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YAZOO CLAY:
Engineering Aspects and Environmental Geology of an Expansive Clay

by

Curtis W. Stover
Ross D. Williams
Charles O. M. Peel

CIRCULAR 1

MISSISSIPPI DEPARTMENT OF NATURAL RESOURCES
BUREAU OF GEOLOGY

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YAZOO CLAY: ENGINEERING ASPECTS AND ENVIRONMENTAL GEOLOGY OF AN EXPANSIVE CLAY

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INTRODUCTION

The name Yazoo Clay has long been associated in central Mississippi with such everyday problems as broken house foundations, sticking doors and windows, cracked plaster on ceilings and walls, and bumpy or "roller coaster" roadways. Scientists and construction engineers have been aware of the problems of building in the Yazoo Clay area for many years and have met with limited success in dealing with these problems. This limited success is not necessarily governed by a lack of expertise, but is often governed by such factors as time and expense.

The purpose here is not to give the building and construction industries new ideas or solutions in solving the problems of the Yazoo Clay and other expansive clays, but rather to define to the general public the location and areal extent of the Yazoo Clay, why it expands, problems associated with construction, and some generally accepted preventive and remedial practices in dealing with the costly problems of building on expansive clays.

GENERAL GEOLOGY

A large amount of expansive clay damage in Mississippi is caused by the Yazoo Clay. Yazoo Clay is the informal name of the unit; more properly it is the Yazoo Formation of the Jackson Group. The informal name will be used in this report. The Yazoo Clay is a fairly homogeneous unit consisting of blue-green to blue-gray, calcareous, fossiliferous clay, cropping out in a northwest-southeast trending belt across nearly three fourths the width of central Mississippi. The surface outcrop belt ranges from 30 to 6 miles wide and covers portions of eleven counties: Yazoo, Holmes, Hinds, Madison, Rankin, Smith, Scott, Newton, Jasper, Clarke, and Wayne (see Figure 1). The thickness of the Yazoo Clay is 400-500 feet when the entire section is encountered and thins to 0 feet along the northern edge of the outcrop belt. Stratigraphically, the Yazoo Formation is conformably underlain by the Moodys Branch Formation and is bounded above by an unconformable contact with the Forest Hill Formation. A generalized geological cross section showing the Yazoo Formation is shown in Figure 2.

A near surface vertical profile of the Yazoo Clay can be divided into three easily recognizable zones (Figure 3). The surface, Zone A, is a soil zone 0.5 to 1.5 feet thick consisting of a highly weathered, brown, silty clay containing roots of grass, trees, shrubs, and other organic material. This zone is the most affected by the chemical and physical weathering process of rain, snow, wind, and periods of alternate wetting and drying. Zone B is the weathered zone, approximately 10 to 30 feet thick, consisting of light tan to yellowish brown, stiff clay containing roots of trees. This zone also contains numerous desiccation cracks that are often 1 to 2 inches wide at the surface, 20 to 30 feet deep, and may be observed on the surface for 100 feet or more. These desiccation cracks will occasionally be filled with the mineral selenite, a transparent gypsum crystal resembling broken glass (see Figure 4). Zone C is the unweathered or neutral zone consisting of a very stiff, blue-green to blue-gray, calcareous (limy), fossiliferous clay. This zone is little affected by any weathering process except where exposed by deep road cuts or other excavations. Upon exposure to air by excavations, Zone C quickly assumes the characteristics of zones A and B.

CONSTRUCTION PROBLEMS

Foundation and structural damage experienced in the Yazoo Clay belt, especially in the Jackson area, is caused primarily by the expansive nature of the clay. An expansive clay is one which is relatively free of impurities such as sand, silt, and organic material, and which has the capability of absorbing large quantities of water during prolonged periods of rainfall or flooding. The term "fat" clay is often used for this type of material. When an expansive clay is subjected to water it expands in much the same manner as a dried out sponge; it will increase in volume (swell) when saturated with water (see Figure 5).

Unlike granular materials such as sand and gravel, clay has relatively low permeability. As such, it will hinder the movement of water through it except through cracks, root holes, and animal burrows. Clay, when exposed to water, will expand or swell, then shrink upon drying or desiccation. This alternate swelling and shrinking will cause weakened areas that crack during dry periods. During future periods of alternate wetting and drying the clay will continue to expand and shrink along the planes of desiccation cracks, causing slickensides (shiny polished surfaces) on the walls of these cracks. These slickensided surfaces are easily recognized during foundation investigations and are positive indications of an unstable or expansive clay. These cracks also allow surface water to enter to great depths and do further damage.

Construction problems are compounded by the thickness and lateral extent of the Yazoo Clay. In many areas an

OUTCROP BELT OF THE YAZOO FORMATION

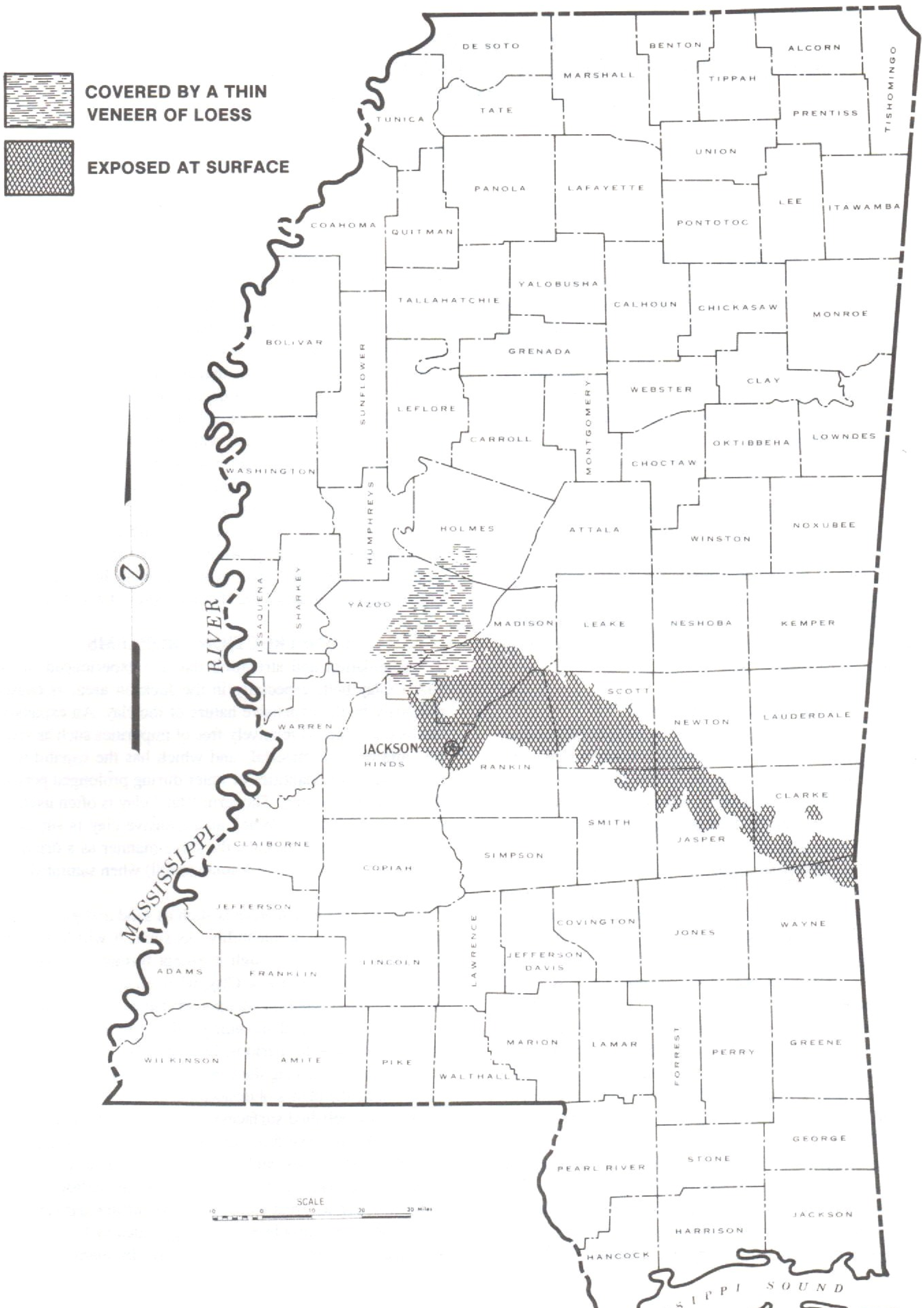

Figure 1. Surface outcrop belt of the Yazoo Formation.

