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STATE OF ARKANSAS

ARKANSAS GEOLOGICAL COMMISSION

Norman F. Williams, State Geologist

THE ATOKA FORMATION IN NORTH-CENTRAL ARKANSAS

by

Charles G. Stone

Little Rock, Arkansas

1968

(reprinted 1978)

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ABSTRACT

The Atoka Formation is the surface rock over most of the eastern Arkansas Valley and the transition zone of the frontal Ouachita Mountains, and has been divided into three members: Lower, Middle, and Upper.

The Lower member in the transition zone consists of about 9,000 to over 13,000 feet of alternating, very thin-to-occasionally-thick-bedded, silty, micaceous, fine-grained, brownish gray sandstone; micaceous, locally sooty, gray siltstone; and silty, gray-black shale. It is considered a deep basin turbidity current deposit. Paleocurrents were generally from the east-southeast. The extreme lower portions of this unit are considered Morrowan. In the southern Arkansas Valley this member thins rapidly (probably across a major scarp or hinge line) and increases in shale percentage. A north-northeastern source is indicated by numerous sedimentary slump and turbidity current features. This unit thins northward across the Arkansas Valley and grades into more massive, medium-grained sandstones of a shelf (distal pro-delta) environment.

The Middle member in the transition zone and the southern Arkansas Valley has a typical thick gray black shale section at the base overlain by usually three flaggy, fine-grained, micaceous, gray sandstone units, the "traceable three", which are separated by fairly thick intervals of gray-black shale. The member thins from about 6,200 feet in the southern transition zone to about 4,100 feet in the southern Arkansas Valley. The Middle Atoka represents the progression from deep basin (turbidity current) to continental slope (sediment flow) deposits. In the northern Arkansas Valley the lower shale unit has not been differentiated, but the "traceable three" is represented by about 600 to 300 feet of medium-to-coarse-grained, cross-bedded, massive, grayish-brown sandstone with minor amounts of black, silty shale. It is a shallow marine (possibly distal pro-delta) deposit and probably had a northeastern source.

The Upper member is composed of approximately 6,500 feet of gray-black shale with minor silty to occasionally quartzose sandstone along the southern border of the transition zone. It is fairly constant in lithologic character and thins rather uniformly northward across the Arkansas Valley. Coal beds, invertebrate fossil horizons, and other features indicate cyclothemic conditions with oscillating continental and shallow marine environments. The Atoka Formation is overlain with a slight unconformity by the Hartshorne Sandstone (Des Moines Series), and is underlain unconformably by the Bloyd Shale (upper Morrowan) in the north and conformably by shale and sandstone of the probable Morrow Group in the south and east-central areas.

INTRODUCTION

The Atoka Formation is the major stratigraphic unit exposed in the highly folded and faulted transition zone of the frontal Ouachita Mountains on the south, and the progressively less deformed eastern Arkansas Valley (Arkoma Basin) on the north (Fig. 1). The Atoka has a restored thickness of over 25,000 feet along the southern boundary at the major "Y" City fault, where older rocks are thrust many miles northward over the sequence. The northern boundary is arbitrarily placed at the normal fault (downthrown to the south) near Clinton where the Atoka has a restored thickness of about 3,500 feet.

The Atoka Formation has been extensively studied because of the large quantities of dry gas obtained from it in the Arkansas Valley. Noteworthy investigations in the area are by Branner (1896), the State Geologic Map (1929), Croneis (1930), Maher and Lantz (1953), Caplan (1954 and 1957), Frezon and Glick (1959), Stone (1966), and Sullivan (1966). Definitive reports in western Arkansas are by Hendricks and Parks (1950), Reinemund and Danilchik (1957), Scull, Glover, and Planalp (1959), Haley (1960, 1961 a and b, and 1966), Merewether and Haley (1961), and Merewether (1961 and 1967).

Special thanks are extended to Mr. Ernest E. Glick of the U. S. Geological Survey for releasing pertinent information in the northeastern Arkansas Valley. Acknowledgment is also made to Dr. Hugh D. Miser of the U. S. Geological Survey for his many contributions; Mr. Norman F. Williams, State Geologist of Arkansas and Mr. William M. Caplan of the State Geological Commission for their invaluable discussions and stratigraphic information; and to the many others for their gracious assistance.

MORROW GROUP

The Morrow Group (Fig. 2) crops out in valleys of the Boston Mountains north of Clinton and occurs in the subsurface to the south. It is generally overlain

