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Geologic Hazards Associated with Shale Strata and Swelling Clays within Fayetteville Quadrangle, Washington County, Arkansas

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Introduction

The population of Washington County, Arkansas, increased more than 100% from 1970 to 2000 (U.S. Bureau of the Census, 2000). Washington County population was 77,370 in 1970 and increased at an average rate 3% per year to 157,715 in 2000 (Fig. 1). Much of this growth occurred within the urban corridor comprised of the cities of Fayetteville and Springdale (Washington County) and Rogers and Bentonville (Benton County). The rapid population growth within these cities was accompanied by extensive new construction of commercial buildings, residential areas, streets, highways, and utilities. However, throughout Washington County, much of this new infrastructure is situated on late Paleozoic (Mississippian-Pennsylvanian) shale strata containing swelling clays that weather rapidly to form expansive soils. As such, structures constructed on these strata are subject to a variety of geological processes that pose a significant hazard to their long-term viability. Damage to these structures resulting from the effects of soil expansion/contraction and other destabilizing processes cost hundreds of thousands of dollars each year in Fayetteville alone.

Geologic Hazards Associated with Expansive Soils. Definition of the Problem.--An expansive soil is one that typically contains an appreciable quantity of clay that swells or shrinks in response to variations in moisture content (Komornik, 1969); as moisture is absorbed, clay particles swell and as moisture is removed, clay particles shrink. The pattern of volumetric change due to swelling and shrinking of these active clays is three-dimensional (Jennings 1969; Komornik, 1969) and influenced by the amount of moisture change in the soil, the soil density, the superimposed lithostatic pressures in various directions, and the geometric boundary conditions created by man-made structures (Jennings, 1969; Komornik, 1969).

Hazards Associated with Expansive Soils.--Expansion/contraction of clay soils becomes important when the movements are sufficiently large to damage or distort overlying or founded structures. Structures built on expansive soils commonly heave, displaying differential movements that result in simple cracking as well as vertical and horizontal displacement. The consequent damage due to heave and differential displacement can be significant (Jennings, 1969; Komornik, 1969).

In addition to damage caused by heave, adverse effects encountered by facilities placed on expansive clay soils include subsidence in parking lots or other pavements, rotting of wood floors and other wooden components of buildings due to water retention in the soils, excessive runoff after heavy rainfall, water seeps emerging from paved areas or water seeping from concrete floor seams in buildings, downslope creep, and slumping of steeper slopes. In the case of organic-rich shales containing abundant pyrite, weathering of shale and subsequent oxidation of pyrite can induce severe corrosion of buried pipes.

Though there are engineering solutions to many of the problems associated with construction on expansive soils (even retroactive solutions that can be applied after structures have been damaged by soil processes), these solutions are often very costly and in the worst cases can represent a significant fraction of the value of the property. For example, an associate of one of the authors (S.K. Boss) was required to install 36 steel piers to reinforce a home foundation less than one year after construction was completed. The total cost of this remediation amounted to approximately 24% of the assessed value of the property. Remediation costs ranging from 10-15% of the assessed value of homes are common. It is important to note that most homeowners' or small business' insurance policies do not provide for repairs to foundations damaged by expansive soil processes. Thus, costs are usually borne entirely by affected individuals.

Expansive Soil Hazards in Fayetteville Quadrangle.--There are four clay-rich stratigraphic units exposed throughout Fayetteville Quadrangle that weather rapidly to form expansive soils. These units are 1) the lower Fayetteville Shale of the Fayetteville Formation (Simonds, 1891; McFarland, 1998), 2) the upper Fayetteville Shale of the Fayetteville Formation (Simonds, 1891; McFarland, 1998), 3) the Woolsey-Dye Members of the Bloyd Formation (Purdue, 1907; Henbest, 1953; McGilvery, 1982;