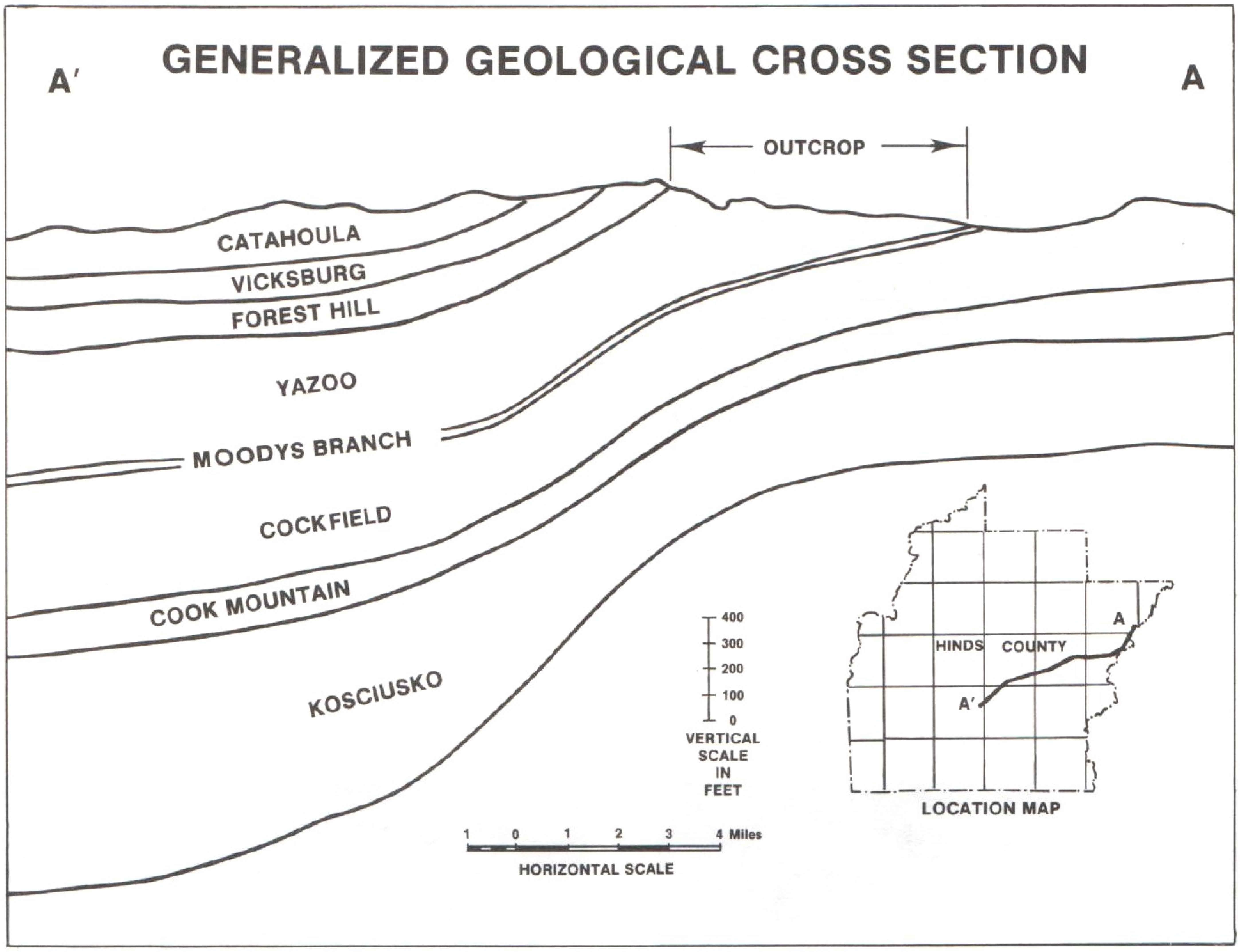

Figure 2. Generalized geological cross section from crest of Jackson Dome to southwestern Hinds County (after Moore, 1965).

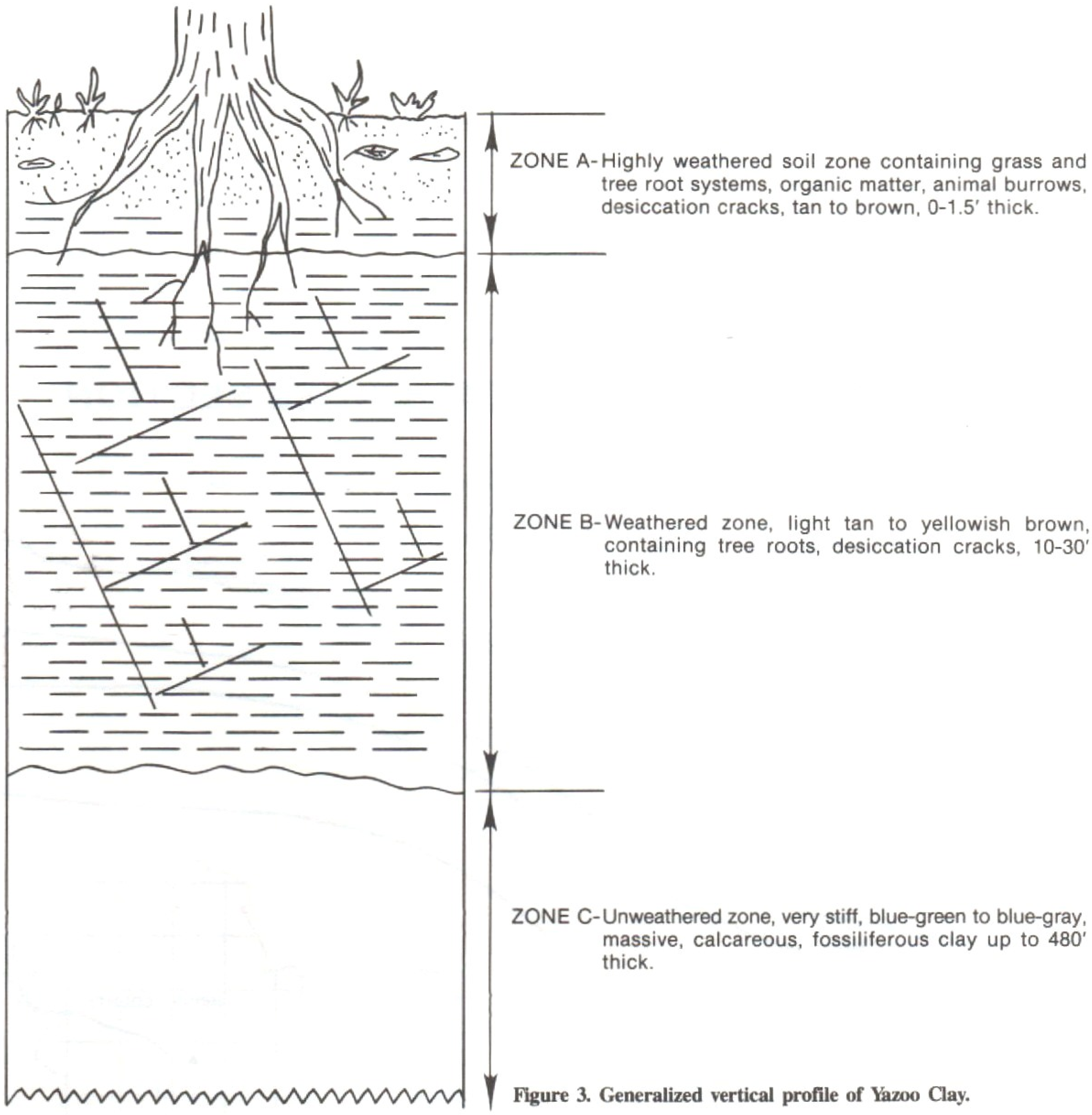

Figure 3. Generalized vertical profile of Yazoo Clay.

Figure 4a. Vein of selenite filling a desiccation crack.

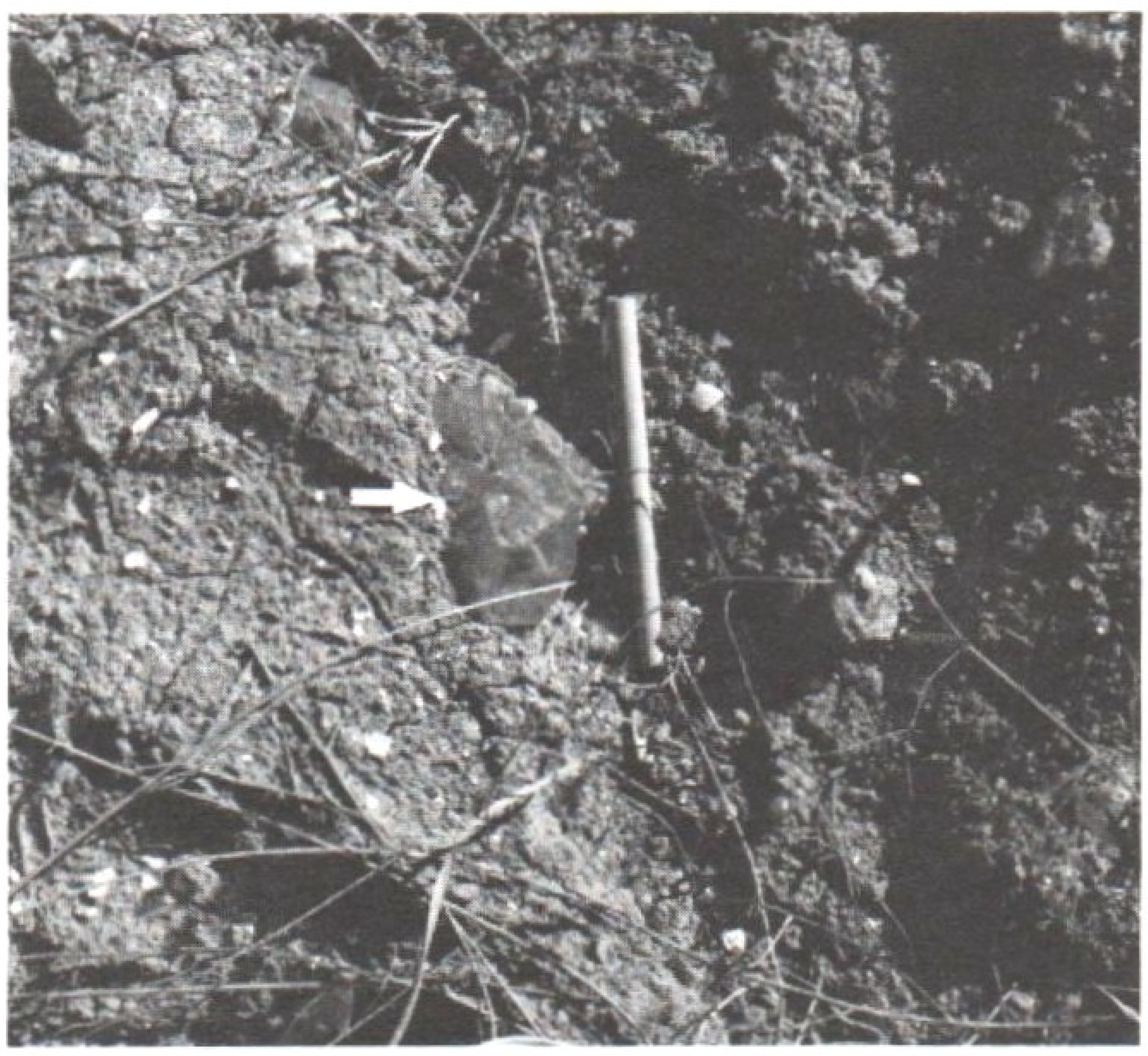

Figure 4b. Arrow in center of photograph points to large selenite crystal. Note ink pen on the right side of crystal for scale.