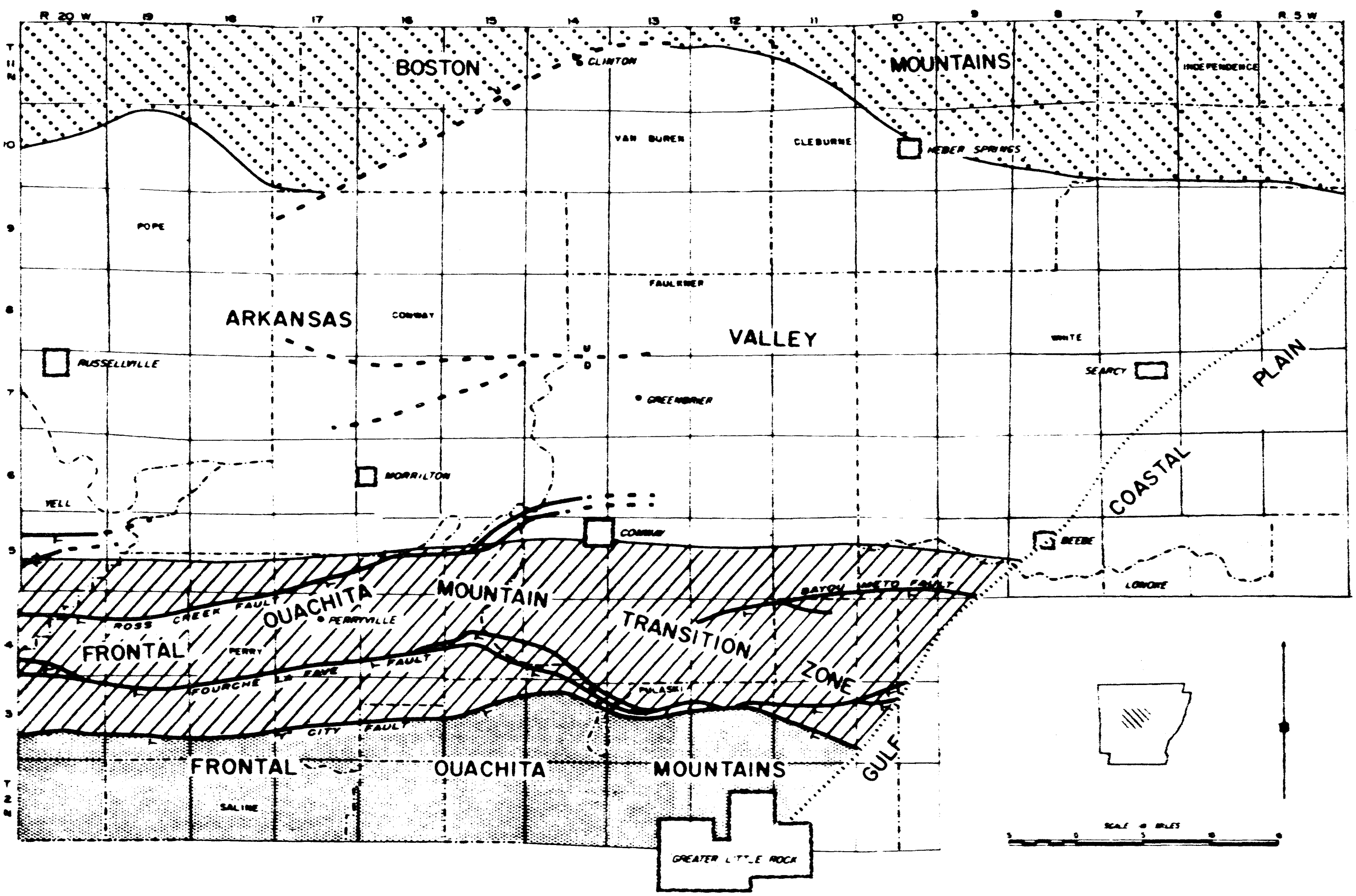
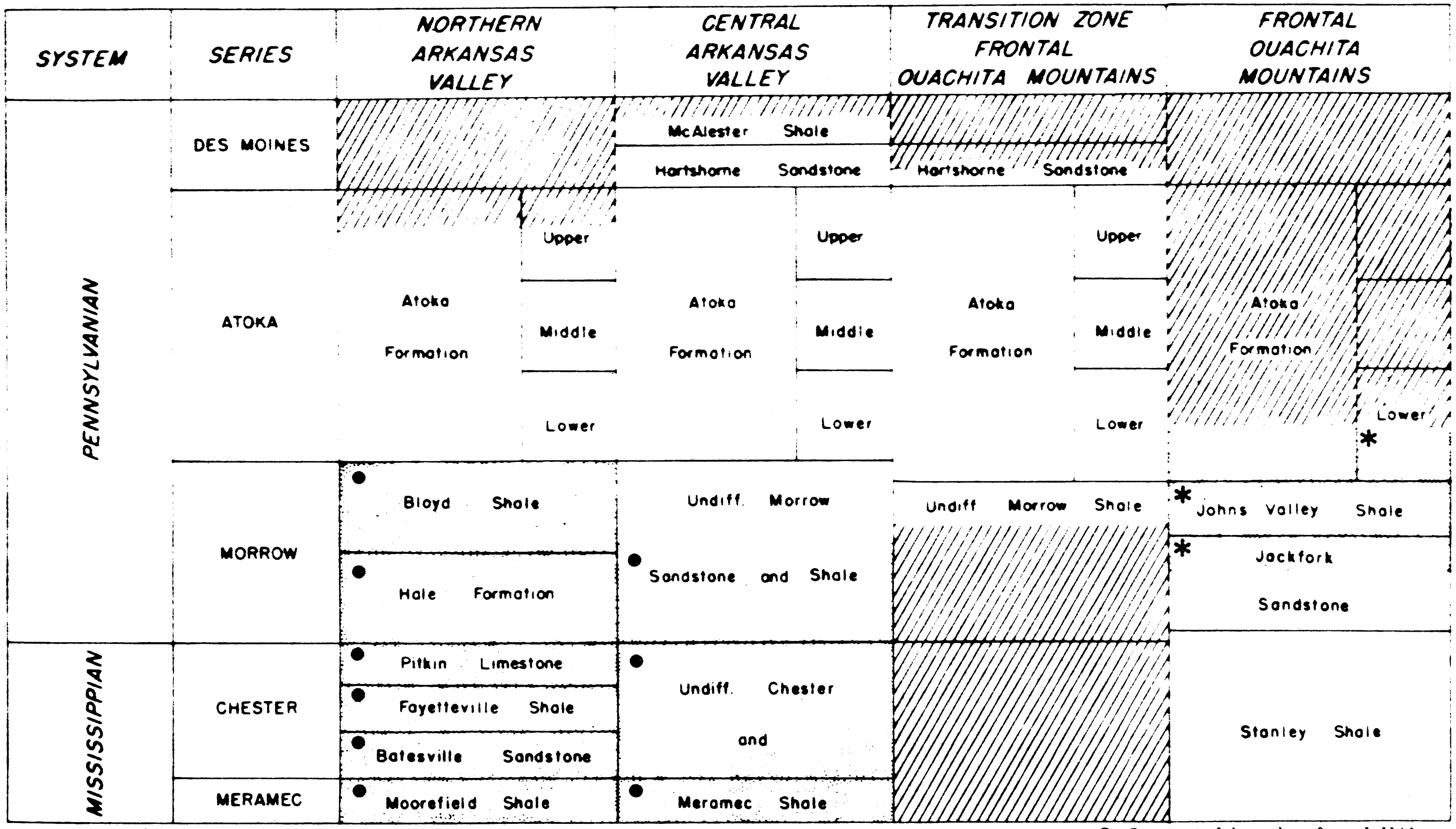