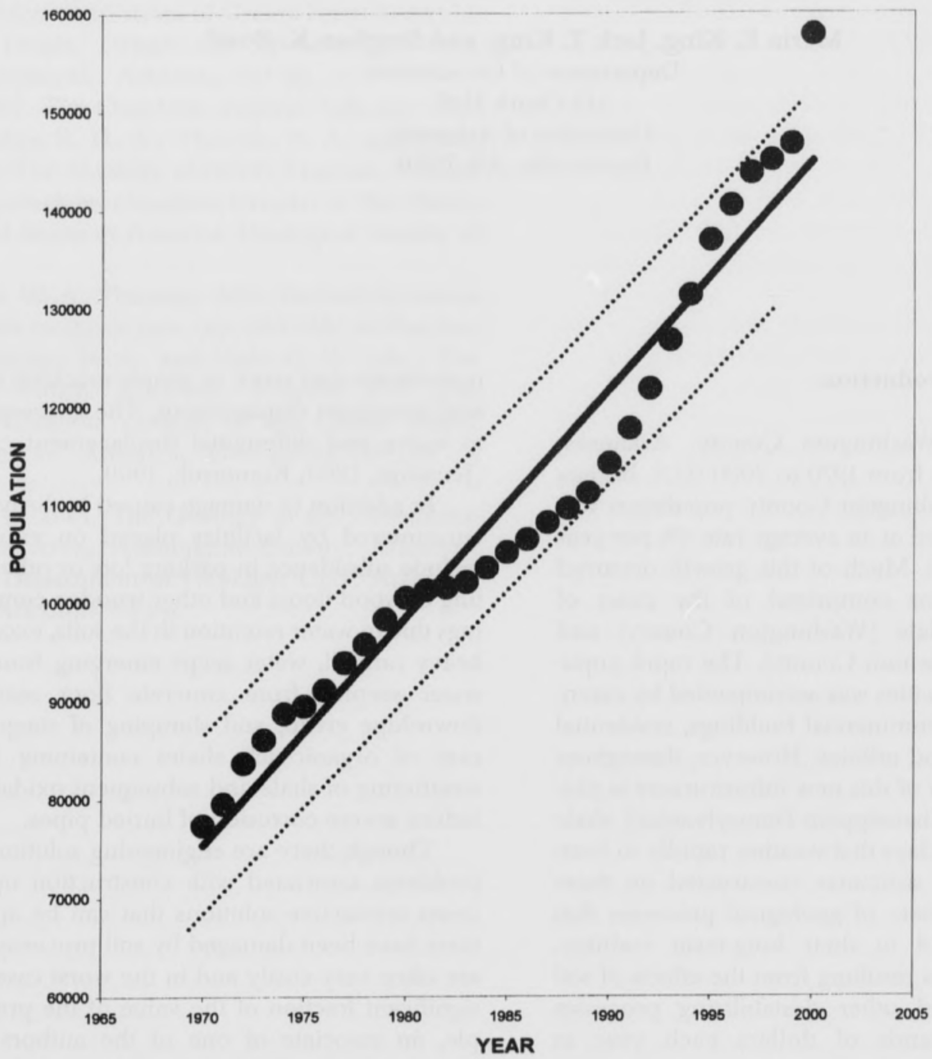

Fig. 1. Population trend for Washington County, Arkansas, 1970 - 2000. Graph shows relatively rapid growth of Washington County over the last 30 years. Note that total population increased 100% (77,370-157,715) from 1970 to 2000. Also note outlying nature of 2000 census result. Solid line indicates best-fit linear regression through data up to 1999 (excluding 2000 data as outlier). Dotted lines represent 95% confidence limits of regression line. Linear regression indicates average annual growth of 3% during the last 30 years. Data obtained from U. S. Census Bureau Arkansas State Data Center, University of Arkansas-Little Rock, Little Rock, Arkansas. URL: (http//www.aiea.ualr.edu/csdc/PopEstimates.html).