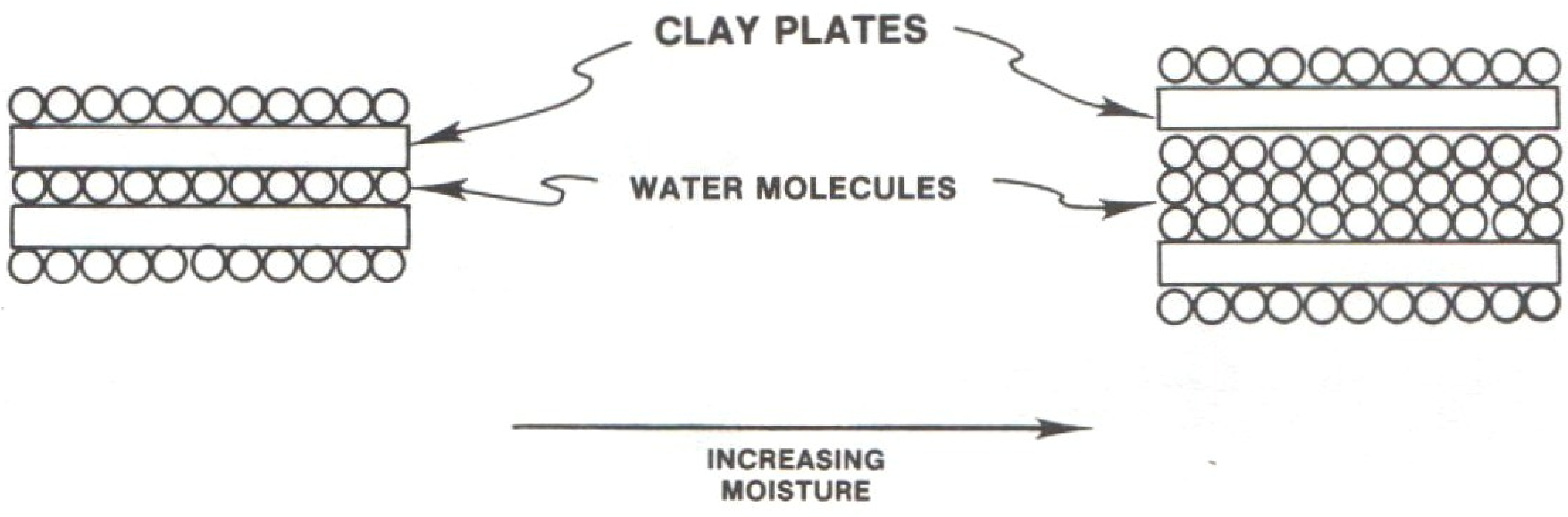

Figure 5. Schematic diagram (not to scale) showing physical change in expansive type clay due to moisture (modified after Holtz and Hart, 1978).

undesirable foundation soil could be excavated and backfilled with a more suitable material. Zones A and B are the troublesome zones, but to excavate below these zones would expose Zone C. Zone C, when exposed to air and water, will assume the same troublesome characteristics as zones A and B. To remove the clay, in most cases, is either impossible or is not economically feasible. It is therefore up to the homebuilders, construction engineers, and homeowners to deal with building on the Yazoo Clay.

The lateral and upward forces generated during expansion are tremendous and are capable of lifting tons of concrete and of disrupting the structural integrity of roadways and buildings. Also, during the process of desiccation or drying, this clay exhibits sufficiently strong adhesion or suction on overlying foundations to pull them down as the soil shrinks. Heave and shrinkage due to expansion and desiccation are rarely distributed evenly under a structure, causing differential movement. This results in one side or part to be higher or lower than the rest. Figures 6-21 illustrate typical types of damage to buildings.

Uneven movement of foundation soils can usually be attributed to uneven distribution of soil moisture or uneven saturation of foundation soils. Houses built after prolonged periods of rain will shield or retain moisture beneath the foundation but will lose substantial amounts of moisture around the outer edges due to evaporation and transpiration. This will result in a downwarping around the edges due to shrinkage. However, houses built under these conditions usually suffer less movement than those built after prolonged dry periods. Houses built after prolonged dry periods will sometimes experience an uplifting or heaving around the outer perimeter during wet periods if the interior sections are allowed to remain dry. Isolated spots of movement are sometimes caused by leaking outside faucets, rain gutter drainage, tree root transpiration, extensive watering of plant beds next to homes, and leaking plumbing and sewage lines underneath foundations. If allowed to continue unrepaired these sources of trouble can result in more damage than rainy and dry periods. Faulty plumbing under slab foundations may be difficult to detect until structural damage appears. Frame houses

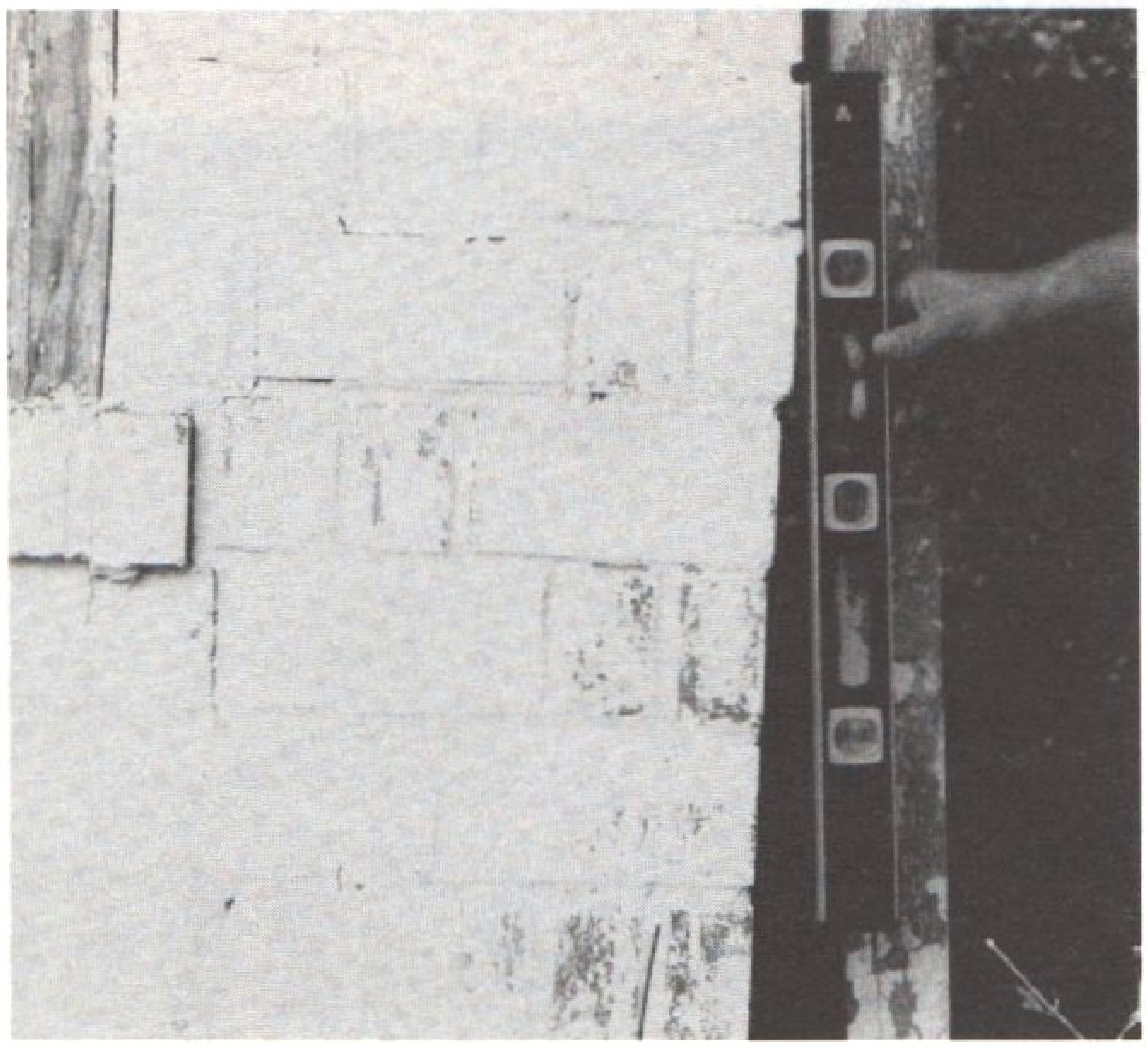

Figure 6. House with horizontal displacement as indicated by level.

