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Abstract

A digital geologic map of West Fork quadrangle was produced at 1:24,000 scale using the geographic information system (GIS) software MapInfo. Data regarding stratigraphic relations observed in the field were digitized onto the United States Geological Survey (USGS) digital raster graphic (DRG) of West Fork quadrangle. The geology of West Fork quadrangle consists of sedimentary rocks of the Mississippian and Pennsylvanian systems. The Fayetteville Shale and Pitkin Formation represent the Mississippian system. The Hale, Bloyd, and Atoka Formations represent the Pennsylvanian System. Each of these formations consists of members that were mapped at 1:24,000 scale, and this mapping effort represents the first time stratigraphic members were mapped utilizing digital technologies at this scale in West Fork quadrangle. The Hale Formation consists of the Cane Hill Member and the Prairie Grove Member. The Bloyd Formation consists of the Brentwood Member, the Woolsey Member, the Dye Member, and the Kessler Member. The Atoka Formation in West Fork quadrangle includes the Trace Creek Member at its base. The overlying units of the Atoka Formation occur as unnamed alternating sandstone and shale units. The most prominent geologic structure in West Fork quadrangle is the Fayetteville Fault, which crosses the northwest quarter of the quadrangle. Several additional faults are associated with a fault zone surrounding the Fayetteville Fault. Another prominent normal fault was mapped striking east-west (downthrown to the south) in the southern part of the quadrangle.

Introduction

West Fork quadrangle (Fig. 1) is located near the center of Washington County, Arkansas and is named for the community of West Fork, which occupies the central portion of the quadrangle (Fig. 1). The quadrangle boundaries are 35°52.5'N 94°15.0'W (southwest), 36°00.0'N 94°15.0'W (northwest), 36°00.0'N 94°07.5'W (northeast), and 35°52.5'N 94°07.5'W (southeast).

Washington County is located on the south flank of the Ozark Dome (Croneis, 1930). The county occupies portions of two erosional plateaus formed along the southern portion of the Ozark Dome. The Springfield Plateau is defined by the top of the Boone Formation, a sequence of Lower Mississippian limestone and chert, whereas the higher Boston Mountains Plateau is formed by Upper Mississippian and Lower to Middle Pennsylvanian strata capped by the Middle Pennsylvanian Atoka Formation. The lithostratigraphic succession observed in West Fork quadrangle is shown in Figure 2 (Brown, 2000).

The landscape is a maturely dissected, dendritic drainage system dominated by the White River which flows north through the quadrangle (Fig. 3). Whereas upland areas throughout the quadrangle are heavily forested, excellent exposures of all lithostratigraphic units were observed in ravines associated with the West Fork of the White River and its tributaries, roadcuts along highways US 71 and Interstate Highway 540, and in on-going excavations produced by construction activities in the region.

The topography of the quadrangle is controlled by a number of units. The Wedington Member of the Fayetteville Formation is often expressed as an elevated bench on hillsides and caps some hills in the northwestern portion of the quadrangle. Prominent bluffs (ranging to 30 meters high) in many places in West Fork quadrangle are also associated with outcrops of the Pitkin Limestone. Finally, sandstone units of the Atoka Formation form bluffs and cap many of the mountaintops in the southern portion of West Fork quadrangle.

Previous Work.–The Carboniferous geology of the southern Ozark region has attracted worldwide interest because of exposures of the Morrowan Series at the base of the Pennsylvanian System and for the excellent outcrops of fossiliferous strata in proximity to the Mississippian-Pennsylvanian boundary (Frezon and Glick, 1959; Manger and Sutherland, 1984; McFarland, 1998). The geologic history and depositional dynamics of this interval continue to attract the attention of the geologic community as a means of investigating the interplay of tectonics and eustasy in the development of continental margin and foreland

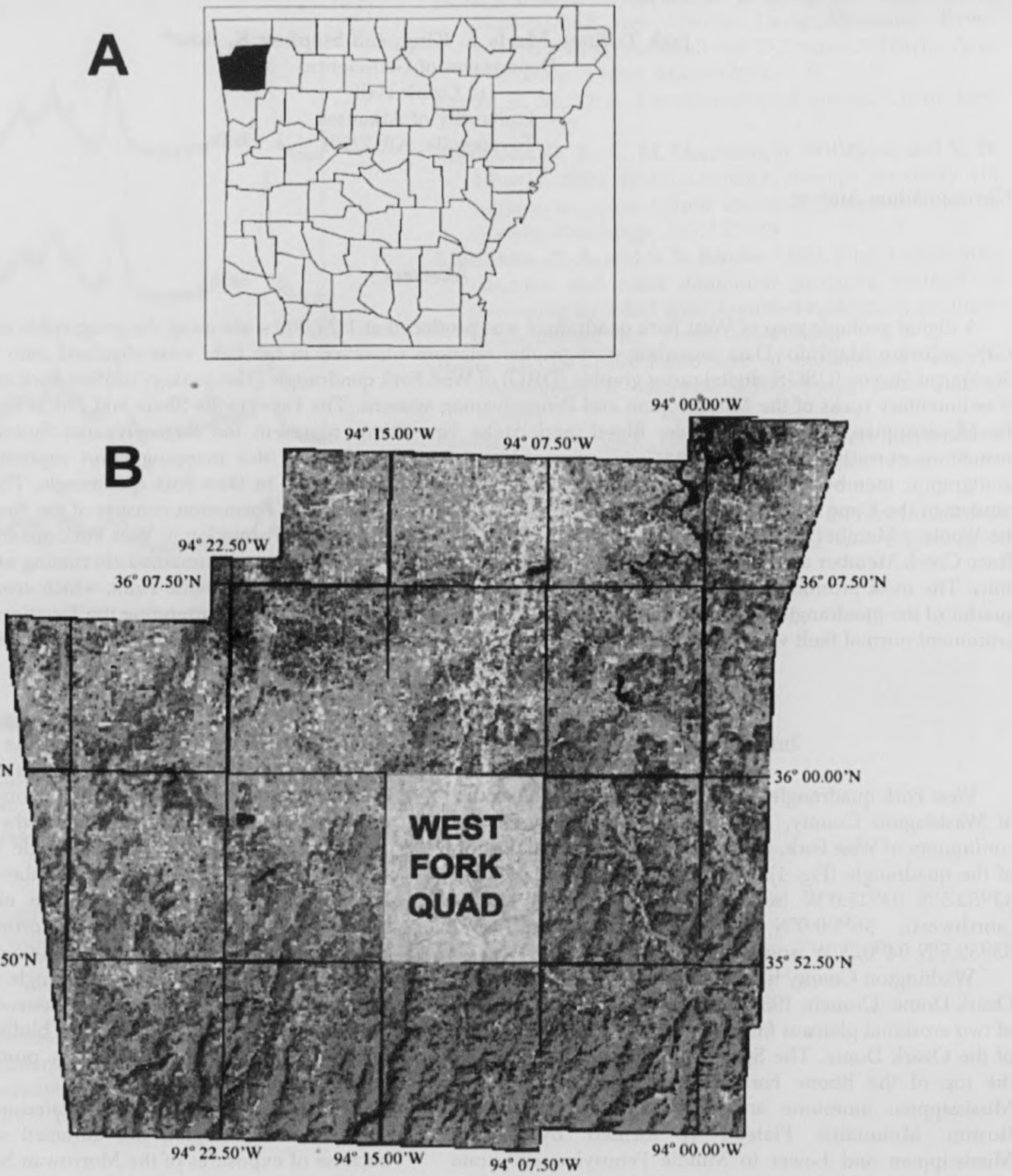

Fig. 1. A) Location map of Arkansas showing Washington County (shaded) and B) West Fork quadrangle in Washington County.