McFarland, 1998), and 4) the Trace Creek Member of the Atoka Formation (Taff and Adams, 1900; Henbest, 1953; McFarland, 1998)(Figs. 2-4). Detailed descriptions of the geology, composition, and depositional environments of these strata can be found in King et al. (2001). These units pose common hazards to construction, but also have unique hazards related to their geological constitution and geomorphology. Observed hazards associated with each of these units are considered in turn below.

Lower Fayetteville Shale of the Fayetteville Formation.-- The lower Fayetteville Shale of the Fayetteville Formation covers an extensive area (45.5%) of the Fayetteville Quadrangle (Figs. 2, 3). The city of Fayetteville is expanding rapidly with residential subdivisions, city streets, utilities, and business complexes into areas underlain by this unit. Indeed, most of the flat and gently sloped land in the Fayetteville Quadrangle is underlain by the lower Fayetteville Shale. Thus, the topography of the lower

Fa etteville Shale is suitable for construction, but the soil as ›ciated with this unit is quite unfavorable. The weathered cl › horizon of this unit ranges from 0 m to 10 m thick and re s on top of the unweathered shale. Adverse effects assoc ed with construction on the lower Fayetteville Shale are d erential subsidence of pavements resulting in extreme cr cking and unevenness (e.g., Fig. 5A, B), cracking of found ions (e.g., Fig. 5C) and retaining walls (e.g., Fig. 5D), cr cking of concrete floors, cracking of concrete driveways, se aration of concrete floor seams, rotting of wooden floors a d other wooden components of houses, various breaks in m sonry above the foundation (e.g., Fig. 5E, F), runoff from h avy rainfall, seeps emerging from paved areas, seeps e nerging in houses between concrete floor seams, and corrosion of buried pipes. With the expansion and contraction of the lower Fayetteville Shale clays, even areas with very gentle slopes display evidence of creep.

Upper Fayetteville Shale of the Fayetteville Formation.--The upper Fayetteville Shale of the Fayetteville Formation has a much smaller areal extent (4.7%) than the lower Fayetteville Shale in Fayetteville Quadrangle (King et al., 2001). The upper Fayetteville Shale occurs mostly on moderate to steep slopes between the underlying Wedington Member of the Fayetteville Formation and the overlying Pitkin Formation or Cane Hill Member of the Hale Formation where the Pitkin Formation is missing (King et al., 2001). The outcrop area of the upper Fayetteville Shale is occupied primarily by residential neighborhoods (Figs. 2, 3). The upper Fayetteville Shale also weathers into expandable clays, but the observed hazards differ somewhat from those observed on the lower Fayetteville Shale. Due to the moderate to steep slopes in areas where the upper Fayetteville Shale crops out, creep and slumping are the most critical hazards. Downslope movement within the upper Fayetteville Shale has resulted in creep of pavements with associated buckling and differential subsidence (e.g., Fig. 5B), shifting and cracking of foundations (e.g., Fig. 5C), cracking of masonry above the foundation (e.g., Fig. 5E, F), and cracking and lateral separation of concrete floors. The basal contact of the upper Fayetteville Shale with the Wedington Member of the Fayetteville Formation is the locus of numerous springs and seeps. Where buildings are located on this contact, damage associated with seeping water (e.g. active seepage through foundations, seepage between seams on concrete floors, and moisture damage to wood) is commonplace.

Woolsey-Dye Members of the Bloyd Formation.--The Woolsey-Dye Members of the Bloyd Formation cover 2.3% of the surface area of the Fayetteville Quadrangle (Figs. 2, 3) (King et al., 2001). The Woolsey-Dye Members occur on moderate slopes above the Brentwood Member of the Bloyd Formation. The Woolsey-Dye Members weather quickly into soft gummy clay. Much of the outcrop area of the Woolsey-Dye Members in the Fayetteville Quadrangle remains uninhabited, though several new housing subdivisions were developed on this unit during the last several years. The observed adverse effects of construction situated on the Woolsey-Dye Members are cracking of foundations, cracking in basements, cracking of sidewalks and driveways, cracking of masonry above the foundation, and surface creep as well as slumping (e.g., Fig. 5). Water seeps and springs are common along the contact of the Woolsey-Dye Members and the underlying Brentwood Member of the Bloyd Formation.