Figure 7. House pier with horizontal displacement indicated by pointer.

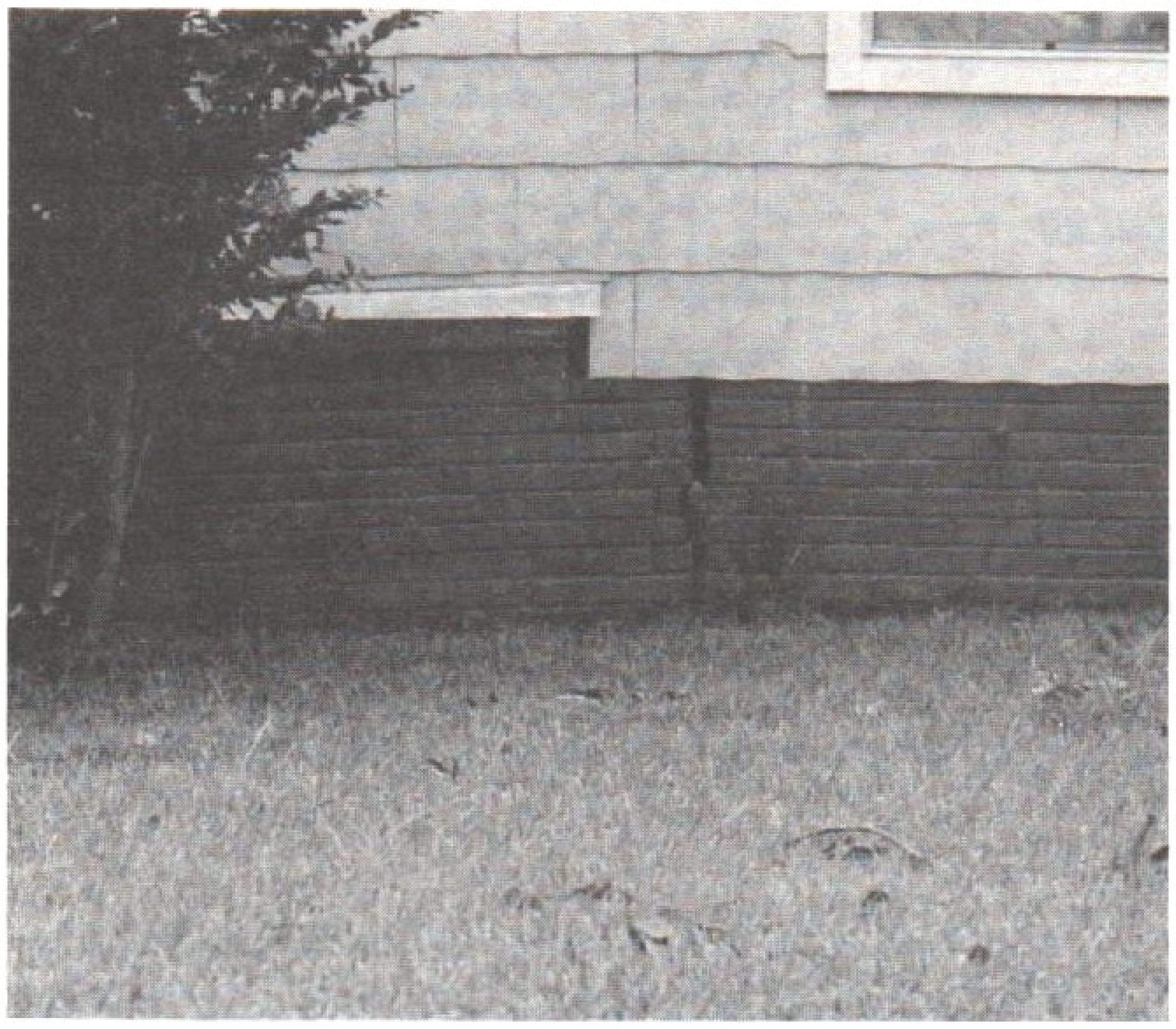

Figure 8. House foundation with horizontal and vertical displacement.

Figure 9. Building pier with vertical and horizontal displacement.

Figure 10. Brick wall with horizontal displacement due to differential vertical movement of the soil.

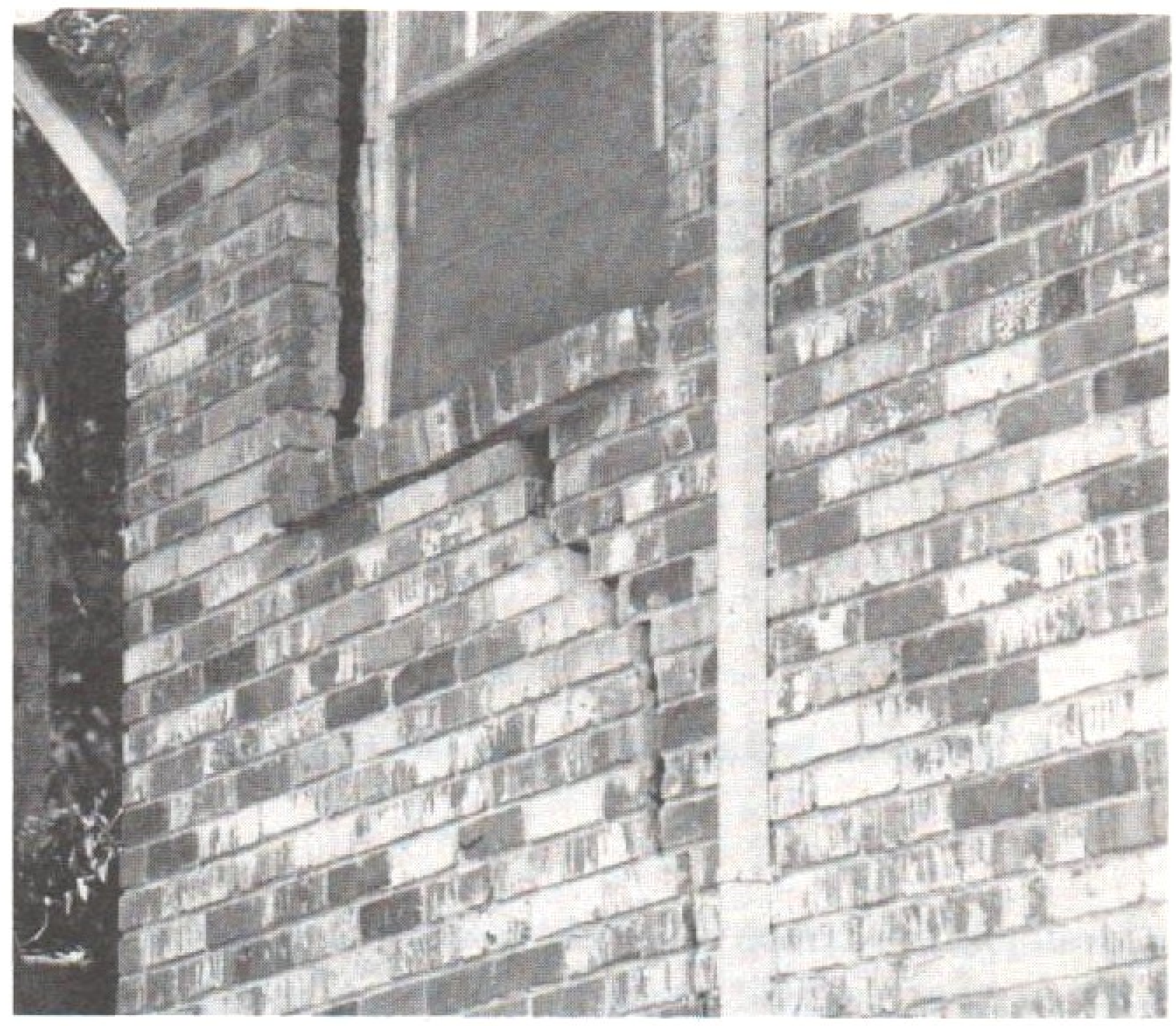

Figure 11. Apartment building, second level, with horizontal displacement due to differential vertical movement of the soil.