basin sequences (Houseknecht, 1986; Viele, 1989; Ethington et al., 1989; Thomas, 1989; Viele and Thomas, 1989; Handford and Manger, 1990, 1993; Valek, 1999; Hudson, 2000; Anderson, 2001; Combs, 2001; Cooper, 2001). However, despite continued interest in the Carboniferous stratigraphy of northern Arkansas, no detailed mapping of the Carboniferous geology of West Fork quadrangle or its vicinity has occurred since thesis work

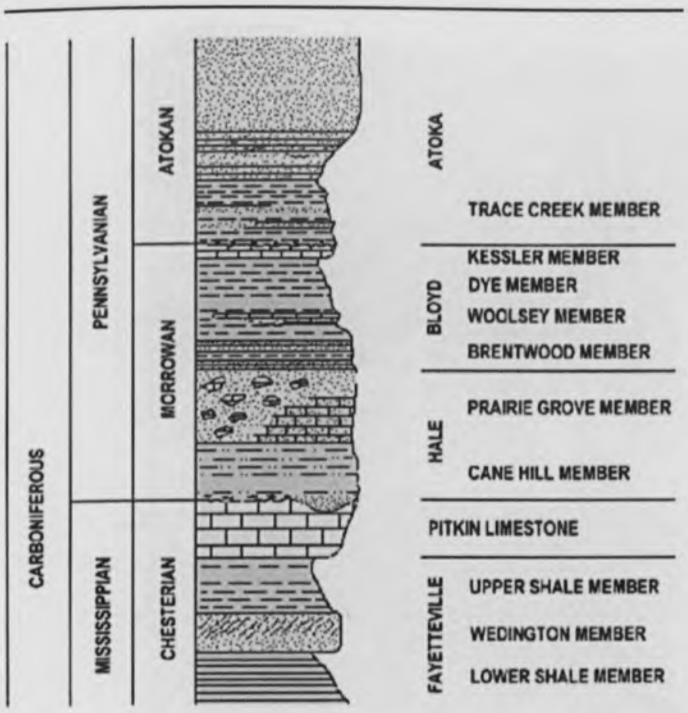

Fig. 2. Generalized stratigraphic column of West Fork quadrangle, Washington County, Arkansas (adapted from Brown, 2000; M.E. King, 2001).

undertaken in the late 1950's and early 1960's (Neumeier, 1959; Wainwright, 1961; Carr, 1963) at the University of Arkansas and since preparation of the revised *Geologic Map of Arkansas* by Haley et al. (1976).

With the advent of satellite positioning services, advanced digital technologies, and geographic information systems during the last decade, it is now possible to develop highly detailed geologic maps from field data with locations determined using the global positioning system (GPS) and transferred to digital mapping programs. Development of geologic maps in digital formats permits relatively easy manipulation of these data and their export to a variety of software platforms where they can be modified or adapted for many projects. This project represents the first effort to map individual stratigraphic members in West Fork quadrangle using digital technologies.

Methods

Field mapping of West Fork quadrangle was conducted throughout the summer of 2000 accessing various locations from a network of county and state roadways or on foot. In areas of low relief where outcrops were poor or missing, a two-meter dutch augur was used to sample soil and weathered rock. Commonly, rock fragments and soil type could be used to determine the bedrock stratigraphy in these areas (J.T. King, 2001; M.E. King, 2001).

Locations of outcrop sites for individual stratigraphic members and observed geologic structures were determined using global positioning system (GPS) receivers capable of receiving differential corrections. These receivers typically have horizontal accuracy of approximately 5 m. For each outcrop or sample location, Universal Transverse Mercator (UTM) coordinates (eastings and northings relative to WGS 84 datum) were noted in the field notebook, and the location was indicated on the field map. A Garmin Etrex Summit with a built-in barometric pressure gauge was used to determine elevations.

A total of 486 field sites was recorded using these methods throughout West Fork quadrangle. These locations were recorded onto a 1:24,000 topographic map in the field, logged into the field book, and later entered into a spreadsheet database that facilitated their transfer to the GIS.

Digital Mapping and Geographic Information System.– A GIS is a computer system that records, stores, and analyzes geospatial information. Information regarding field geologic relations was transferred from the field map to a digital raster graphic (DRG) of West Fork quadrangle using a "heads-up" digitizing method. Using this method, geologic contacts were drawn directly on the computer screen by moving the cursor over a digital raster graphic (DRG) of West Fork quadrangle and clicking the mouse button at short intervals to trace contacts onto the displayed topography (Sullivan, 1999). Each stratigraphic unit was digitized as a separate layer within the geographic information system such that the display of each layer could be toggled on or off. Faults were digitized as lines onto a separate layer as well. Once all stratigraphic units and geologic structures were digitized, map layers representing those stratigraphic units and geologic structures could be displayed hierarchically to generate the geologic map of the study area (Figs. 4 and 5). A legend for the map is presented as Figure 6. The final step in preparing the digital geologic map was to convert all data layers to several digital formats to ensure compatibility with popular GIS applications. Digital formats produced for this study were 1) MapInfo native format, 2) ArcView shape files, and 3) AutoCad DXF. All data were archived on CD-ROM.

Results

In West Fork quadrangle, the Mississippian System is represented by, in ascending order, the Fayetteville Shale and the Pitkin Formation (Simonds, 1891; Adams and Ulrich, 1904, 1905; Purdue, 1907; Croneis, 1930; Frezon and Glick, 1959; Haley et al., 1976; McFarland, 1998). The Mississippian System comprises a substantial portion of the