Figure 1. Index map of north-central Arkansas



Adapted from Maher and Lantz (1953), Caplan (1954 and 1957), Freson and Glick (1959), Gordon (1964), Stone (1966), and other reports.

● Penetrated by subsurface drilling
* Exposed in western Arkansas

Figure 2. Correlation of Pennsylvanian and Mississippian stratigraphic units.

unconformably by the Atoka Formation in this area. The Morrow Group varies in thickness from about 400 feet in the Boston Mountains to about 800 feet in the northern Arkansas Valley and is considered a typical shelf facies. It is composed of fine-to-medium grained, often conglomeratic, sandstone; gray-black shale, and gray, crystalline, fossiliferous limestone. Subsurface data by Maher and Lantz (1953), Caplan (1957), and Frezon and Glick (1959), indicates that the Morrow Group gradually thickens and changes somewhat in facies to the south, but generally is identifiable in the central Arkansas Valley.

The probable upper Morrow Group is about 1,400 feet in thickness and undergoes marked lithologic changes in exposures near Searcy in the east-central Arkansas Valley. It is composed of alternating, massive-to-thin-bedded, often fossiliferous, very fine to coarse grained, commonly conglomeratic and limy sandstone and greenish-gray shale, and is conformably overlain by the Lower member of the Atoka Formation. The questionable boundary is arbitrarily placed at the change from gray-black (Atoka) to light greenish gray (probable Morrow) shales. In the subsurface Maher and Lantz (1953), and others, describe an additional 1,200-1,600 feet of interbedded, massive, fossiliferous sandstone and black shale (lower Morrow Group) and about 2,500 feet of black shale and minor sandstone (Mississippian). Maher and Lantz (1953) applied Ouachita terminology, Jackfork Sandstone and Stanley Shale, to these subsurface units. It is agreed with Caplan (1957) that this sequence is a shallow basin development in the eastern Arkansas Valley. A northeastern source of sediment is suggested.

The Lower Atoka conformably overlies about 1,000 feet of probable upper Morrowan rocks along the faulted axis of the Bayou Meto anticline in the eastern transition zone. The sequence is composed of highly sheared, black, fissile shale; with minor thin-bedded, discontinuous, bottom marked, silty sandstone; and small clay ironstone concretions. Paleocurrents from the east-southeast are indicated. This sequence greatly resembles the upper Morrowan (Gordon, 1964) Johns Valley Shale of the western frontal Ouachita Mountains; except that, no erratics or microfossils have been noted. A considerable thickness of Morrowan and Mississippian shale with minor amounts of sandstone probably occur below this section in the subsurface. In the transition zone several hundred feet of the basal portions of the Lower Atoka member are probably upper Morrowan in age.