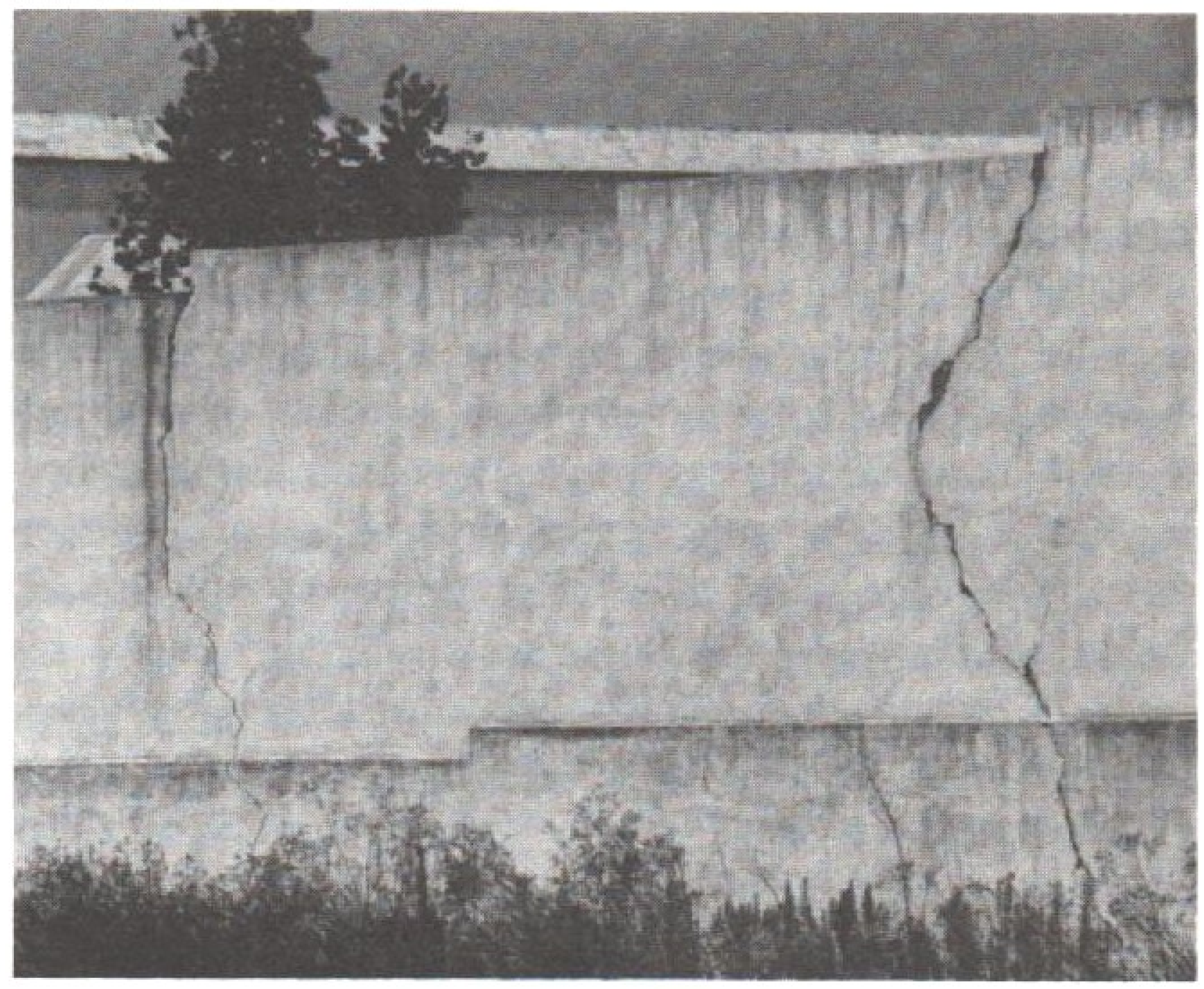

Figure 12. Concrete wall with horizontal displacement.

Figure 13. Building pier, third level, with horizontal and vertical displacement.

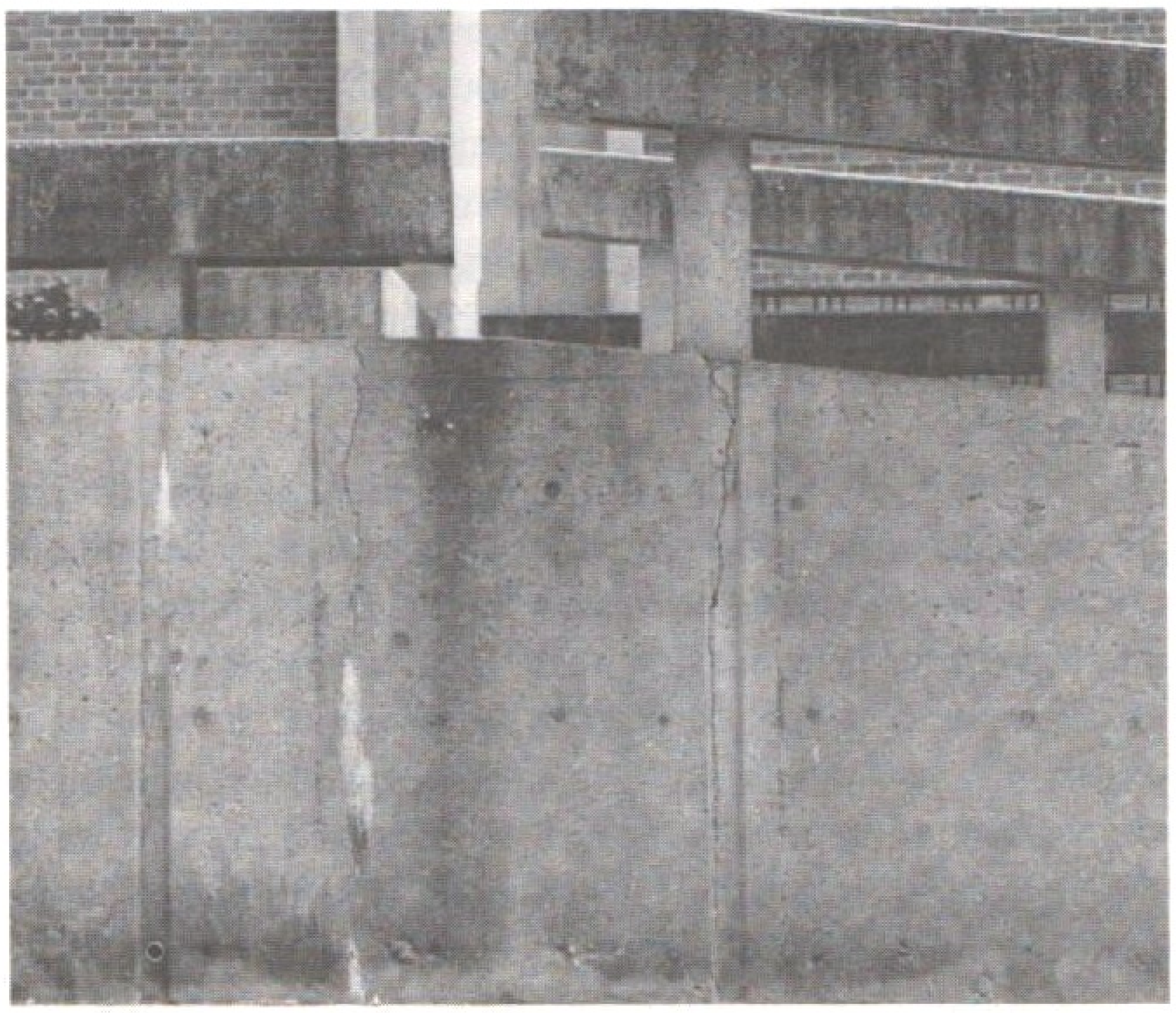

Figure 14. Concrete wall with hairline fractures.

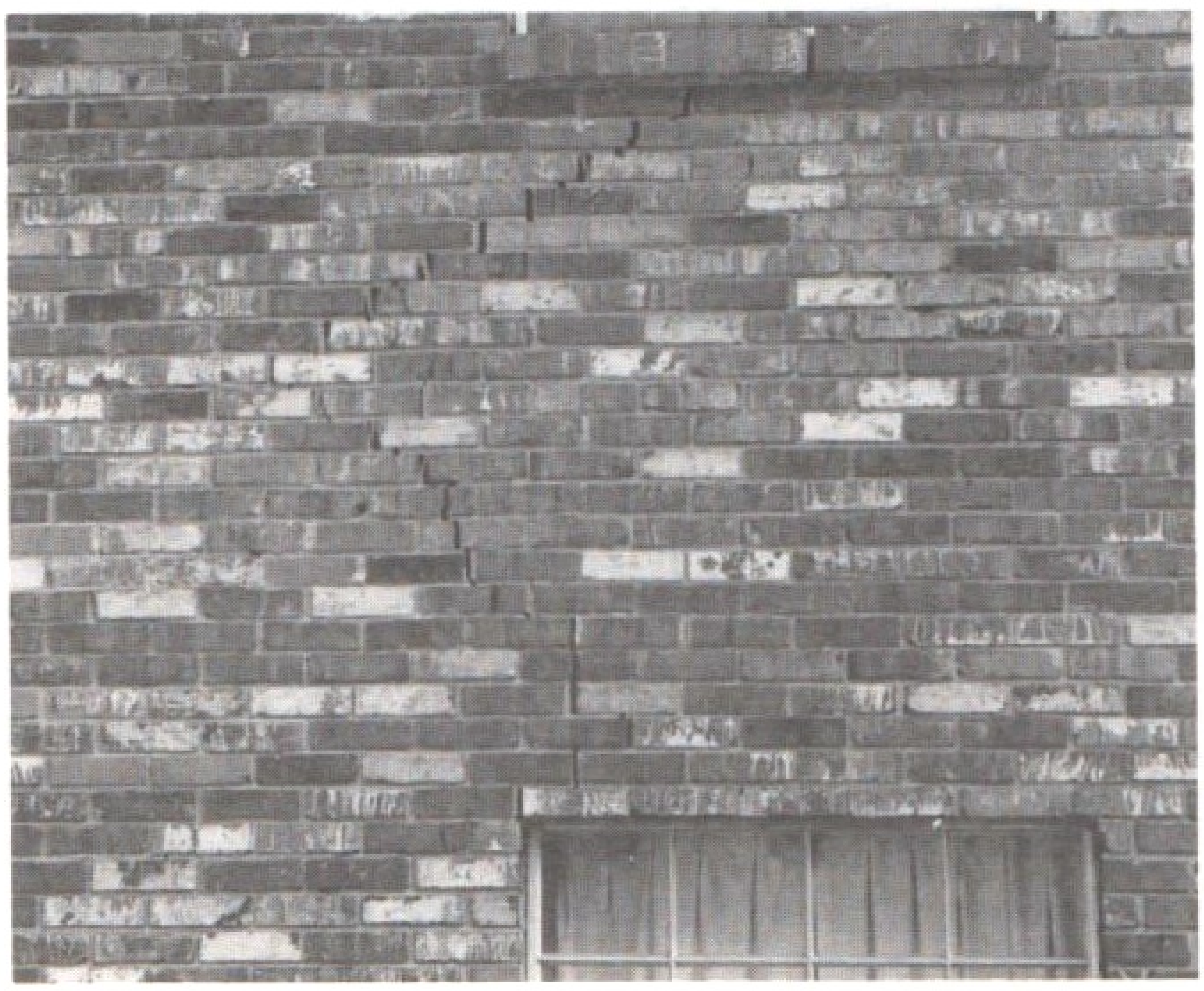

Figure 15. Apartment building wall, first and second levels, with horizontal displacement.