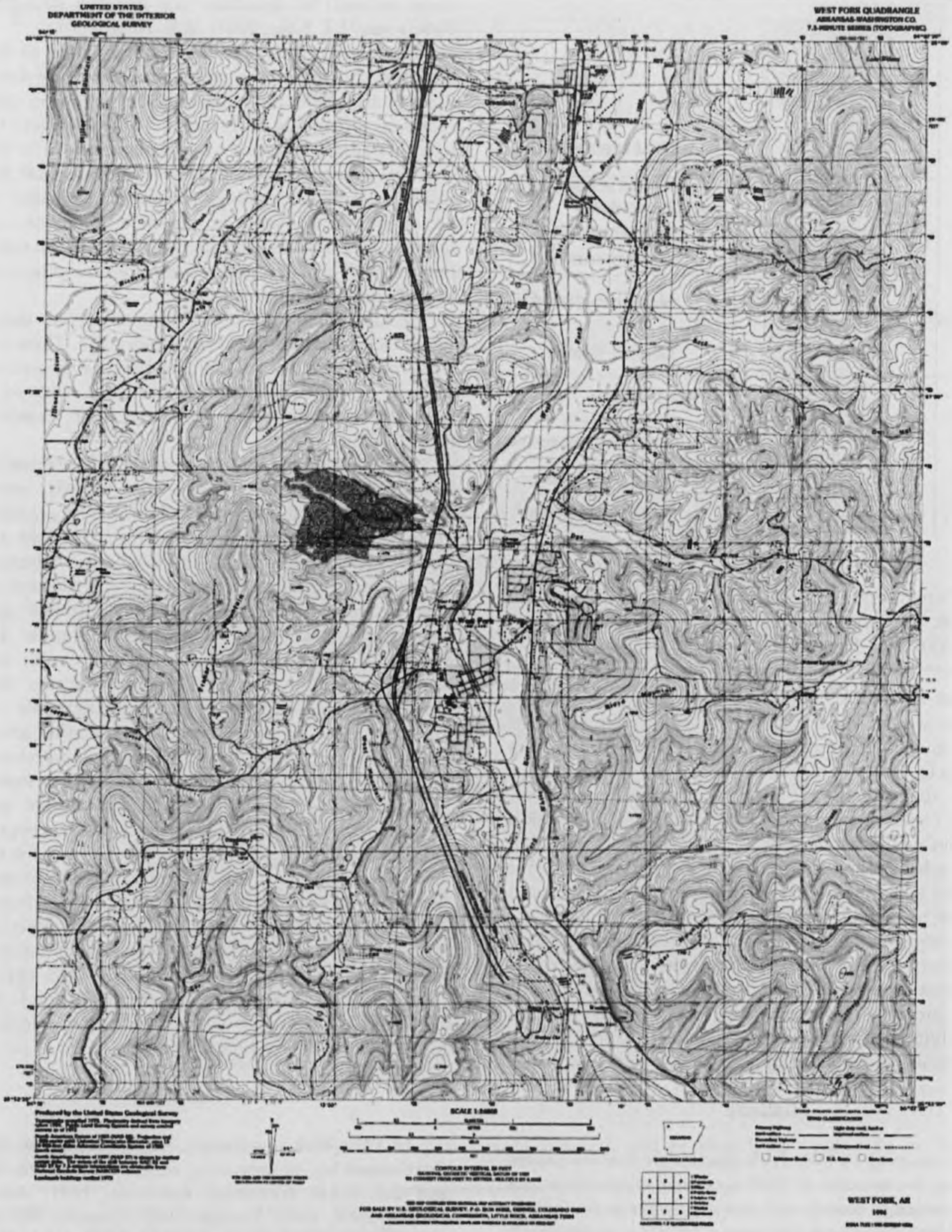

Fig. 3. United States Geological Survey 7.5-minute topographic quadrangle map of West Fork quadrangle, Washington County, Arkansas.

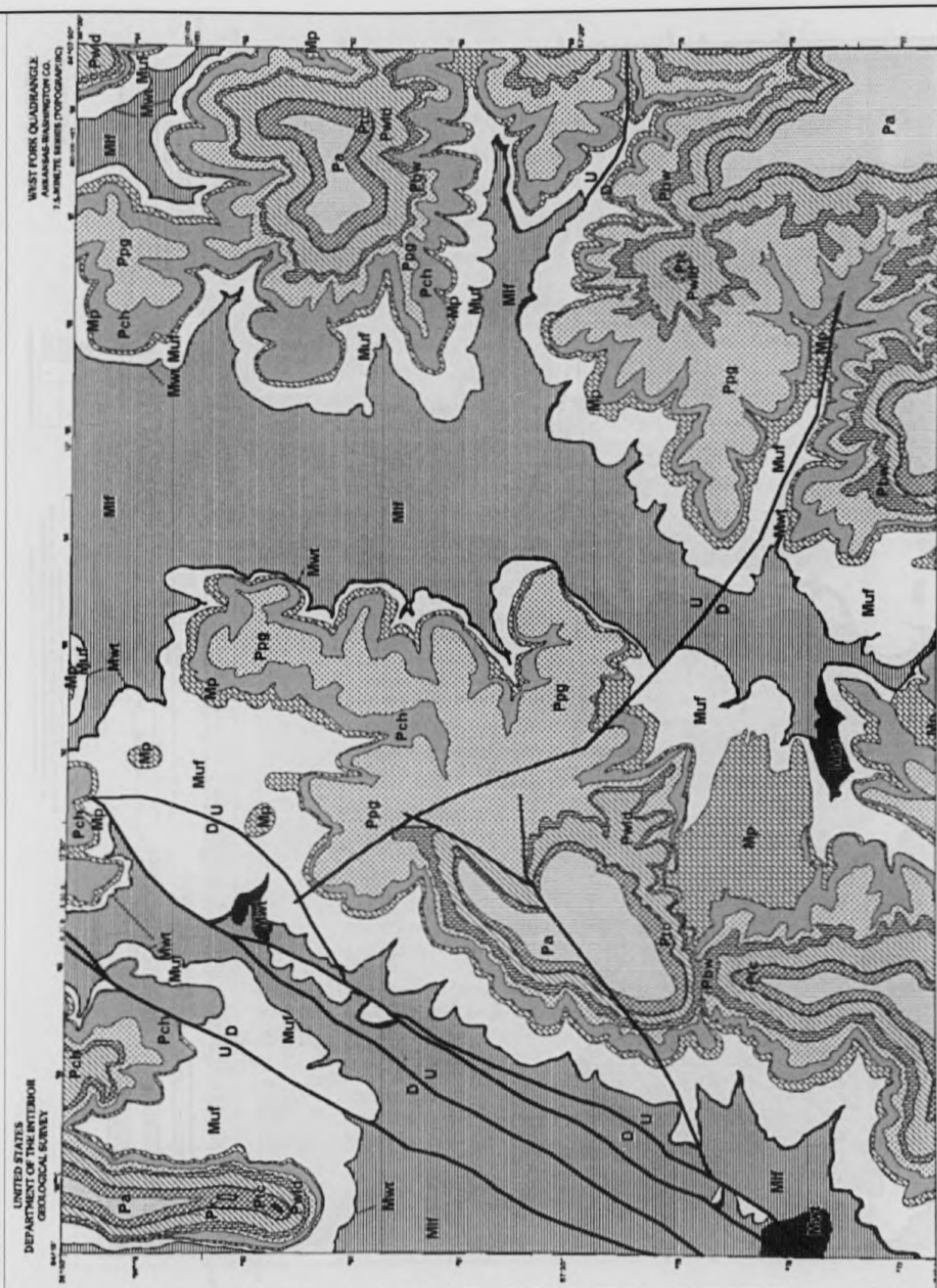

Fig. 4. Map showing bedrock geology northern half of West Fork quadrangle digitized onto West Fork quadrangle 7.5-minute digital raster graphic (DRG).