In the frontal Ouachita Mountains south of the very large "Y" City thrust fault, approximately 2,700 feet of massive, fine grained, quartzitic sandstone and thick shale of the upper Jackfork Sandstone (Pennsylvanian) and about 4,500 feet of intensely folded, often chaotic, black shale and discontinuous, dense, fine-grained sandstone masses of the Stanley Shale* (Mississippian-Pennsylvanian) are exposed (Fig. 3). Rocks above the middle upper portions of the Jackfork are not present due to faulting and the basal massive sandstone interfingers with black shale to the north. The Stanley and Jackfork are considered fairly deep basin turbidity current deposits that were derived from the northeast and southeast. Minor lenses in the upper Stanley are interpreted as submarine slump deposits from postulated northern scarps. Present information suggests that Ouachita terminology is not applicable in this area north of the "Y" City fault.

ATOKA FORMATION

The Atoka Formation was named by Taff and Adams (1900) after the town of Atoka, Oklahoma, where about 7,000 feet of faulted Atoka strata crops out. Branson (1961) indicates that in northwestern Atoka County, Oklahoma, the entire formation is exposed and should logically serve as the type locality. Simonds (1891) called the sandstones and shales above the Kessler Limestone (upper Morrow Group) in Washington County, Arkansas, the Millstone Grit Formation. Simonds used Millstone Grit to include the section between the Kessler Limestone of the Ozark region and the productive Coal Measures in the Arkansas Valley (lower Hartshorne coal-McAlester Shale). Adams (1904) changed the name to Winslow Formation after exposures in the town of Winslow, Washington County, Arkansas, but its upper limit was not definite. Adams presumably included strata belonging to the Lower, Middle, and Upper Atoka of the present study in the Winslow Formation. Henbest (Branner, 1927) and others dropped Winslow in favor of the earlier established Atoka; Quinn and Carr (1963), McCaleb (1963), and others, restored Winslow, but restricted it to the lower Atoka of Croneis (1930) and retained Atoka for the upper and middle portions of the formation. It is agreed with Henbest (Branner, 1927) and the State Geologic map (1929) that Atoka and Winslow are synonymous and that Atoka has priority.

Branner (1896) first noted the thick Carboniferous section (essentially Atoka) in the transition zone when about 18,500 feet was measured between Round Mountain south of Conway and the faulted axis of the Bayou Meto anticline to the east. An additional 2,000 feet of Atoka is present in this area. Croneis (1930) measured about 9,500 feet of Atoka (incomplete Lower member) in Perry County and suggested a possible eastern source of sediments.

*The rocks identified as Stanley Shale in this area are now regarded as mostly middle and lower Jackfork Sandstone as a result of intensive studies for the new State Geologic Map.

Reinemund and Danilchik (1957) in the Waldron quadrangle of western Arkansas first mapped in detail the great thickness (18,500 and 19,000 feet in two incomplete sections) of the Atoka Formation. In two earlier reports on central Arkansas (1963 and 1966) I indicated a minimum thickness of over 19,000 feet and briefly described the Atoka Formation.

The westward tilt of the Arkansas Valley has created almost continuous Atoka exposures in the region. The formation is divided into three members which undergo changes in facies, environment, thickness and occasionally source, and are mapped with some qualifications from the transition zone to the Boston Mountains (Fig. 3). A brief description of these units follows. **Lower Member.** The Lower Atoka in the transition zone (Fig. 3) consists of about 9,000 to over 13,000 feet (Fig. 4) of alternating very thin-to-occasionally-thick-bedded, brownish gray, poorly sorted, fine-to-medium-grained, silty, micaceous, sandstone; micaceous, sandy, often sooty, gray siltstone; and silty, black shale. Shale comprises about 40 percent, sandstone about 35 percent, and siltstone about 25 percent of the interval. Most of the sandstones have a sharp contact with shale below and grade upwards through siltstone to shale. There are many thousands of these rhythmic or cyclic units, which also form larger sequences, both of which are widespread. Massive sandstones are more common in the lower half of the member. Most siltstones have abundant coalified plant fragments and coarse mica. The Lower Atoka is characterized by graded bedding, laminations (convolute, parallel, and current), bottom markings (flute, prod, and load molds), slump structures and pseudo-boulders. Interference and current ripple marks occur on some sandstone beds. There are few observable fossils, but some crinoid fragments occur in an occasional quartz pebble conglomerate. Some fairly large carbonized plant fragments occur in the siltstone and shale. Some beds have worm trails and other spoor (trace fossils). Paleocurrent data, lithology, and influx of new heavy minerals (Wiegel, 1958) from a metamorphic terrain indicate the major source was from the east-southeast. Deposition was by turbidity and possibly overloaded marine currents. Sedimentary slump and turbidity currents from the northeast transported minor clastics down the flank of the basin. These deposits were co-mingled in the Ouachita geosyncline, possibly bathyl environment, where dark mud was normally accumulating, and carried down a slight paleoslope to the west-southwest, controlling the longitudinal filling of the deep basin.

Miser and Purdue (1929) and Walthall (1967) in the southern Ouachita Mountains of Arkansas indicate about 5,500 feet of incomplete Lower Atoka in synclines or along faults. This sequence has features suggesting a deep basin deposit.