Trace Creek Member of the Atoka Formation.--The Trace Creek Member of the Atoka Formation is a black, organic-rich shale at the base of the Atoka Formation (King et al., 2001). The Trace Creek Member has an outcrop extent of 1% in the Fayetteville Quadrangle (Figs. 2, 3). The only inhabited area on the Trace Creek Member in the City of Fayetteville is a residential neighborhood on Mount Sequoyah (Fig. 2). The Trace Creek Member forms steep slopes between a bench formed from the Kessler Member of the Bloyd Formation and the first sandstone of the Atoka Formation. On exposure, the Trace Creek Member weathers quickly into expandable clay subject to slumping. Problems associated with construction on the Trace Creek Member are cracking of foundations and lateral separation of outside walls of houses related to down slope processes.

Conclusions

Paleozoic shale strata are exposed over more than 50% of Fayetteville Quadrangle (Figs. 2, 3). These shale units are known to weather to expansive soils, creating numerous problems for construction. Damage to structures (dwellings, business complexes, streets, sewers, sidewalks, parking lots, etc.) associated with expansion and contraction of weathered clays within these units costs hundreds of thousands of dollars annually to an unsuspecting public.
Many of these costs (particularly those related to repair of damaged home or business foundations) are not protected by homeowners' or businesses' insurance.

Detailed mapping of these clay-rich strata provides an aid to identifying and mitigating these potential hazards. Knowledge of the areal distribution of hazardous stratigraphy in Fayetteville Quadrangle may reduce the overall costs of mitigation through incorporation of appropriate engineering solutions during construction yielding improved building design, better building quality, and lowered building repair costs. Thus, geologic mapping of Fayetteville Quadrangle is relevant and valuable to city planners and developers.