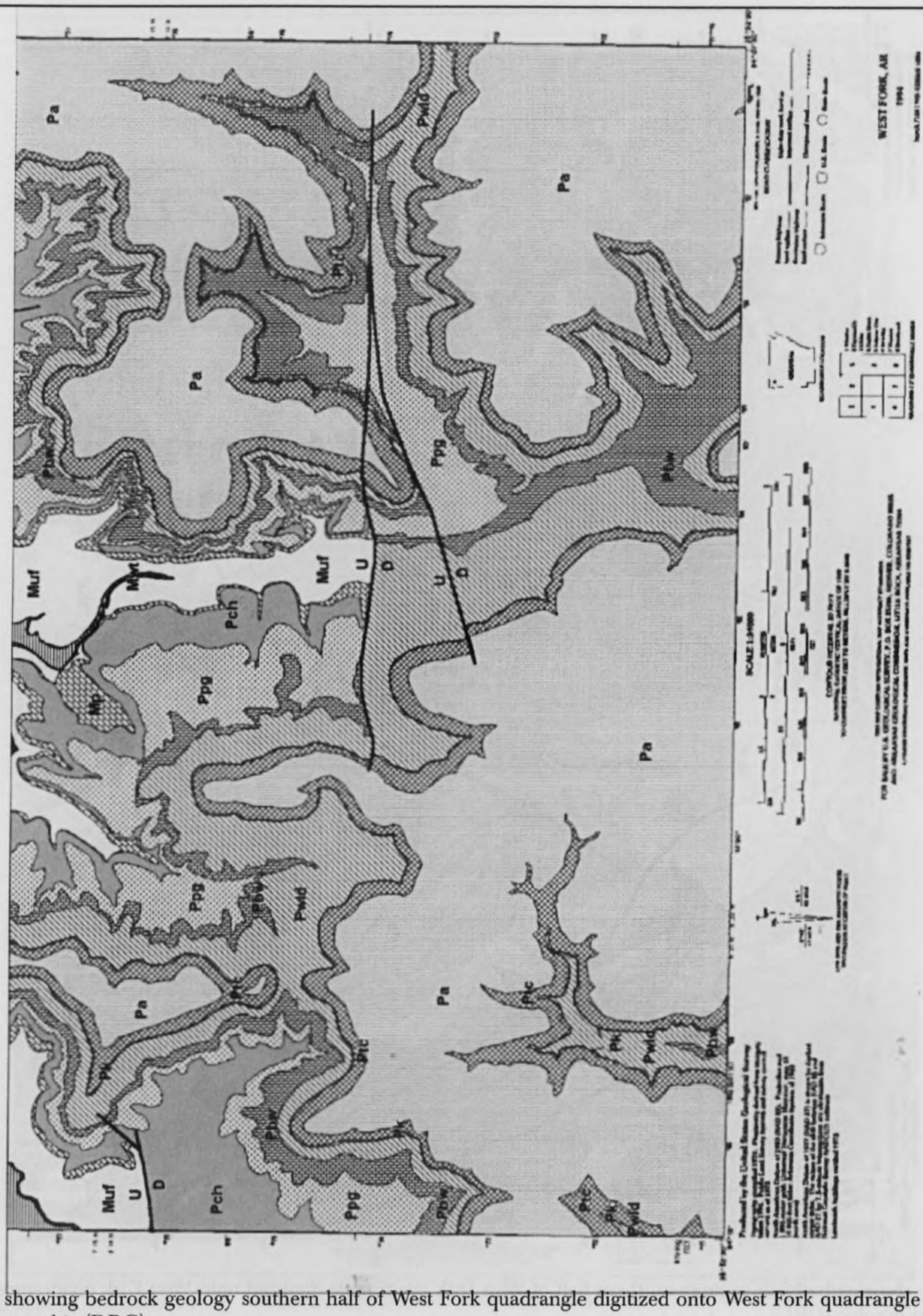

Fig. 5. Map showing bedrock geology southern half of West Fork quadrangle digitized onto West Fork quadrangle 7.5-minute digital raster graphic (DRG).

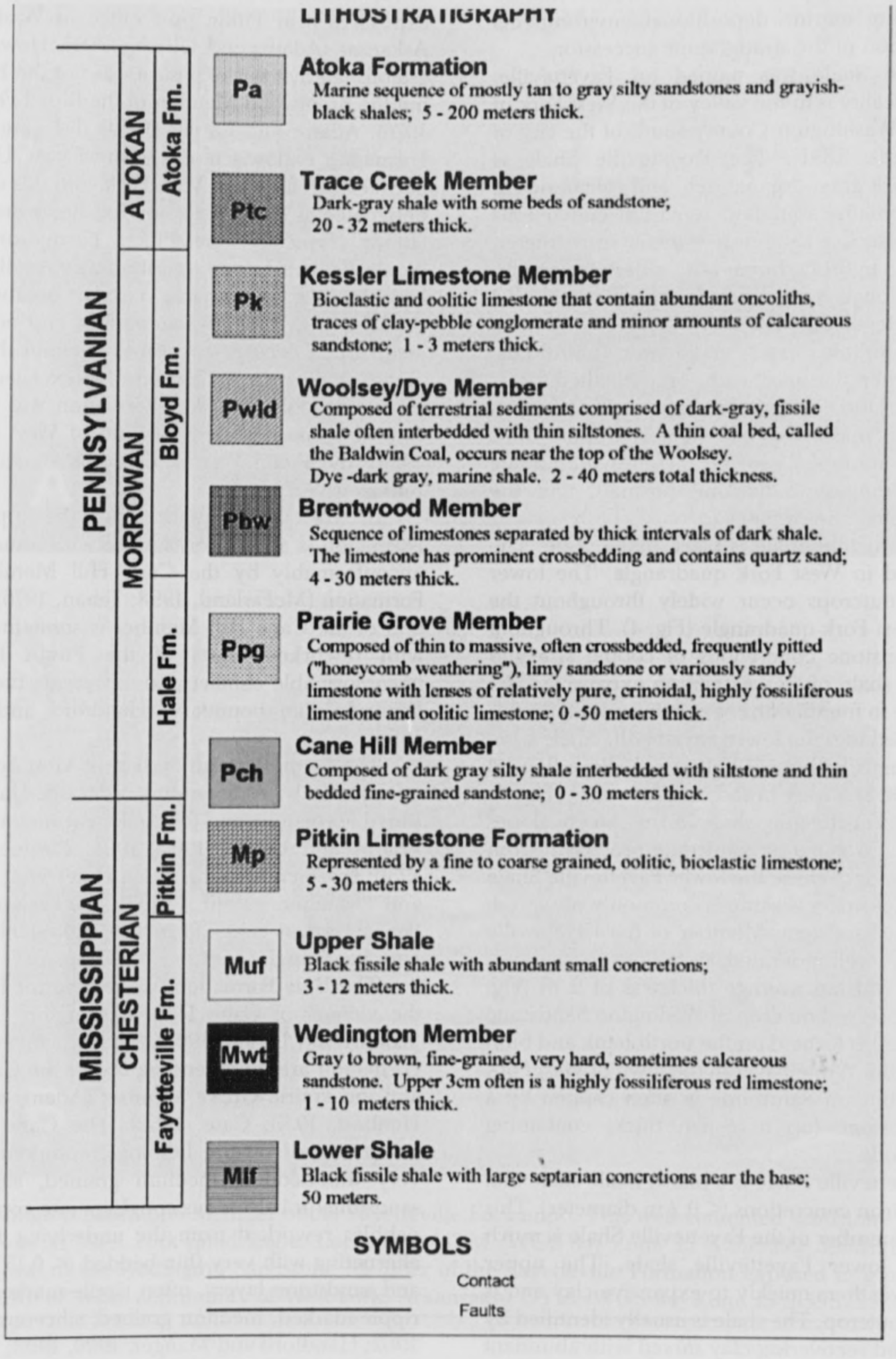

Fig. 6. Legend to accompany geologic map of West Fork quadrangle (Figs. 4 and 5).

surface area of West Fork quadrangle (Figs. 4 and 5). Each formation of the Mississippian System contains marine fossils, thus indicating marine depositional environments throughout this portion of the stratigraphic succession.