In the extreme southern Arkansas Valley limited data suggests that the Lower Atoka thins rapidly to about 5,000 feet along a postulated major (possibly east-west) scarp or hinge line and is more shaly. The sandstones are brownish-gray, very fine-to-medium grained, silty to quartzose, and micaceous. They are usually lenticular, and have numerous slump features, bottom markings, and sharp contacts above and below. There are abundant oscillation, interference, and current ripple marks. Crinoids and brachiopods occur sparingly in minor quartz or shale pebble conglomerates, also several new spoor were noted. This narrow zone separates the deep basin Lower Atoka on the south from the neritic Lower Atoka on the north. The clastics were probably derived from a north-northeastern source and deposited by sedimentary slump and turbidity currents.

There are very limited studies of the continuously exposed Lower Atoka along the eastern and northern portions of this area (Fig. 3). Maher and Lantz (1953), Caplan (1954 and 1957), Freeman (1957), Frezon and Glick (1959), and others, have examined much of the fairly abundant subsurface information. The Lower Atoka thins northward in the Arkansas Valley and a series of postulated northeast trending normal (growth) faults which are downthrown to the south and submarine topographic lows probably influenced deposition. The unit has a restored thickness of about 1,700 feet along the northern boundary (Fig. 1). The member increases rapidly in sandstone percentage to the north and is often medium-to-occasionally-coarse-grained, conglomeratic (quartz and shale pebbles), limy, ripple mark, crossbedded, and fossiliferous. Thin, gray, crystalline, fossiliferous limestone lenses occur sparingly at some localities. Crinoids, brachiopods, goniatites, meager microfossils, spoor (Conostichus and others) are present in some horizons. Sedimentary slump features are abundant in many sandstones. These clastics are considered neritic marine deposits formed largely by the buildup of the seaward portions of a prograding delta with either multiple transgressive and regressive cycles or aggradation of the landward portions. A north-northeastern source is suggested. Frezon and Schultz (1961) indicate that three wells in the area contain probably bentinites; the Western Gas Company No. 1 Chapman in T. 9 N., R. 12 W., the Carter Oil Company No. 1 Williams in T. 9 N., T. 16 W., and the Blackwell Oil Company No. 1 Scroggins in T. 7 N., R. 16 W. Probable bentonites occur in other wells in the area. Future mapping should delineate these markers at the surface.

Middle Member. -- The Middle Atoka consists of approximately 6,200 feet of shale and sandstone in the southern transition zone (Figs. 3 and 4). It has a typical thick, gray-black, silty shale section at the base (3,400 feet) usually overlain by three flaggy-to-thin-bedded, fine-grained, silty, micaceous, gray sandstone units, the "traceable three", which are