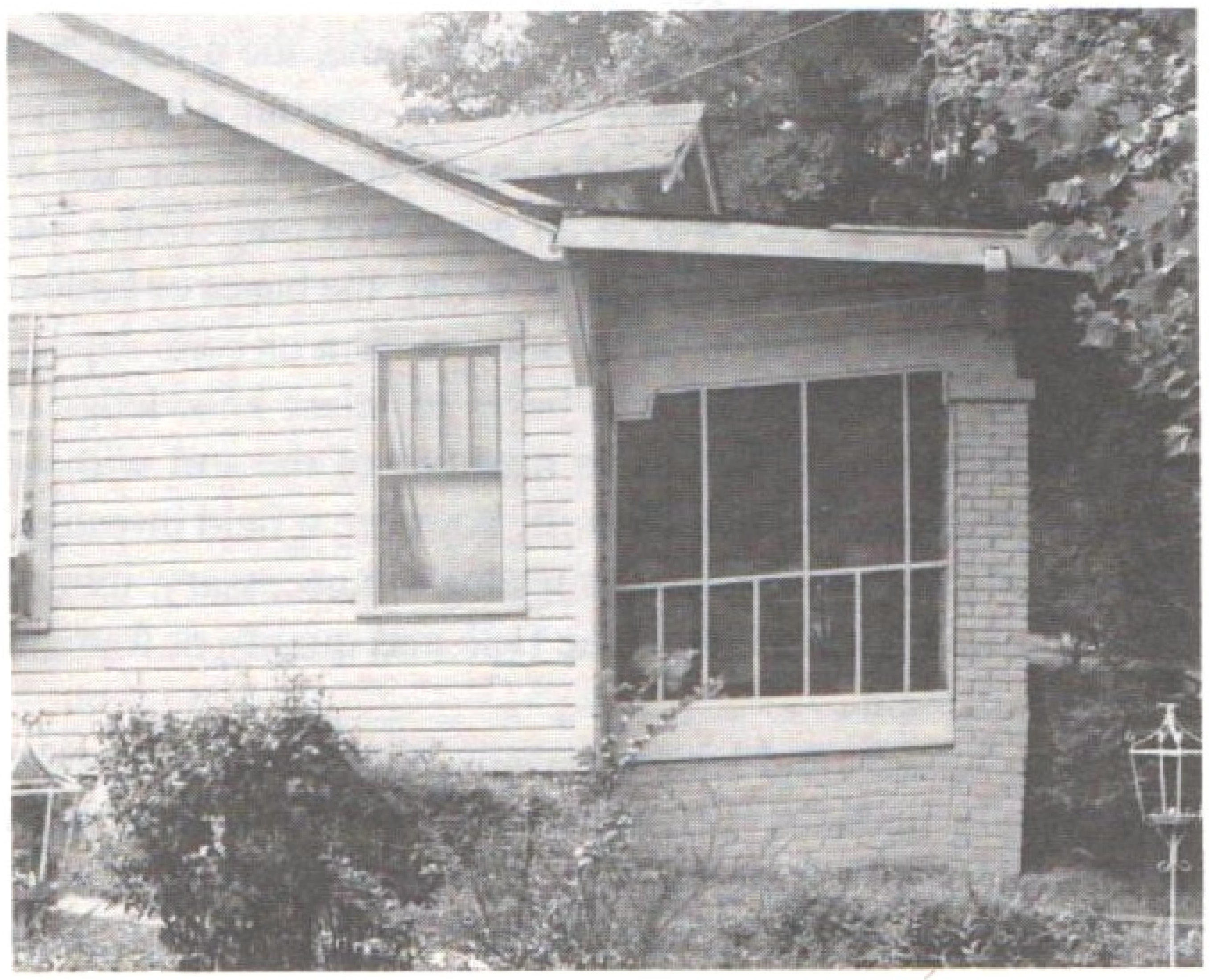

Figure 16. House foundation and pier with horizontal and vertical displacement.

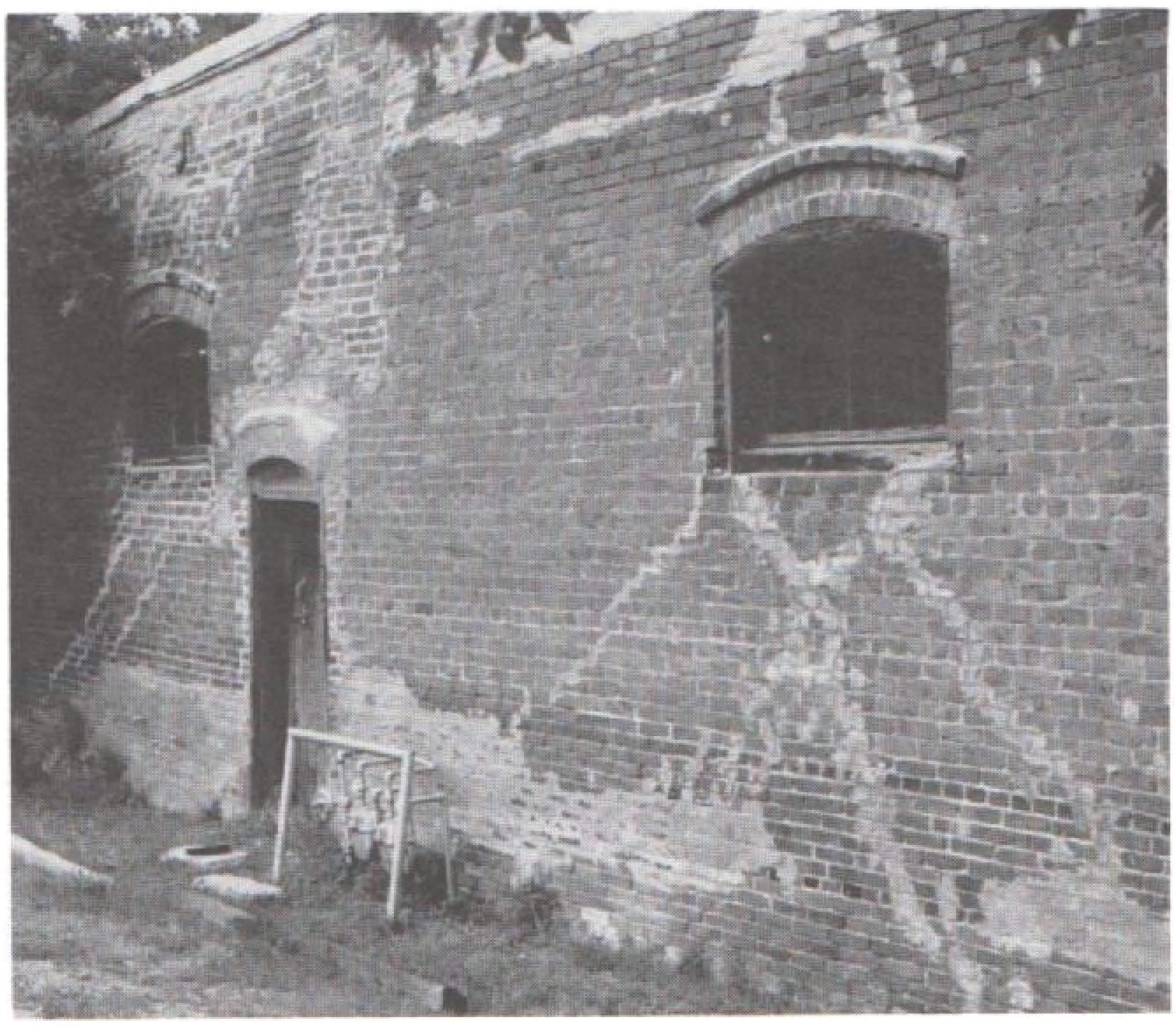

Figure 17. Building with horizontal displacement.

Figure 18. Common inside house damage.

Figure 19. Building with wall cracked from foundation to roof.