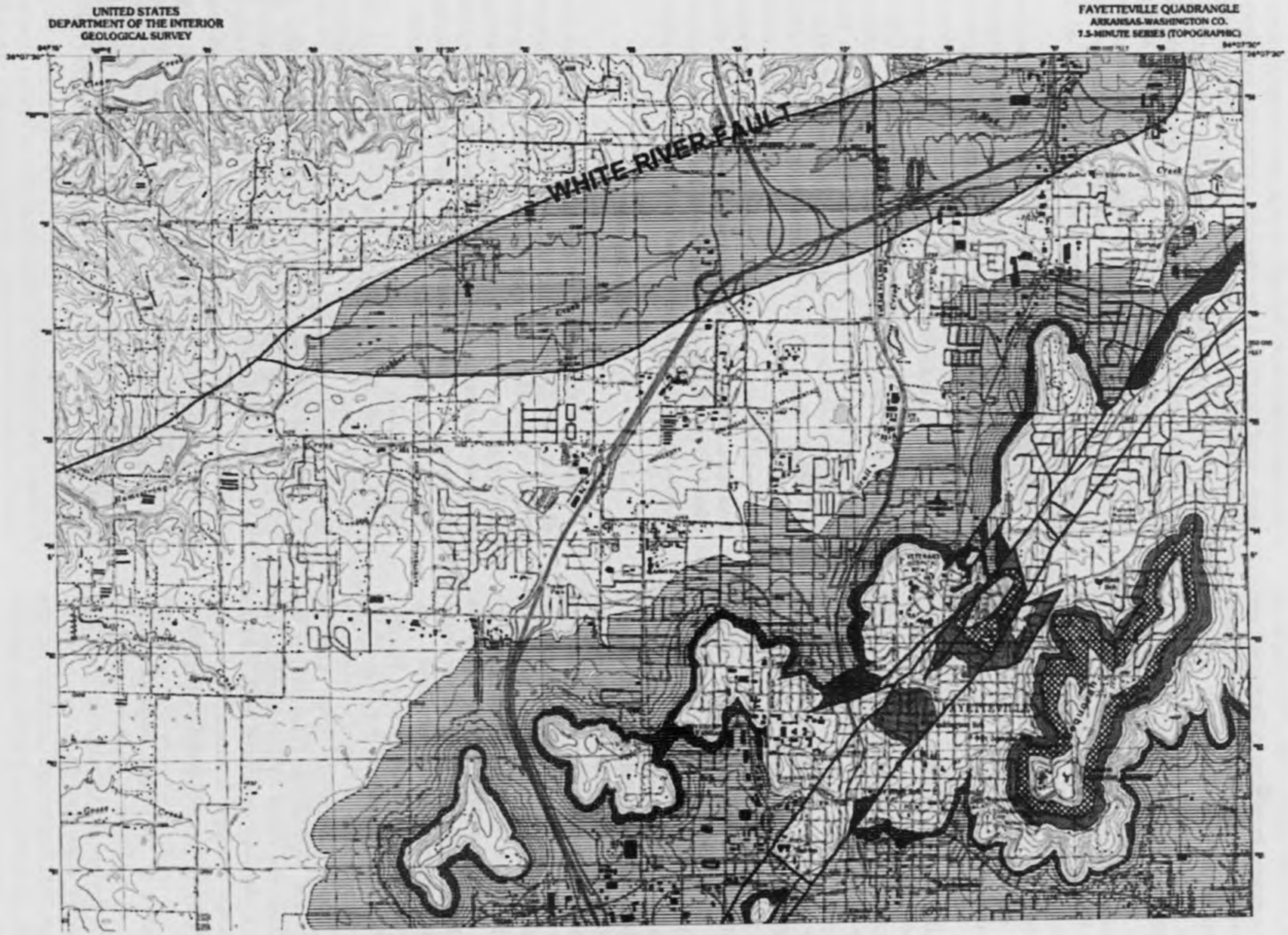

Fig. 2. Map of northern half of Fayetteville 7.5-Minute Quadrangle, Arkansas showing outcrop extents of shale strata containing swelling clays and known to weather to expansive soils.