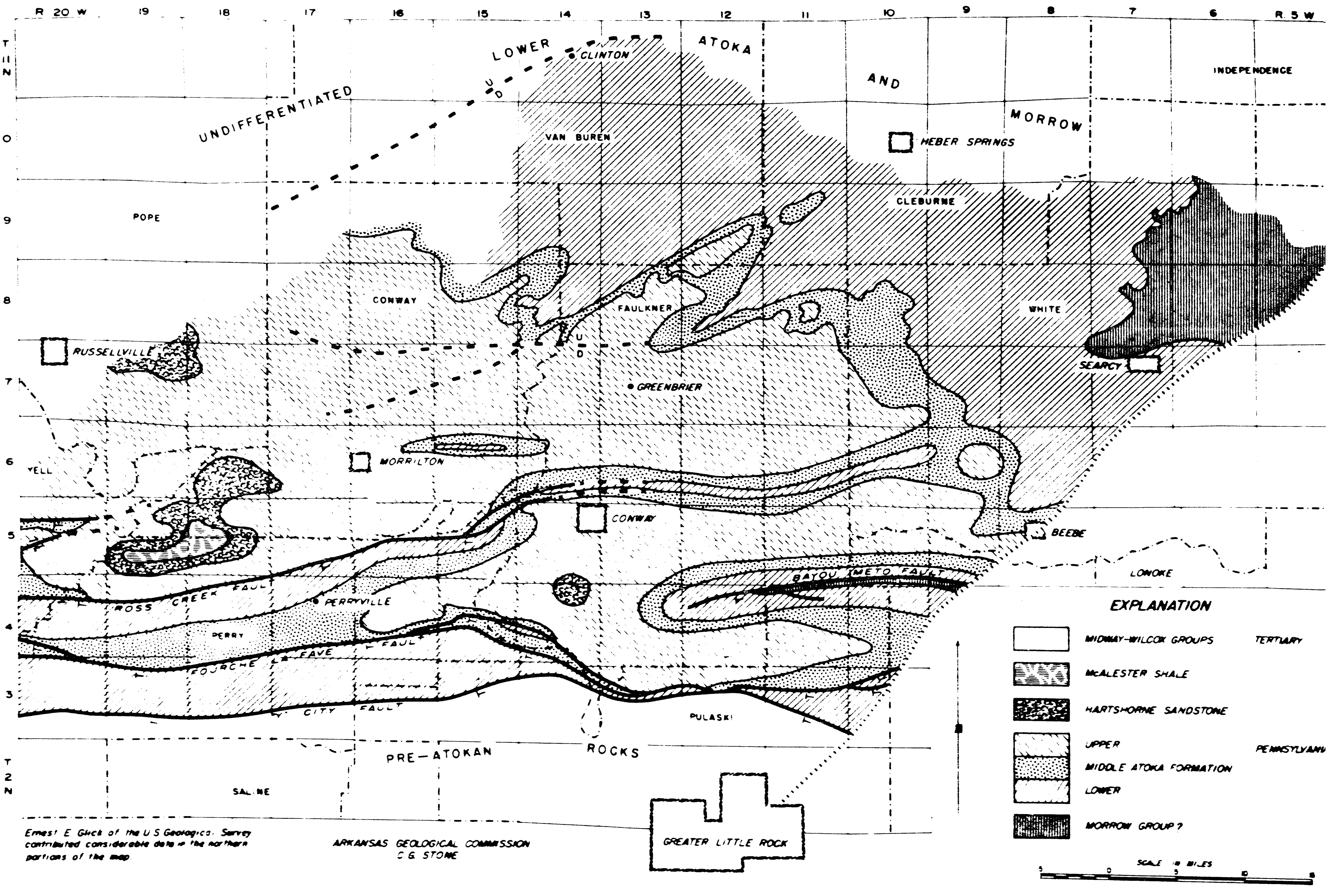


Figure 3. Generalized geologic map of north-central Arkansas.

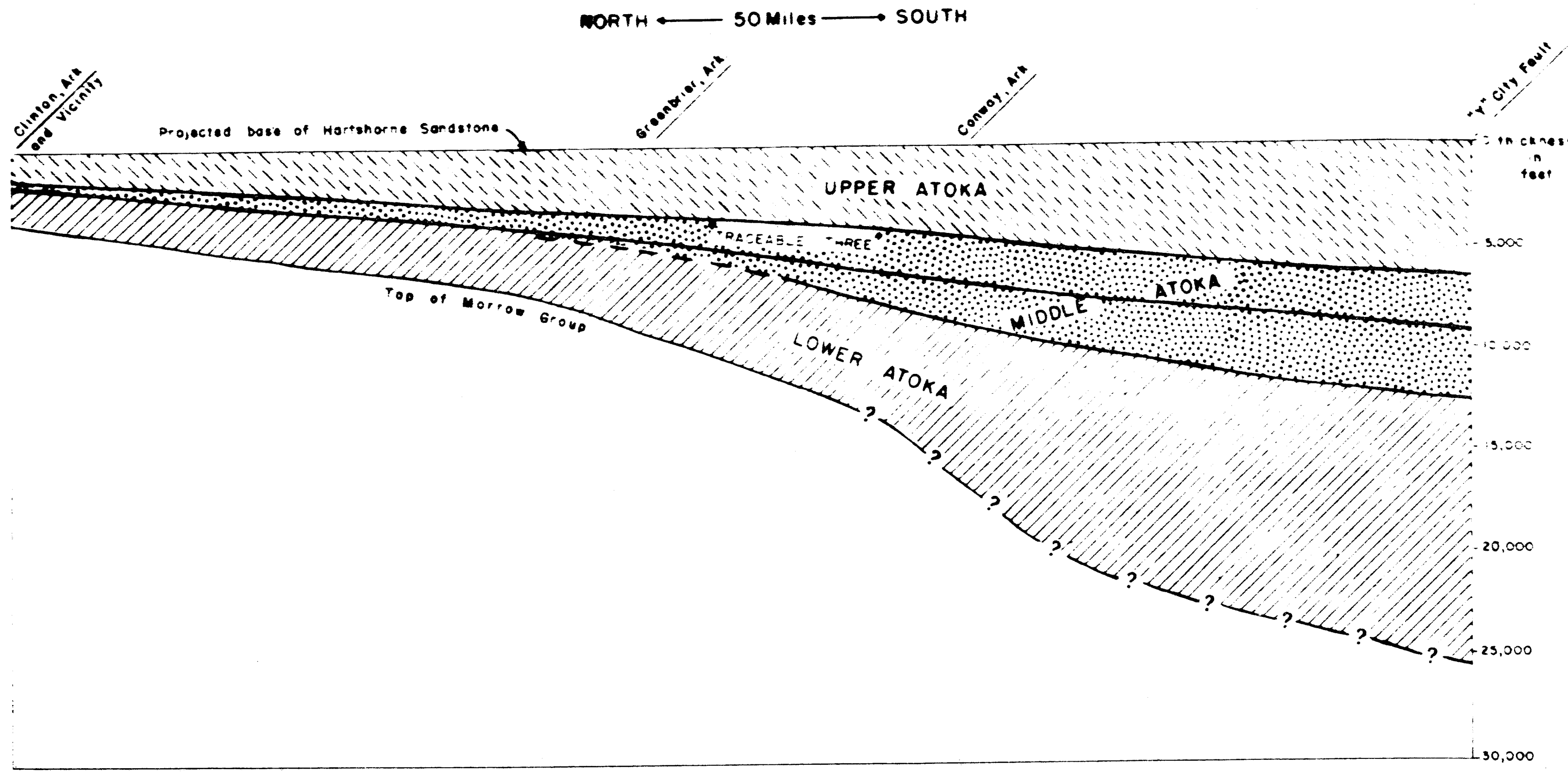


Figure 4. Diagrammatic cross-section showing restoration of the Atoka Formation.