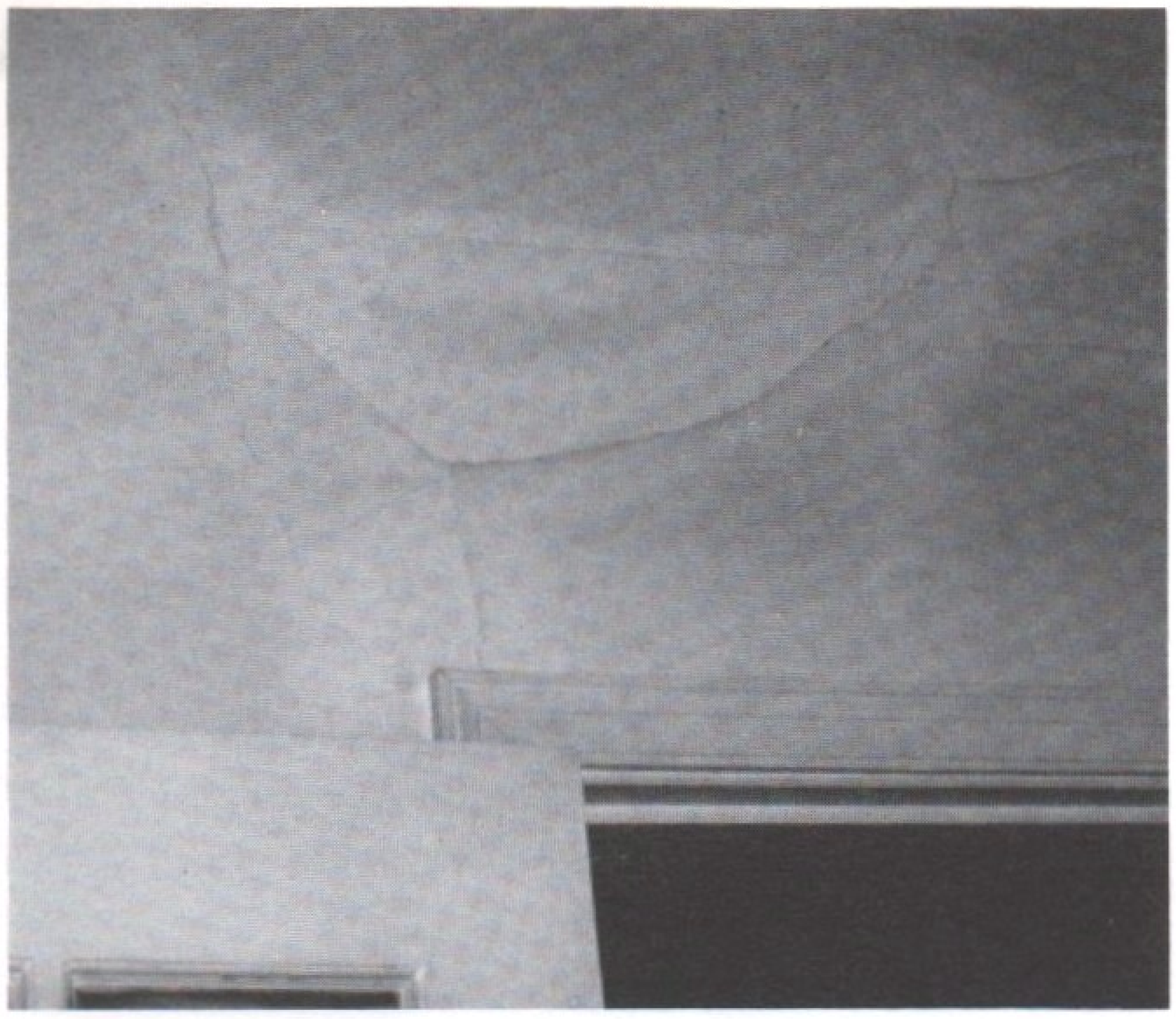

Figure 20. Common inside house damage.

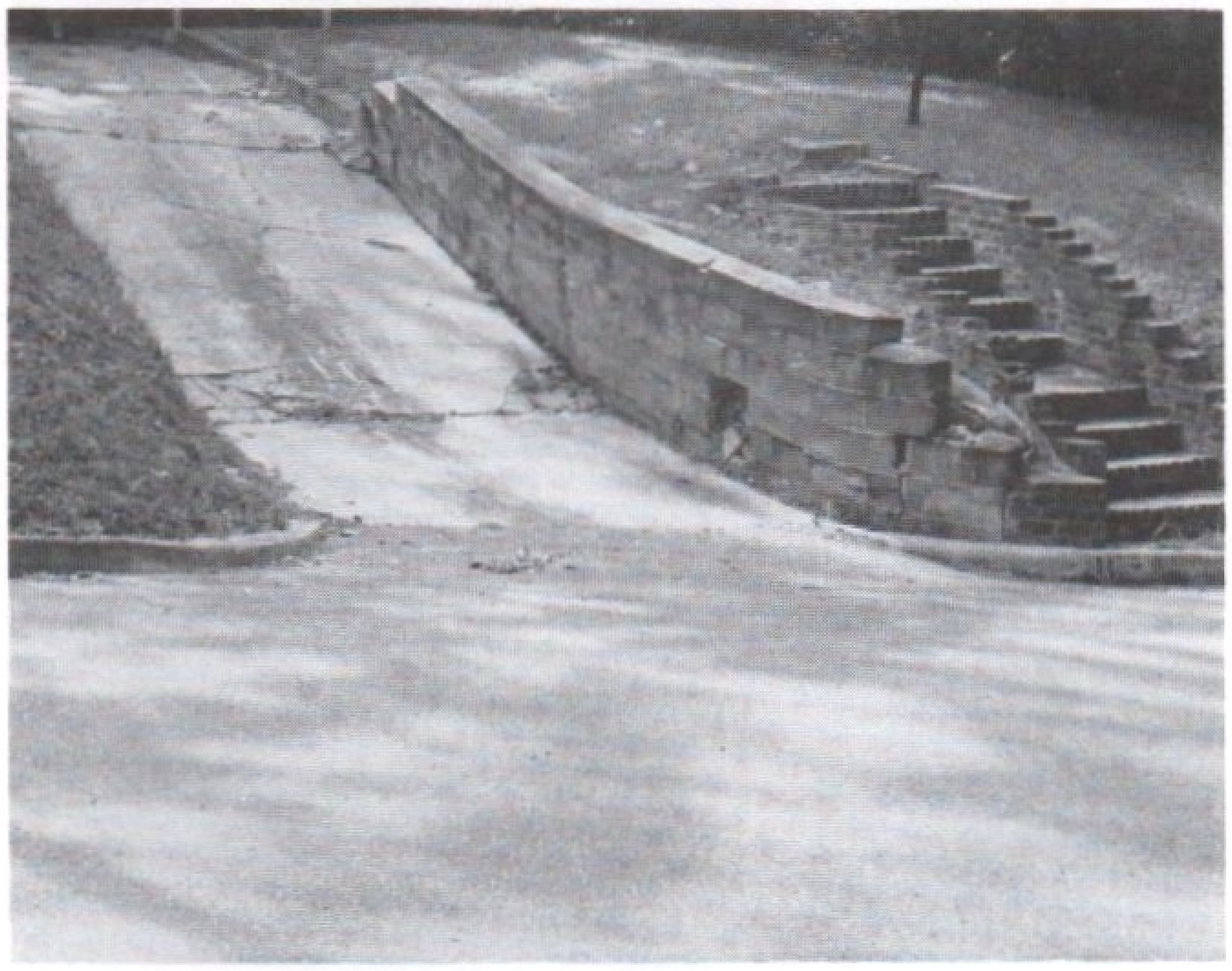

Figure 21. Horizontal and vertical movement damaging retaining wall and driveway.

Figure 22. Example of damage done to roadway caused by allowing water to seep underneath.

built on pier type foundations are usually more susceptible to soil movement than are houses built on slab foundations. However, potential problems are easier to detect and damage is easier to repair. "An ounce of prevention is worth a pound of cure." Improperly sealed expansion joints in concrete highways, sidewalks, and foundations can allow water to seep under concrete or pavement and do considerable damage (see Figure 22).

Foundation problems due to expansive clays should not be confused with problems caused by settlement. Settlement and/or consolidation are caused by the foundation soils or a compressible layer settling under the added weight of a new structure or building. Structures subjected to the effects of expansive clays may heave or contract depending on changes of moisture content in the soil. Structures that are subsiding due to a compressible soil may continue in a downward movement for an indefinite period of time.

Another problem encountered in the Yazoo Clay outcrop belt is the occurrence of the slumping of earth material. Slumping has frequently occurred where the Yazoo Clay has been used as a fill material to construct highway embankments and bridge approaches. These occurrences, although damaging and costly to repair, are relatively small and confined to the filled-in area. Several massive slides have occurred where new highways have made deep cuts through hills, exposing the clay to abnormal weathering (see Figures 23-27). These cuts also removed much of the restraining forces that were holding the clay in a state of equilibrium. Numerous landslides have occurred in areas where the clay is overlain by several feet of sand and silt. During periods of high rainfall, surface water may seep down through the silt and sand, but when it reaches the clay it may go no farther. If this water cannot be discharged back onto the surface in the form of springs, subsurface water pressures, and the weight of the water held, build up. The end result of such a situation is frequently a slope failure along a plane of weakness at the sand-clay interface.

PREVENTION

Prior to buying or building a new home, the prospective buyer or builder could, as a first step, consult a geologist or view a geologic map in order to determine if the site in question is on the outcrop of an expansive clay. If the site is on the outcrop belt of an expansive clay, the buyer or builder should consult a competent foundation firm or soils expert. Sometimes the consultant will have sufficient knowledge of an area to know the expansive qualities of the soil without conducting a field investigation. If, however, a field investigation and subsequent laboratory testing are necessary, money could be well spent to know the type and quality of foundation soil present.

The simplest and least expensive type of soil investigation usually includes the collection of several soil samples at varying depths from borings, and a series of laboratory tests known as the "Atterberg Limits." The Atterberg Limits series of tests, conducted somewhat by trial and error, define those physical properties of most fine-grained soils, and par-

Figure 23. Highway damage caused by massive slide.

