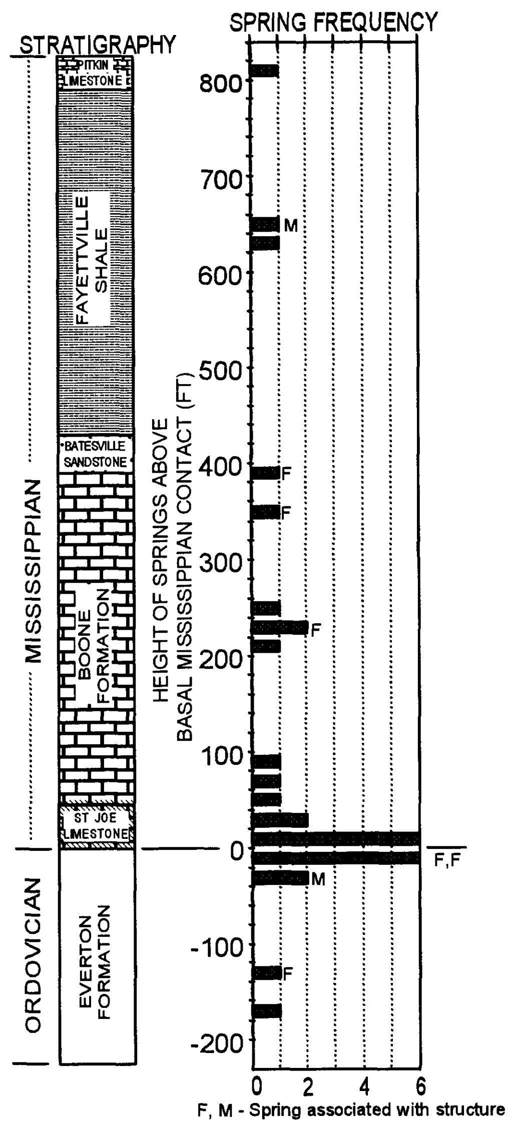

Figure 5. Histogram of springs frequency versus stratigraphic height above the basal contact of the Boone Formation within the study area. F and M represent springs spatially associated with faults and monoclines, respectively.

zone, two other springs may also coincide with this footwall upstep suggesting a similar ground water control.

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