separated by fairly thick shale intervals (2,800 feet). These sandstones have many features suggesting sediment (density) flow deposition; micro cross lamination, lack of sorting, and general lack of graded bedding. They form characteristic topographic expressions throughout most of the area. The sandstones have numerous current ripple and oscillation marks and minor plant fragments and invertebrate marine fossils. Some sandstones in the lower thick shale unit have bottom markings, convolute laminations, and related features suggesting turbidity current deposition. Paleocurrents were generally from the northeast in the "traceable three" and from the southeast in the minor sandstones of the lower thick shale unit. The Middle Atoka probably represents an environment ranging from deep basin (turbidites) with a probable east southeastern source in the lower portion to continental slope (sediment flow) deposits with a probable northeastern source in the upper beds. It is thought that the rate of clastic fill exceeded the rate of subsidence in the basin.

The Middle Atoka thins to about 4,100 feet ("traceable three" about 1,900 feet) in the southern Arkansas Valley, with some indication that the postulated major scarp or hinge line was only slightly active. Generally all the units are recognizable, but there is less shale in the section. The sandstones of the "traceable three" are typically fine-grained, micro cross-laminated, poorly sorted, and flaggy-to-thin bedded. Invertebrate and plant fossils are fairly common at some localities. Deposition was mainly by sediment flow from a northeastern source in the updip portions of the continental slope.

In the central and northern Arkansas Valley the lower shale unit of the Middle Atoka has not been differentiated from the Lower Atoka. It is included in a thin sequence of shale and sandstone in the upper part of the Lower Atoka. Two or more units of the "traceable three" are mappable northwestward from the Cadron anticline in T. 7 N., R. 9 W., to T. 9 N., R. 11 W., and then westward to T. 9 N., R. 15 W. The upper bed of the "traceable three" was tentatively extended to T. 9 N., R. 17 W., a few miles south of the large Clinton normal fault (Fig. 3). Detailed studies are needed to further delineate this unit in the area. The "traceable three" consists of massive-bedded, medium-to-occasionally-coarse grained, current and oscillation ripple marked, and crossbedded sandstone; minor black, silty shale; and small amounts of gray, finely crystalline limestone. Invertebrate fossils occur at many places in the member. The unit varies in thickness from about 600 feet in the south to probably less than 300 feet in the north. These beds are considered marine neritic (possibly distal pro-delta) deposits with a probable northeastern source.

Upper Member The Upper Atoka is composed of about 6,500 feet of gray-black shale (about 90 percent) and silty, fine-grained sandstone in the southern portions of the transition zone (Figs. 3 and 4). Some of the fine-grained sandstones have minor sediment flow and slump features. The shale is dark gray to black, silty, fissile, and has thin lenses of concretionary siltstone. Minor channel sandstones are occasionally medium-to-coarse-grained, quartzose and porous, with abundant shale fragments at the base. A thin coal seam near the middle of the member was previously mined on Round Mountain southwest of Beebe. Invertebrate fossils, spoor (including Conostichus), and plant remains are common at some locations. Diastems, channel sandstones, thin coal beds, and small discontinuous fossiliferous sandstone lenses are characteristic of the unit, and indicate cyclothemic conditions with oscillating continental-swamp and marine-littoral environments.

The Upper Atoka thins progressively northward across the area and is about 4,500 feet thick in the southern Arkansas Valley. It is essentially black, silty shale with minor (often channeled) silty to occasionally fine-to-medium-grained, quartzose sandstone. Invertebrate fossil and plant-bearing horizons, and thin coal beds are fairly common. A thin coal bed near the base of the unit has been mined sporadically near Centerville in Yell County. A three foot, ashy, white, sandy, probable bentonite zone occurs at the base of a massive sandstone in the lower portion of the member northwest of Morrilton.

The Upper Atoka thins from about 3,500 feet in the central Arkansas Valley to a restored thickness of less than 1,500 feet at the northern boundary (Fig. 4). It is mostly black, silty shale; with minor (often channeled) silty to quartzose, very fine-to-medium-grained sandstone; and a few thin lenses of gray, silty, finely crystalline limestone. The member increases slightly in total sandstone percentage and there is convergence of some sandstone beds. Invertebrate fossils horizons are fairly common.

The Upper Atoka probably has a dominant northeastern source. A slight, but regionally important, unconformity separates the Atoka Formation from the overlying Hartshorne Sandstone.

KREBS GROUP

In the area of investigation the Krebs Group of the Des Moines Series comprises the Hartshorne Sandstone and the lowermost part of the McAlester Formation (Fig. 2).

HARTSHORNE SANDSTONE

The Hartshorne Sandstone is one of the most persistent and distinctive horizons in the western Arkansas Valley. Three outliners of this formation are preserved in synclines in the report area (Fig. 3).