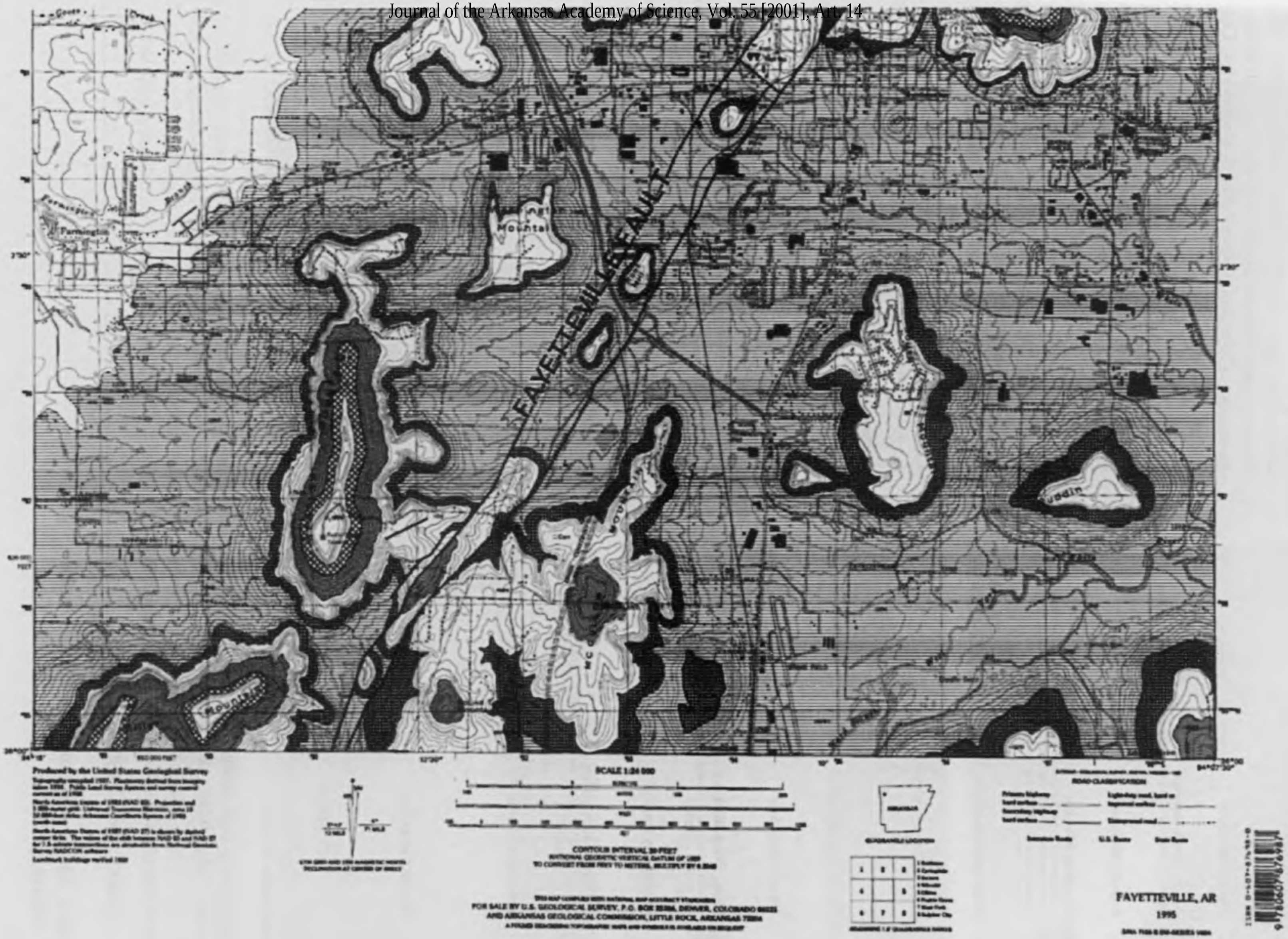

Fig. 3. Map of southern half of Fayetteville 7.5-Minute Quadrangle, Arkansas showing outcrop extents of shale strata containing swelling clays and known to weather to expansive soils.