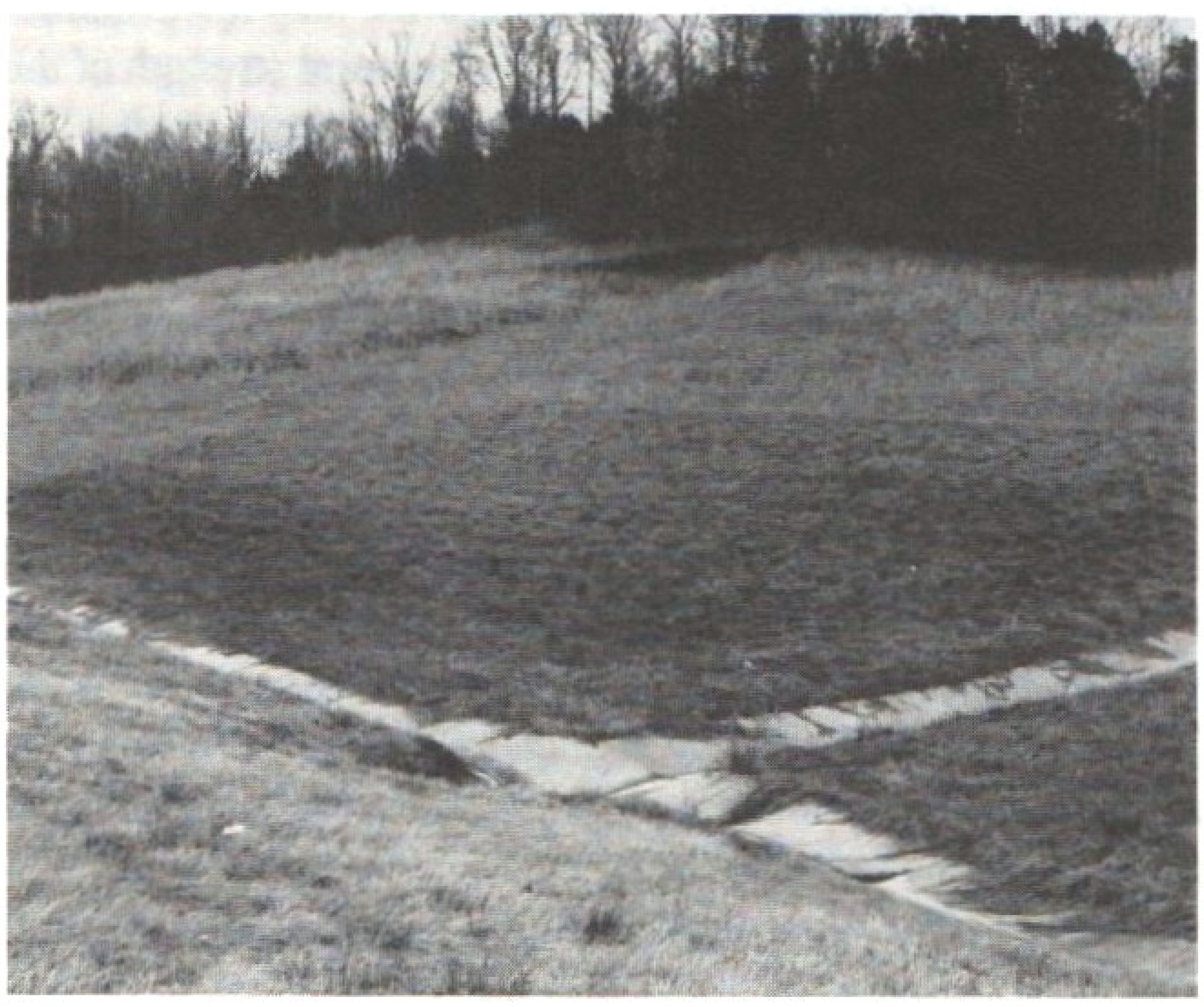

Figure 24. Example of massive slide due to side-hill cut.

Figure 25. Close-up of photograph in Figure 24.

ticularly clayey soils, which are greatly affected by changes of water content. These properties are termed soil consistency.

Four stages or states of soil consistency are determined by the Atterberg Limits series. These are: (1) the liquid state, (2) the plastic state, (3) the semi-solid state, and (4) the solid state.

A very wet clay soil may have a tendency to flow like a very thick or viscous liquid. In this condition it is said to be in the liquid state. As the soil loses moisture through drying, it slowly changes from a liquid state to a plastic state. The moisture content at this critical point where a soil changes from the liquid to the plastic state is called the liquid limit (L.L.). Further drying will cause the soil to change from a plastic state to a semi-solid state. The moisture content at this critical point is termed the plastic limit (P.L.). The difference between the liquid limit and the plastic limit (L.L.-P.L.) is known as the plasticity index (P.I.). The plasticity index represents the range of moisture contents within which the soil is in a plastic condition. As the clay soil dries and passes from the liquid state through the plastic state and to the semi-solid state, shrinkage will also occur. When the soil changes from the semi-solid state to the solid state a condition of equilibrium is reached where shrinkage stops even if additional moisture is removed. This point of moisture content where shrinkage stops is called the shrinkage limit (S.L.) of the soil.

The plasticity index in combination with the liquid limit is an indication of the sensitivity of the soil to changes in moisture. Expansive clay soils usually exhibit high liquid limits and high plasticity indices. Non-expansive soils, such as sandy and silty material, exhibit low liquid limits and low plasticity indices.

It should be noted that although the results of the Atterberg Limits series are valuable tools and are widely used throughout the country, they are only indications of soil sensitivity and may not accurately reflect how natural (in situ) soil will react to moisture change.

A more detailed and costly foundation investigation might include a very detailed boring program with the collection of undisturbed core samples. The laboratory testing in such a program might include swell tests, triaxial and unconfined compression tests, and consolidation tests. The cost of a detailed investigation for an ordinary dwelling is usually inhibitive; however, this is normal procedure for bridges, roads, large office buildings, and other large structures.

If the soil investigation reveals that the house or structure could be built on a potentially expansive clay, several construction techniques adopted by industry are commonly used to combat the destructive forces of the expansive clay:

(1) Remove the expansive clay by excavation and backfill with a non-sensitive material.

(2) Design foundations and structures strong enough to withstand expansion and contraction forces.

(3) Treat the soil to keep soil moisture at a constant level.

(4) Treat the soil to change its physical and chemical properties in order to destroy the expansive qualities.

Figure 26. Example of slide along a drainage ditch.

Figure 27. Example of slide and the damage done to roadway.

On major construction projects one or all of these principles may be used.

Excavating an expansive clay and backfilling with a nonsensitive material has been briefly discussed. This method would be the most obvious choice in eliminating swell problems provided that the expansive clay stratum is thin and suitable replacement materials are available. The selection of and proper compaction of the backfill material is essential to prevent excessive consolidation. Granular materials such as gravel and crushed rock have been used successfully in some areas.

One method used to build structures to withstand expansive force is by the application of surcharge pressures. This means to place a load on the soil greater than the expansive forces. This method is used in the case of large buildings and structures that impose high loads on the foundation soil.

Use of properly constructed steel reinforcing in concrete slab foundations increases the stiffness of the slab and superstructures. This added rigidity aids in minimizing distortion of the structure from both horizontal and vertical movements. Increasing the stiffness of the slab also reduces differential heave. Regardless of the structural strength of the slab, foundation movement due to swelling cannot be prevented if the weight of the slab and structure produces less downward force than the swelling force of the clay.

Pile foundations, both driven and bored, have been used successfully in the Yazoo Clay area. Pile foundations provide an economical method of transferring the structural load from expansive foundation soils to deeper, less expansive soils. Bored piles are generally more economical than driven piles provided the expansive zone is fairly thin. It is desirable to have pile foundations in the unweathered zone of the Yazoo Clay. An advantage of pile foundations is that the structure can be built so that only the piles are in contact with the expansive foundation soils.

The floating floor slab method of construction employs a flexible rather than a rigid design, whereby the floor slab can move independently of outside walls and wall foundation. Inside walls can be attached to the slab floor or ceiling with flexible or slip joints. Independent movement of the slab and interior walls minimizes cracking and damage to the exterior walls as well as the interior.

Since it has already been determined that the major source of problems in an expansive clay such as the Yazoo Clay is fluctuation of soil moisture, it is only logical to consider soil treatment and landscaping techniques that would keep soil moisture contents constant or nearly constant.

Soil treatment is always more successful when done prior to construction. This procedure involves pre-wetting by flooding and allowing the water to stand on the surface until the soil has achieved an optimum moisture content. Building after prolonged periods of rain or natural flooding could save the expense of artificial pre-wetting, provided the soil moisture has reached the proper level. After the soil moisture has reached an optimum level and the surface water removed, the soil surface is plated with a moisture barrier such as an asphalt membrane to prevent moisture loss. Topsoil can then be placed over the membrane. This technique has been used with very satisfactory results in the construction of highways in several states. However, the time required to saturate the soil may be several months and this could pose problems in house construction.

Proper landscaping can be extremely important in the prevention of foundation failures due to expansive soils. Preventive landscaping should be incorporated into the initial foundation plans. The soil surrounding a house foundation should have sufficient slope away from the foundation that drainage from roof eaves and gutter spouts will not collect near the foundation. Trees and shrubs should be planted far enough from the foundation so as not to draw soil moisture from around and under the foundation. Care should also be taken not to excessively water lawns and shrubs near house foundations.

CONCLUSION

This paper is not intended as a definitive source for the problems and solutions of building and construction on expansive clays. It should be used as an outline for the general public to better understand problems, remediation, and terminology associated with an expansive clay such as the Yazoo Formation.

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