The Fayetteville Shale was named for Fayetteville, Arkansas. Its type locality is in the valley of the West Fork of the White River in Washington County south of the city of Fayetteville (Simonds, 1891). The Fayetteville Shale is typically black to dark gray, organic-rich, and calcareous in places. It locally contains abundant septarian concretions ranging from a few inches to almost a meter in diameter, and some contain hydrocarbons and siderite cement. Bethonic fossils, though rare, include brachiopods and mollusks. The Fayetteville Shale is better known for its fossil cephalopods – goniatites and orthoconic nautiloids. Ammonoids were often pyritized, with some silicified fossils also present (McFarland, 1998). The Fayetteville Shale is subdivided into two informally named stratigraphic units and one formal member: lower Fayetteville Shale (informal), the Wedington Sandstone (formal), and the upper Fayetteville Shale (informal).

The lower Fayetteville Shale is black fissile shale. The base is not exposed in West Fork quadrangle. The lower Fayetteville Shale outcrops occur widely throughout the northern half of West Fork quadrangle (Fig. 4). Throughout this unit, small ironstone concretions of cobble size and smaller occur. The shale often weathers to expansive clay, resulting in damage to foundations of structures built on this shale. Streams incised into the lower Fayetteville Shale have deep, narrow channels with mud bottoms. Valleys floored by lower Fayetteville Shale are broad with low relief (Fig. 4). Rarely, the lower Fayetteville shale forms steep slopes where the overlying Wedington Sandstone protects it from weathering and erosion. Where the lower Fayetteville Shale is located on hillsides, mass wasting is commonly observed.

The Wedington Sandstone Member of the Fayetteville Shale is tan to gray, well-indurated, very fine- to medium-grained sandstone with an average thickness of 2 m (Fig. 7A). The thickest observed outcrop of Wedington Sandstone (approximately 10 m) is located on the north bank and bluff of the West Fork of the White River in the town of West Fork (Fig. 7B). The Wedington Sandstone is often capped by a thin layer of limestone (up to 5 cm thick) containing abundant brachiopods.

The upper Fayetteville Shale is a black, fissile shale that contains abundant iron concretions ($<$ 0.2 m diameter). This informally-named member of the Fayetteville Shale is much thinner than the lower Fayetteville shale. The upper Fayetteville shale weathers quickly to expansive clay and is rarely observed in outcrop. The shale is usually identified by auguring 1 - 2 m and recovering clay mixed with abundant small concretions.

The Pitkin Formation is the uppermost formation of the Mississippian System in West Fork quadrangle (Easton, 1942; Tehan, 1976). The Pitkin Formation was named for exposures near Pitkin post office in Washington County, Arkansas (Adams and Ulrich, 1904). However, later study established that this exposure was not the Pitkin Formation, but the Brentwood Member of the Bloyd Formation (Tehan, 1976). Adams and Ulrich (1904) did note a cliff of Pitkin Formation exposed along what is now U.S. Highway 71 between Woolsey and West Fork, and this outcrop was later designated as the type section for the formation by Henbest (1953). Typically, the Pitkin Formation is an oolitic, bioclastic limestone containing fossils of crinoids, brachiopods, bryozoans, corals, bivalves, gastropods, cephalopods, trilobites, conodonts, and occasionally shark teeth. Chert occurrs sometimes at either the top or bottom of the interval in some localities; an excellent example of the black chert of the Pitkin Formation was observed in the extreme central-western portion of West Fork quadrangle where the Pitkin Formation forms a natural dam on the Illinois River (Fig. 8).

In West Fork quadrangle, the top of the Pitkin Formation is an erosion surface with minor relief overlain unconformably by the Cane Hill Member of the Hale Formation (McFarland, 1998; Tehan, 1976). The lowermost unit of the Cane Hill Member is sometimes conglomerate with reworked clasts of the Pitkin Formation. This unconformable contact also represents the Mississippian – Pennsylvanian boundary (Handford and Manger, 1990, 1993).

The Pennsylvanian System in West Fork quadrangle is represented by, in ascending order, the Hale Formation, the Bloyd Formation, and the Atoka Formation (Simonds, 1891; Adams and Ulrich, 1904, 1905; Purdue, 1907; Croneis, 1930; Frezon and Glick, 1959; Haley et al., 1976; Handford and Manger, 1990, 1993; McFarland, 1998). The Pennsylvanian strata form the highest elevations in West Fork quadrangle.

The Hale Formation was named for Hale Mountain in the vicinity of Cane Hill, Washington County, Arkansas (Adams and Ulrich, 1905). The two members of the Hale Formation are (in ascending order) the Cane Hill Member and the Prairie Grove Member (Adams and Ulrich, 1905; Henbest, 1953; Cate, 1962). The Cane Hill Member is comprised of several lithologic components: a basal tan, very thin-bedded, medium grained, siliceous/calcareous sandstone or calcareous conglomerate containing limestone pebbles reworked from the underlying Pitkin Formation, alternating with very thin-bedded ($<$ 0.15 m thick) siltstone and sandstone layers, often ripple-marked, and thick, tan, ripple-marked, medium grained, siliceous sandstone (Cate, 1962; Handford and Manger, 1990, 1993; M.E. King, 2001).