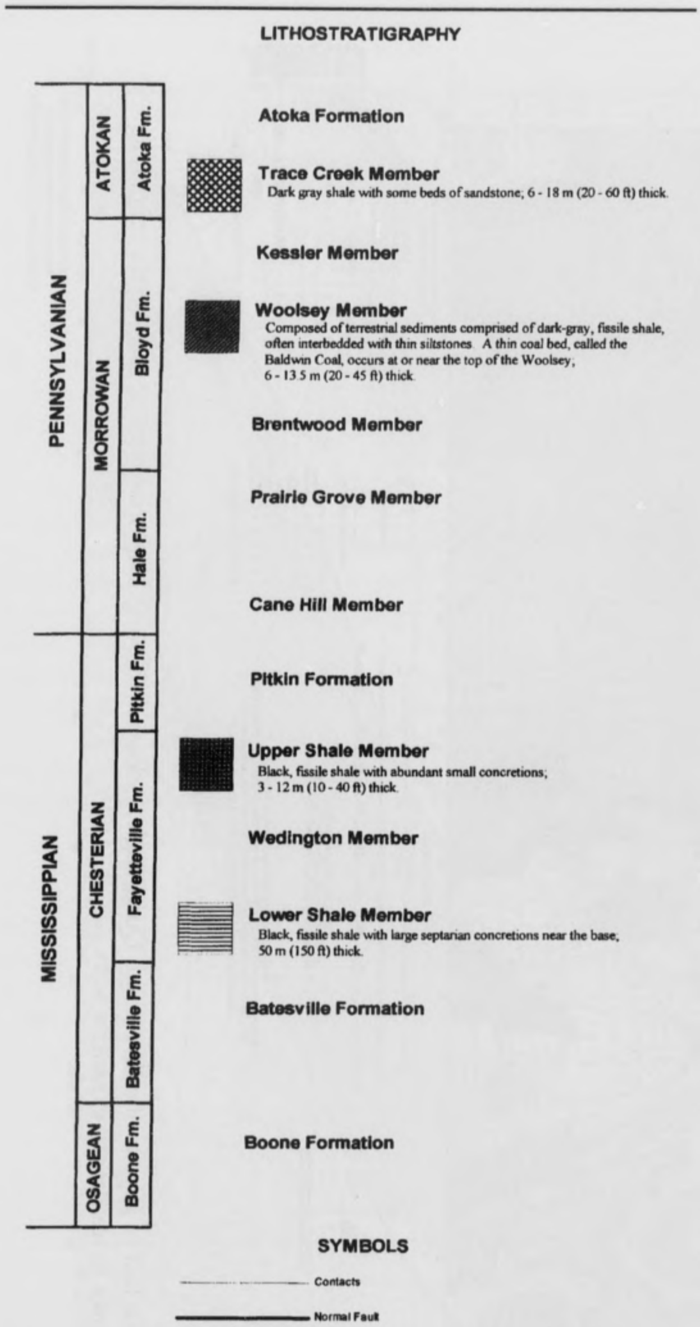

Fig. 4 Legend to accompany Figs. 2 and 3 showing schematic stratigraphic chart of shale strata in Fayetteville Quadrangle.

Literature Cited

Henbest, L. G. 1953. Morrow Group and Lower Atoka Formation of Arkansas: Amer. Assoc. Petrol. Geol. 37:1935-1953.

Jennings, J. E. 1969. The engineering problems of expansive soils. (pp. 11-17). Proceedings of the Second International Research and Engineering Conference on Expansive Clay Soils: Texas A&M University, College Station, Texas.

King, M. E. 2001. Bedrock geology of Fayetteville Quadrangle, Washington County, Arkansas: M.S. Thesis, Department of Geosciences, Univ. Arkansas, Fayetteville, Arkansas, 154 pp.

King, M. E., J. T. King, and **S. K. Boss.** 2001. Bedrock geology and sea-level history of Fayetteville Quadrangle, Washington County, Arkansas. J. Arkansas Acad. Sci. 55:86-96.

Komornik, A. 1969. Factors affecting damage due to movements of expansive clays in the field. (pp. 37-41.) *In* Proceedings of the Second International Research and Engineering Conference on Expansive Clay Soils: Texas A&M University, College Station, Texas.

McFarland, J. D. 1998. Stratigraphic Summary of Arkansas: Arkansas Geological Commission Information Circular, pp. 36-39.

Purdue, A. H. 1907. Description of the Winslow Quadrangle: U.S. Geological Survey, Geologic Atlas of the United States, Folio No. 154, 6 pp.

Taff, J. A. and G. I. Adams. 1900. Geology of the eastern Choctaw coal field, Indian Territory: United States Geological Survey, 21st Annual Report, Pt. 2, 273 pp.