The Hartshorne is composed of thick to thin bedded, fine to coarse grained, light brown to grayish white, usually quartzose, well cemented sandstones with small amounts of shale and siltstone. Current ripple marks, cross and foreset bedding, and lineations are characteristic of most exposures. Unusual rock shapes caused by spheroidal weathering are also common. Some large plant remains and a few brackish water invertebrate fossils occur in the formation. The Hartshorne varies in thickness from about 80 feet on Carrion Crow Mountain north of Atkins to over 300 feet at places on Petit Jean Mountain west of Morrilton. About 35 feet of the lower Hartshorne Sandstone is preserved on its easternmost exposure on Round Mountain south of Conway. Haley (1961 a) states that the axis of the Hartshorne sedimentary basin was in the Arkansas Valley. The major source of sediments was from the north, with minor sources from the east and south.

MCALESTER FORMATION

About 500 feet of the lower McAlester Formation is exposed on the south side of Petit Jean Mountain (Fig. 3). It is primarily a silty, black shale, with minor gray, silty, fine-grained, flaggy sandstone. One thin coal bed (the lower Hartshorne) occurs at the locality. The sandstones often have characteristics of sediment flow deposition. Some marine and brackish invertebrate fossils and abundant plant fossils occur in the formation. Haley (1961 a) shows a maximum McAlester thickness of over 2,000 feet in the southern Arkansas Valley of western Arkansas, with thinnning both to the north and south. The McAlester represents cyclic continental and shallow marine deposits with sediments supplied from both the north and south (Haley, 1961 a).

SUMMARY AND CONCLUSIONS

1. The Atoka is a clastic (essentially marine) sequence that ranges from a restored thickness of about 3,500 feet in the extreme northern Arkansas Valley to over 25,000 feet in the southern transition zone, and can be divided, with some qualifications, into three mappable members - Lower, Middle, and Upper.

2. The Atoka was deposited in deep basin, scarp, slope, shelf, and continental environments; with a general progressive shallowing of the water to the north and with time.

3. The Lower member of the Atoka is considered a deep basin, essentially a turbidite sequence (flysch), in the transition zone. In the extreme southern Arkansas Valley the member probably was deposited in a marine scarp environment. In the central and northern Arkansas Valley the Lower Atoka was deposited in the neritic environment (distal pro-delta).

4. The Middle Atoka in the transition zone probably represents the progression from fairly deep basin (turbidity current) deposits in the lower portion to continental slope (sediment flow) deposits in the upper beds. In the extreme southern Arkansas Valley the member was apparently deposited essentially in the updip portions of the continental slope. In the central and northern Arkansas Valley the "traceable three" was deposited in a shallow marine (possibly distal pro-delta) environment.

5. The Upper Atoka represents oscillating nearshore marine and continental deposition throughout the study area.

6. During most of Atokan time the Arkansas Valley and transition zone was the northern part of a larger depositional basin that included much of the Ouachita Mountain province from early to late Atokan times.

7. Possibly beginning in very late Atokan and extending through Desmoinesian times the axis of deposition shifted into the transition zone of the frontal Ouachita Mountains and the Arkansas Valley, with the Ouachita Mountains being a positive element and undergoing major orogenetic spasms. The major folds and thrust faults of the region are related to this activity.

8. The Eastern Interior Basin to the northeast in Illinois is considered the major dispersal center for clastics in the Upper and most of the Middle Atoka of the Arkansas Valley and the transition zone, and the Lower Atoka of the Arkansas Valley.

9. The Black Warrior Basin of northern Mississippi and Alabama and the postulated land mass of Llanoria to the south are considered the major sources for the clastics of the Lower Atoka and the lower portions of the Middle Atoka in the transition zone.

10. The Hartshorne Sandstone and the "traceable three" of the Middle Atoka are reliable datums in the area of study.

OTHER CONSIDERATIONS

Probable bentonites occur near the base of the Atoka and are locally reliable markers in portions of the northern Arkansas Valley and may prove useful in determining the Morrow Group-Atoka Formation boundary in the east-central Araknsas Valley and the transition zone.

Detail mapping should further delineate the Middle Atoka in the northern portions of this area. It is also feasible that the Atoka will eventually be further subdivided into regionally mappable units.

Future collections and determinations of invertebrate fossils from the many potential horizons in the north and northeastern portions of this area should help to resolve the age of the Atoka Formation. Spores, in Upper Atoka coal beds are generally obliterated by a high fixed carbon ratio, but abundant plant leaflets in some shales offer possible determinations. Blythe (1959), Henbest (1952), Gordon (1964), and others consider most of the fossils obtained from the Lower Atoka member as Atokan in age. However, Quinn and Carr (1963) and McCaleb (1963) from goniatite data indicate the Lower Atoka (Winslow by their definition) may be extreme upper Morrowan in age. Also, it has been questioned whether portions of the Upper Atoka is of Desmoinesian age. However, this seems unlikely since Smith (1897) and Gordon (1964) report Atokan fossils from the Upper member in the area. Also the slight unconformity at the base of the Hartshorne Sandstone likely represents a major break in deposition.

Finally, petrographic and heavy-mineral studies of the Atoka clastics are needed to determine exact rock types and to confirm source directions.

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