The Prairie Grove Member is composed of thin to massive, commonly cross-bedded, calcareous sandstone or

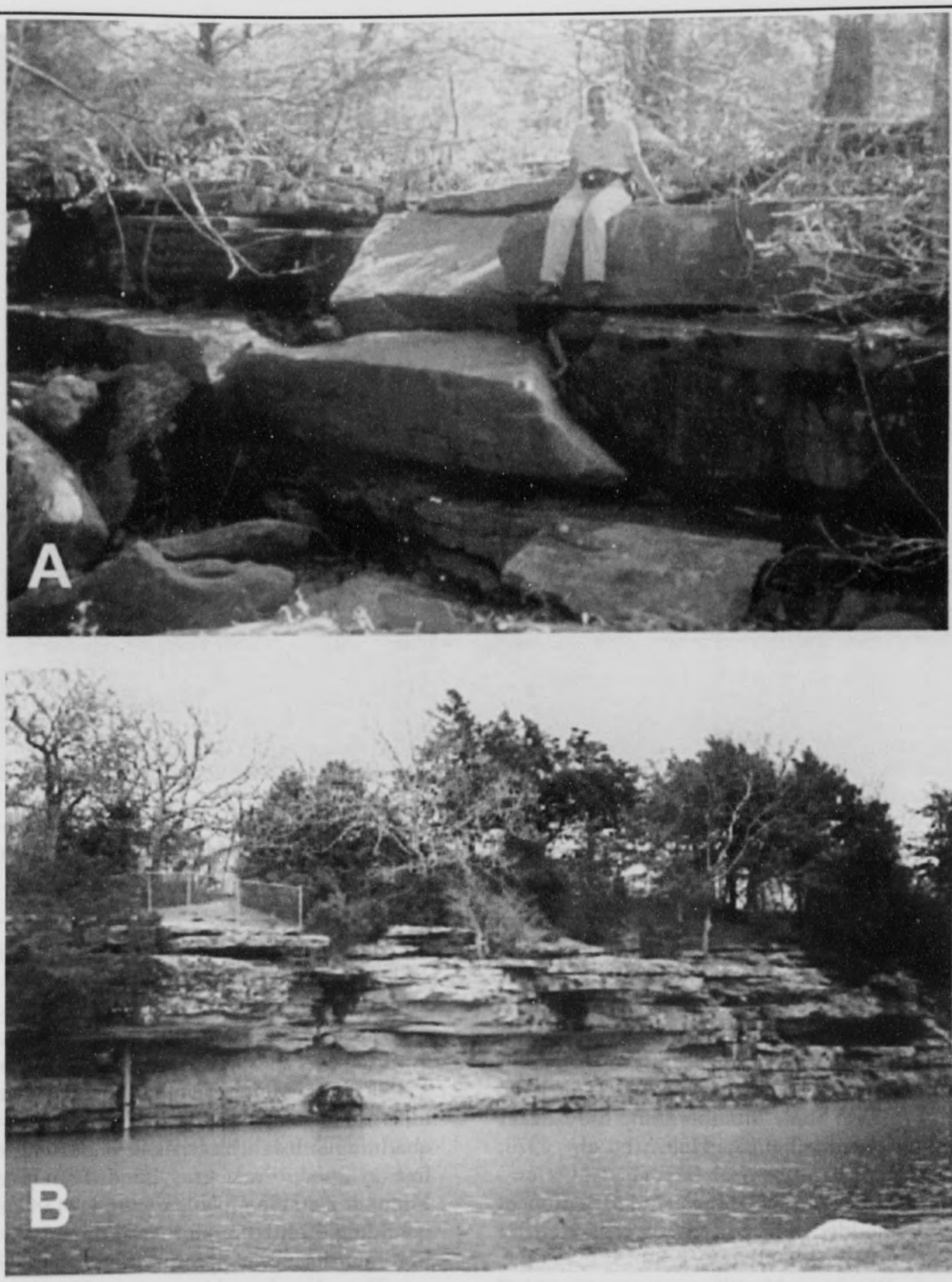

Fig. 7. A) The Wedington Sandstone Member of the Fayetteville Formation. This well-cemented sandstone commonly forms a bench of two meters in West Fork quadrangle. Located at UTM (WGS-84) Zone 15 S 396222 3983128. B) Thick section (approximately 10 m) of the Wedington Sandstone Member of the Fayetteville Formation exposed in a park along the West Fork of the White River in the community of West Fork, Arkansas at UTM (WGS-84) Zone 15 S 393223 3976680).

sandy limestone with lenses of crinoidal and oolitic limestone. Occasional bryozoan bioherms (Hoaster, 1996) are observed within the Prairie Grove Member in West Fork quadrangle (Fig. 9). Prairie Grove Member outcrops typically have a mottled appearance when fresh. The contact of the Prairie Grove Member on the underlying

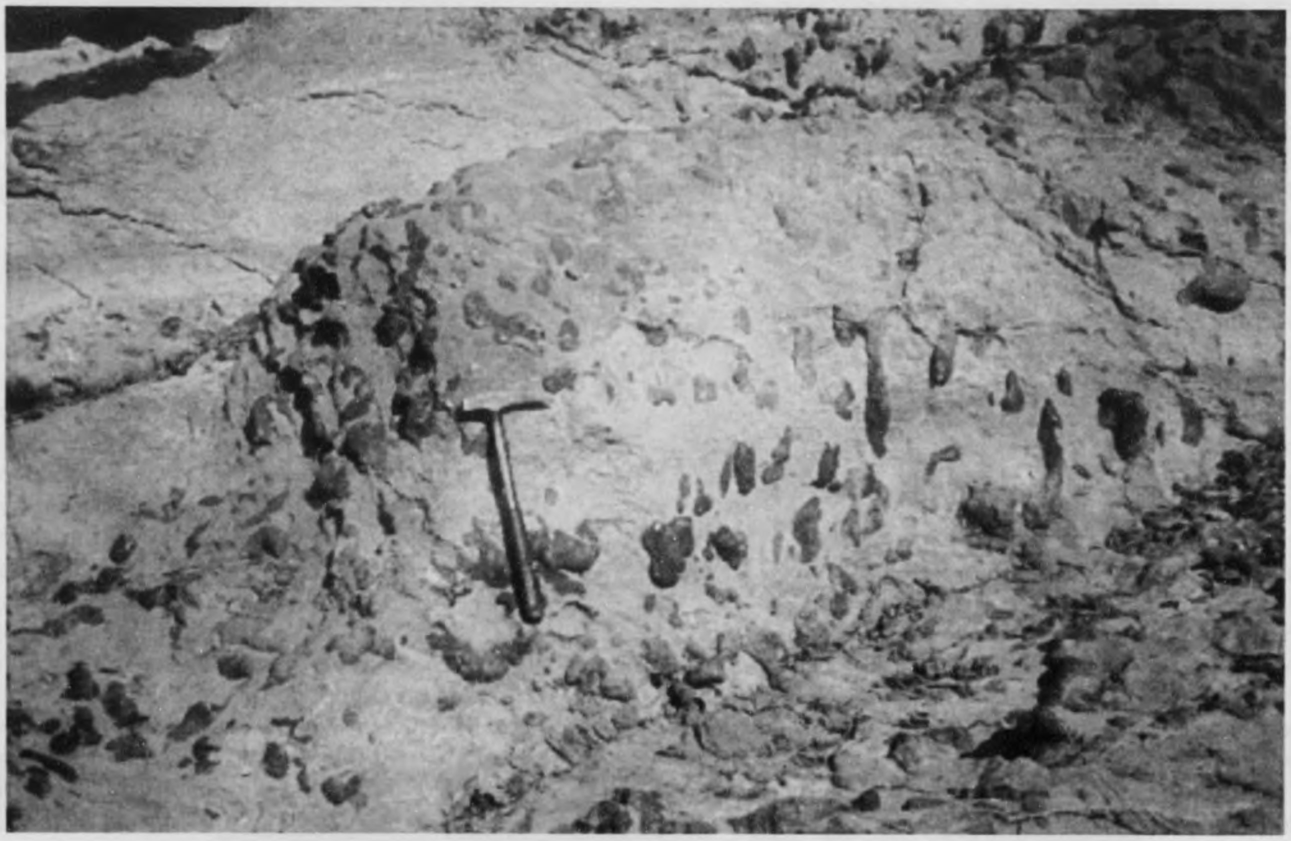

Fig. 8. Black chert of the Pitkin Formation in an outcrop forming a natural dam in the Illinois River on the western boundary of West Fork quadrangle. Rock hammer for scale is approximately 0.3 m. Location UTM (WGS-84) Zone 15 S 387242 3979343.