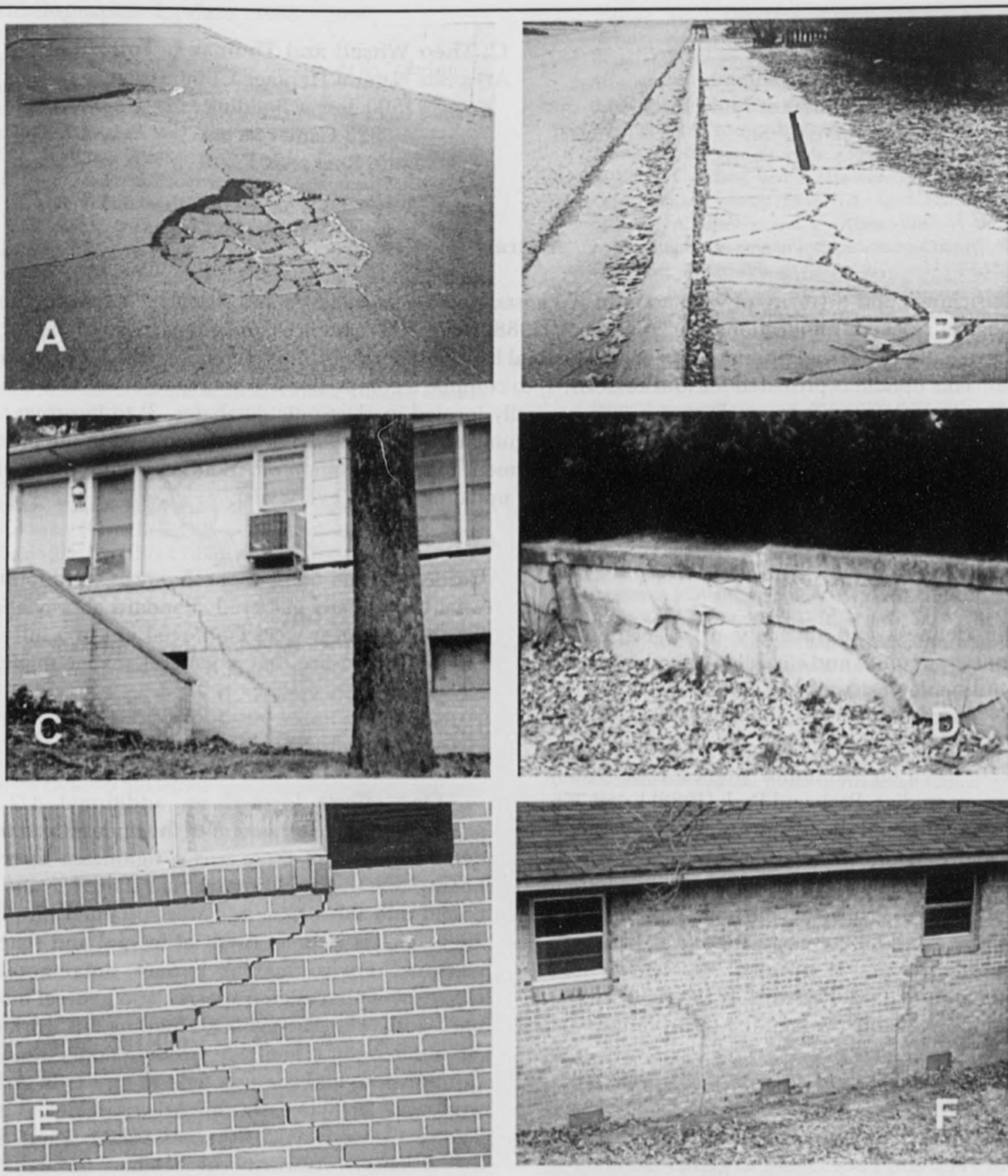

Fig. 5 Images illustrating examples of most common effects of expansive soils on pavements and buildings throughout the Fayetteville Quadrangle. A) Differential subsidence and cracking of pavement; B) Differential subsidence and downslope creep with associated buckling of a sidewalk; C) Cracked masonry foundation of a single-family dwelling; D) Severe cracking and horizontal displacement of a small retaining wall; E) and F) cracking of masonry above foundation of single-family dwellings.