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ABSTRACT

Aerial photography has been employed to map stratigraphic and structural features in the Boston Mountains of Washington and Crawford Counties, Arkansas. Exposures of resistant stratigraphic units within the lower Atoka Formation were delineated on a series of large scale aerial photographs over an area of about 150 square miles. With the aid of a Bausch & Lomb Zoom Transfer Scope, the positions of the units were subsequently transferred to 1:24,000 scale topographic base maps. The presense of east trending anticlines and synclines and a series of low displacement normal faults is reflected by either gradual or abrupt changes in elevation of the mapped units. The technique allows a substantial reduction in the amount of time and effort required to complete geologic mapping of such features.

INTRODUCTION

Geologic mapping of the gently deformed sedimentary rock of northern Arkansas involves the location of stratigraphic units on topographic maps. Structural deformation is shown by elevation changes of these units, as determined by field investigations. The field work involves the tracing of stratigraphic contacts, measuring of rock sections, and the determination of the true strike and dip of bedding at many points.

Recent investigations at the University of Arkansas at Fayetteville show that accurate geologic maps may be produced directly from aerial photography. Such maps show the aerial extent of stratigraphic units and the location of folds and faults. Concurrent field studies are used to confirm the accuracy of the photo-mapping in problem areas and to establish a lithic description of the stratigraphic units mapped. Time-consuming field studies are thus held to a minimum.

REGIONAL GEOLOGY

Photogeologic mapping of portions of Washington and Crawford Counties of northwest Arkansas, has been completed recently. The mapped area covers a part of the western Boston Mountains where local relief ranges from 500 to 1000 feet.

The stratigraphic sequence in this area consists largely of Morrowan and Atokan age rocks (Fig. 1). The most widely exposed unit is the Atoka Formation which consists of interbedded sandstone and shale. Sandstone bluffs of the basal Atoka cap the mountains in the northern portion of the area, but to the south, the formation makes up most of the exposed section. The Atoka thickens to the south in the Arkoma basin.

The Atoka Formation was named by Taff and Adams in 1900 for a sandstone and shale unit in the Ouachita Mountains of eastern Oklahoma. Croneis (1930) applied the name to the post-Bloyd rocks of the Boston Mountains, replacing the name Winslow Formation of Adams and Ulrich (1904). Henbest (1953) named and described a basal member of the Atoka, the Greenland Sandstone, for exposures in Washington County. A further subdivision of the Atoka Formation was attempted by Lamb (1974) while working in the Fern Quadrangle of northeast Crawford County.

In 1975, Young reported two thick, mappable sandstone units at the base of the Atoka in the Lee Creek area of south central Washington County. The base of the first sandstone unit is separated from the underlying Kessler Limestone Member of the Bloyd Formation by a shale interval (Trace Creek Member) which ranges in thickness from 50 to 130 feet. The second sandstone unit is separated from the first by a thinner interval of shale. Hoover (1976) and Kelley (1977) extended Young's first and second Atoka sandstone units across southern Washington and northern Crawford Counties by carefully tracing their outcrops on aerial photographs. In many areas, the two sandstones form a distinctive "double ledge" exposure with a narrow bench developed on the intervening shale.

The Boston Mountains of Washington and Crawford Counties include portions of the north Arkansas structural platform and the Arkoma basin (Chinn and Konig, 1973). The late Paleozoic Ouachita Orogeny produced a series of gentle east trending folds across the area. In northern Crawford County, these structures exhibit flank dips of from three to five degrees, and have been recognized in the field by Purdue (1907), Croneis (1930) and others. To the north, in

System	Series	Formation	
Pennsylvanian	Atokan	Atoka	sandstone and shale
			Third Sandstone
			shale
			Second Sandstone
			shale
			First Sandstone
	Morrowan	Bloyd	Trace Creek Member
			Kessler LS.
			Dye Shale
			Woolsey Shale
			Brentwood Limestone
		Hale Formation	

Figure 1. Stratigraphic sequence in the Boston Mountains of Washington and Crawford Counties, northwest Arkansas.