Cane Hill Member is considered unconformable (McFarland, 1998).

The Bloyd Formation was named from Bloyd Mountain, 14.5 km southwest of Fayetteville, Washington County, Arkansas (Purdue, 1907). The Bloyd Formation consists of (in ascending order) the Brentwood Limestone Member, the Woolsey-Dye Shale Members, and the Kessler Limestone Member (Purdue, 1907; Haley et al., 1976; McFarland, 1998).

The Brentwood Limestone Member is a succession of well-indurated, cross-bedded limestone beds separated by intervals of thin, dark shale (McGilvery, 1982).

The overlying Woolsey Member is composed of greenish gray silty shale in West Fork quadrangle and sometimes contains a one-meter thick, medium grained, siliceous sandstone layer. Plant fossils were observed in the Woolsey Member, as well as a coal bed known as the Baldwin Coal (McFarland, 1998) that is 0.2 m thick and appears to be continuous throughout West Fork quadrangle (J.T. King, 2001) and widespread in Fayetteville quadrangle (M.E. King, 2001) where it serves as a convenient marker horizon. The Woolsey Member weathers to expansive clay and forms gentle to moderate slopes. It is commonly observed in ravines and excavations and by auguring. Seeps and springs are common at the contact between the Woolsey Member and the Brentwood Member.

The Dye Member of the Bloyd Formation was observed in a roadcut of Interstate Highway-540 in West Fork quadrangle. It is a black fissile shale with thin beds of hard, fine grained, dark gray sandstone (Fig. 10). The Dye Member is not mappable on the 1:24,000 scale in West Fork quadrangle and therefore was lumped with the Woolsey Member during mapping.

The Kessler Limestone Member was observed throughout West Fork quadrangle. It was observed in roadcuts and as small bluffs up to three meters high on steep hillsides or forming a bench on moderate slopes. This limestone usually yields a strong smell of petroleum distillate and weathers to a dull tan to brown, crumbly surface. In some areas, it contains abundant sand. The top of the Kessler Limestone is a phosphatic conglomerate representing the unconformity between the Morrowan and

Fig. 9. Bryozoan bioherm in the Prairie Grove Member of the Hale Formation exposed in a road cut of Interstate Highway 540 in West Fork quadrangle. Bioherm is approximately 2.5 m tall. Location UTM (WGS-84) Zone 15 S 391251 3983774.

Atokan epochs (Fig. 11).

The Atoka Formation was named for the town of Atoka, Oklahoma (Taff and Adams, 1900). The Atoka is a series of tan to gray, silty sandstones and grayish-black shales. In West Fork quadrangle, the lowermost member of the Atoka is the Trace Creek Shale. It rests unconformably on the Kessler Limestone Member of the Bloyd Formation. The Trace Creek Shale is black, fissile shale with some thin beds of sandstone. This unit was rarely observed in outcrop but instead usually forms a moderate slope below the first sandstone of the Atoka Formation to the bluff or bench formed by the Kessler Limestone Member of the Bloyd Formation (Fig. 12).

Above the Trace Creek Shale Member, the Atoka Formation forms prominent bluffs composed of sandstone interbedded with shale slopes. The Atoka Formation caps the Boston Mountains in the southern portion of West Fork quadrangle. The Atoka Formation in West Fork quadrangle is typically fine- to medium-grained, well-indurated sandstone alternating with black shale. Many road cuts along Interstate Highway 540 in the southern third of West Fork quadrangle were carved out of the Atoka Formation.

Structural Geology.–West Fork quadrangle is situated on the southern flank of the Ozark Dome that is centered in southeast Missouri (Croneis, 1930). Regional dip of exposed strata is generally less than 5° to the south. Fractures were observed in outcrops of both Mississippian and Pennsylvanian strata, and these fractures were believed to result from brittle deformation related to flexure of the Ozark Plateaus and formation of the Ozark Dome during the Ouachita orogeny (Viele, 1989; Viele and Thomas, 1989; Hudson, 2000).

Fractures were observed on pavement outcrops of the Pitkin Formation (Mississippian) and the Brentwood Member of the Bloyd Formation (Pennsylvanian). Fractures on the surface of the Pitkin Formation have strikes of N90°E and N20°W. Fractures observed on the surface of the Brentwood Member of the Bloyd Formation in the bed of Winn Creek have strikes of N50°E.

Several faults were observed in West Fork quadrangle. The dominant structure in the quadrangle is the Fayetteville Fault, which crosses the northwest quarter of the quadrangle

Fig. 10. The Dye Member of the Bloyd Formation is black, fissile shale with thin, very dark, fine grained sandstone located beneath the Kessler Limestone Member (Bloyd Formation) which is the massive, gray limestone shown in this photo. Location UTM (WGS-84) Zone 15 S 392505 3973730.

from southwest to northeast (Figs. 4 and 5). The Fayetteville Fault is a normal fault downthrown to the southeast. In West Fork quadrangle, the fault is poorly expressed because it occurs in weathered deposits of the Fayetteville Shale. A geologic worksheet (West Fork quadrangle) prepared by the Arkansas Geological Commission during preparation of the 1:500,000 geologic map of Arkansas (Haley et al., 1976, 1993) showed several parallel faults associated with the Fayetteville Fault, suggesting a broader fault zone associated with the Fayetteville Fault. These faults were apparently interpreted from lineaments observed on aerial photographs by Haley (Dr. D. Zachry, personal communication, 2002). However, focused efforts by the authors to locate field evidence for these faults proved difficult because the faults are wholly within deeply weathered profiles of the Fayetteville Shale. The faults are included in the present report as represented on the Arkansas Geological Commission worksheet compiled in conjunction with development of the state geologic map (Haley et al., 1976, 1993).

Other faults in West Fork quadrangle are oriented with northeast and east-west strikes (Figs. 4 and 5). A prominent fault in the southern portion of the quadrangle (Fig. 5) crosses Interstate Highway 540 with an east-west strike. This fault is downthrown substantially to the south such that south of the fault, the Mississippian section is no longer observed. However, the elevation of the Kessler Limestone (uppermost member of the Bloyd Formation) remains the same on the north and south sides of the fault. Thus, it appears that activity on this fault occurred prior to deposition of the Kessler Limestone.