Washington County, the amplitude of these east trending folds decreases, until the structures can usually be detected only by the observation of changes in elevation of stratigraphic contacts. A series of broad northeast trending folds of Morrowan age has been described by Quinn (1959) and others. Subsidence of the Arkoma basin has been cited as the cause of some normal faulting, as has uplift of the Ozark dome to the north (Diggs, 1961). Solutioning of subsurface carbonate rocks along pre-existing zones of weakness has resulted in localized subsidence structures which complicate the regional structure (Quinn, 1963). All of the above features are superimposed upon a gentle (25 to 50 ft/mile) regional dip to the south.

METHODS

Geologic mapping from aerial photography requires suitable topographic base maps, high quality imagery and resistant stratigraphic rock units that are well expressed on the photography. Suitable 7½-minute maps are now available for most of the Boston Mountains and have served as the base for photogeologic mapping.

High quality black and white aerial photography, ranging in scale from 1:20,000 to 1:40,000 may be obtained from the Arkansas Highway Department, the U.S. Department of Agriculture (A.S.C.S.) and other agencies. This photography must be of high contrast, free of serious distortions, and must possess adequate overlap and sidelap between adjacent frames, to permit stereoscopic viewing. In addition, the photography should have been obtained when broad leaf trees were defoliated, because many outcrops will otherwise be obscured.

Sandstone units of the lower Atoka Formation are ideal for photogeologic mapping purposes. Each of the sandstone bodies, which are bounded above and below by non-resistant shale, forms either a prominent bluff or perhaps only a narrow zone of increased slope. These slope differences are due to thickness changes of the unit, local drainage features, and/or the position of the sandstone on the hillside. In any case, these units nearly always have photographic expression and may be traced with confidence on stereoscopic photography.

The success of photogeologic mapping depends upon the familiarity of the interpreter with the geologic, physiographic, and cultural features of the mapped area. Such familiarity can be obtained only through study of these features in the field in combination with a study of their appearance on aerial photography and topographic maps.

The first task in the mapping process is the delineation of the rock units on the photography. A mirror stereoscope equipped with a binocular lens attachment is used to study stereo pairs of photographs. Acetate overlays are placed on each frame and the position of the top of each rock unit is highlighted on the overlays with colored ink. In some areas the units may be traced rapidly over ground distances of several miles. However, in areas of poor exposure or in fault zones the mapping must proceed more slowly and sometimes requires supporting field work.

The transfer of the units from the photography to topographic base maps is accomplished primarily by comparing relief, drainage and cultural features as they appear on the maps, with the images of these same features on the photography. The location of the upper boundary of rock units close to these features can then be accomplished.

Throughout the Boston Mountains differential erosion of the sandstone and shale of the lower Atoka Formation has produced a series of bluffs and benches. Farmers often clear the gently sloping benches of vegetation, leaving the steep bluffs in a natural state. On both the photography and the topographic maps, the boundary between a cleared bench and the top of the adjacent wooded bluff (and thus, the top of a sandstone unit) is sharply defined. The position of the mapping unit may be drawn directly onto the map, along the downhill side of the cleared bench. Other cultural features, like farm buildings, stock ponds and roads also aid in positioning rock units. In the absence of cultural feaures, positioning of the mapping units requires close attention to their effects on drainage patterns and topography.

The availability of a Bausch & Lomb Zoom Transfer Scope makes possible simultaneous viewing of aerial photographs and base maps. Illumination controls permit the operator to alternately concentrate his attention on either the photography or the map. A zoom magnification capability allows the photograph to be magnified up to 14x, while the base map is viewed at a constant 1x magnification. This feature permits the registration of small scale photography to large scale maps. Geometric distortions in the photography, arising from either aircraft instability or relief displacement, may be minimized by adjustment of the zoom magnification and anamorphis correction controls of the Zoom Transfer Scope.

The accuracy with which the mapping units may be positioned on topographic maps is variable. In areas of good exposure, where many control points are available, the tops of the units may be positioned to within 10 feet of their true elevation on 20 feet contour interval base maps. In places where exposures are poor and good control points lacking, errors in positioning may exceed 30 feet. Although such errors tend to obscure subtle structural features, associated dips of one to two degrees result in elevation changes of over 100 ft./mile, which are readily discernible.