Discussion

The stratigraphy of West Fork quadrangle is composed of alternating layers of shale, limestone, and sandstone in genetically related packages bound by prominent regional unconformities. These depositional series represent the

Fig. 11. Phosphatic conglomerate on the upper surface of the Kessler Limestone Member of the Bloyd Formation. This surface is the unconformity between the Morrowan and Atokan epochs of the Pennsylvanian Period. Hammer for scale is approximately 0.3 m. Location UTM (WGS-84) Zone 15 S 392505 3973721.

response of the sedimentary system of northwest Arkansas to fluctuating relative sea-level changes during the late Mississippian and Pennsylvanian Periods.

The Mississippian (Chesterian) Pitkin Formation rests conformably on the Fayetteville Shale. The Pitkin Formation represents a shallow-marine inner shelf environment (Handford and Manger, 1990). The end of this deposition was clearly a regressive phase that exposed the top of the Pitkin Formation subaerially and eroded it. North of West Fork quadrangle, in the Fayetteville quadrangle, the Pitkin Formation was completely eroded and the overlying Cane Hill Member of the Hale Formation (Pennsylvanian) was deposited unconformably on the Fayetteville Shale. Development of the Mississippian-Pennsylvanian unconformity is the major geologic event recorded by strata in West Fork quadrangle.

The Pennsylvanian Cane Hill Member of the Hale Formation was deposited across the eroded top of the Pitkin Formation as seas transgressed the erosional surface. Pebbles of Pitkin Formation were incorporated into basal Cane Hill Member deposits. However, relative sea-level rise over the top of the Mississippian-Pennsylvanian unconformity was apparently slight as the Cane Hill Member represents tidal deposits throughout its extent. Relative sea-level rise apparently continued with deposition of the Prairie Grove Member (Hale Formation) and Brentwood Member (Bloyd Formation). The Brentwood Member represents a broad transgression interrupted by lesser regressions and transgressions. A final regressive phase terminated Brentwood deposition (McGilvery, 1982). Following the regressive phase, the Morrowan Woolsey Member of the Bloyd Formation was deposited in a brackish

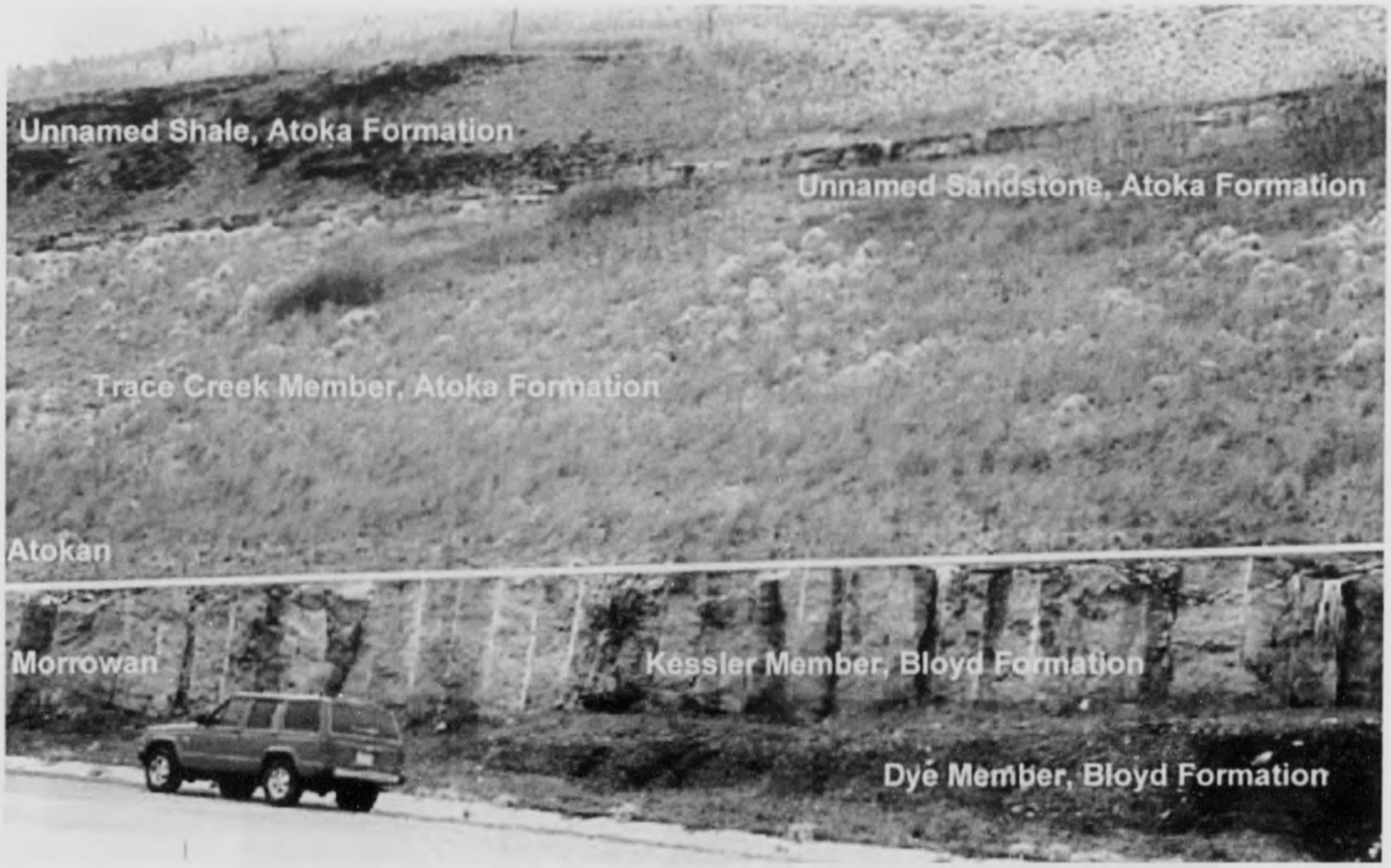

Fig. 12. Bloyd Formation – Atoka Formation contact. Road cut on the west side of Interstate Highway 540 shows the contact of the Kessler Limestone Member (Bloyd Formation) and Trace Creek Member (Atoka Formation) representing the Morrowan-Atokan. Location UTM (WGS-84) Zone 15 S 392505 3973721.

water environment that included deposition of the Baldwin Coal (McGilvery, 1982). Continued marine incursion during the Morrowan epoch is indicated by deposition of the Dye Member (a marine shale; Henbest 1953; McGilvery, 1982) of the Bloyd Formation unconformably on the Woolsey Member, culminating with deposition of the Kessler Limestone Member and eventual relative sea-level fall leading to development of the phosphatized, conglomeratic upper surface of the Kessler Member. This erosional conglomerate represents the Morrowan-Atokan unconformity. Finally, alternating deposition of nearshore marine and deltaic sandstone, shale, and siltstone of the Atoka Formation suggests renewed, minor, and fluctuating relative sea-level episodes in West Fork quadrangle during the Atokan epoch.

ACKNOWLEDGMENTS.—Geologic mapping of Fayetteville quadrangle was accomplished through a grant from the United State Geological Survey National Cooperative Geologic Mapping Program under assistance award #00HQAG0084.

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