RESULTS AND DISCUSSION

The procedures outlined were used to produce a photogeologic map of a 150 mi² area in Washington and Crawford Counties. Although the initial aim of the project was to delineate structural features, a further stratigraphic subdivision of the Atoka Formation was achieved. It was discovered that a third sandstone unit, separated from the two lower sandstone units by a thick shale interval, could be mapped across the area. This unit often forms a bluff above a broad bench developed on the underlying shale. Another thick shale interval often overlies this third sandstone, so that a prominent bench usually develops higher on the hillside as well. Across the area, the "double ledge" of the basal Atoka sand units often combine with the single bluff of the third sandstone to form a distinctive pattern on aerial photography.

Changes in elevation of the map units permitted the delineation of a number of east trending structural features. In the Mountainburg Quadrangle of northern Crawford County, the photographic data reflect the presence of all the folds mapped by Croneis (1930) in that area. In Washington County, the trace of the Evansville Creek syncline and associated Devils Den fault are well defined on the photogeologic map and in the field. Features described for the first time include the east trending Union Star syncline and Boyd Hollow anticline, which are located in the upper Lee Creek area. These structures lie immediately south of a small gas field at West Fork, Arkansas. The presence of these folds was confirmed in the field, along with that of several small, previously unmapped faults in northern Crawford County.

In a number of places where folding and/or faulting had been reported by previous investigators, the photographic data does not support their existence. For example, several of the east trending folds which were reported by Johnson (1963), Kimbro (1960) and others to extend across the area appear to be discontinuous at best. In addition, northeast trending folds reported by Quinn (1959) and others were not detected on either photogeologic maps or structural cross sections prepared from these maps. A regional dip of approximately one half degree to the south was observed on a cross section extending from near Brentwood to Mountainburg. This dip causes the top of the third Atoka sandstone to be lowered about 600 feet over a distance of approximately 14 miles.

A total of 13 fold axes and four fault traces were defined by the photographic data of this study. The fact that most of these features had been mapped previously is presented as evidence of the reliability of the mapping method. The larger structures, which most workers readily recognize in the field, are easily identified on the photogeologic map. In certain areas however, the photographic data suggest interpretations which are at variance with past field mapping. Interestingly, many of the field workers could not themselves agree on the origin and location of the structures. In certain cases data from aerial photographs may be of higher reliability than data obtained by normal field methods. Photographic data are compiled under uniform conditions within a short interval of time. It also allows very low magnitude dips to be determined over wide areas.

Local anomalous dips that are associated with non-tectonic features are eliminated.

Results from this mapping project have encouraged further photogeologic study to the east in southwest Madison County. Preliminary mapping in that area indicates the persistence of all three lower Atoka sandstone units. In addition, data have been obtained which will assist in describing the character of deformation in the Drakes Creek fault zone. If available, U.S.G.S. orthophotoquads will be used in the confirmation of photographic mapping in this area. Given the requirements noted earlier, photogeologic techniques promise to aid considerably in the solution of stratigraphic and structural problems throughout the Boston Mountains.

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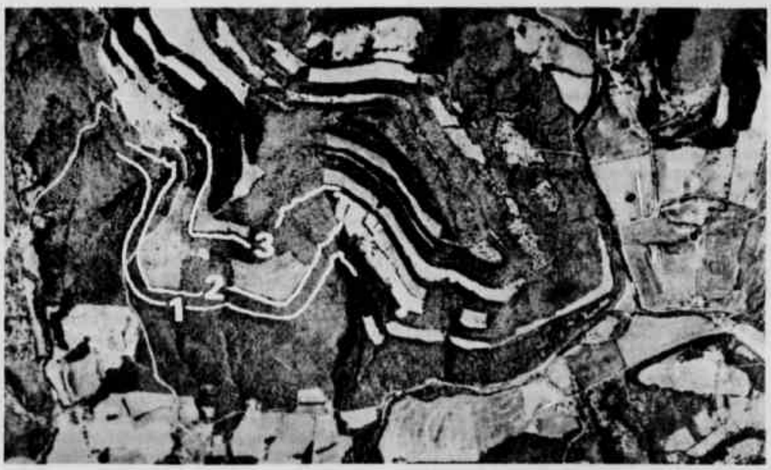

Figure 2. Aerial photograph of Hammond Mountain, southeastern Washington County. North is to left, scale is approximately 1:31,000. First, second and third sandstone units of the lower Atoka Formation form prominent bluff lines on the mountainside. All units dip to the southeast, into the Drakes Creek fault zone. U.S.D.A. (A.S.C.S.) photograph, March, 1972.