



WILLIAM B. HAZELRIGG  
COMMISSIONER

COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS  
FRANKFORT, KENTUCKY 40601

ADDRESS REPLY TO  
DEPARTMENT OF HIGHWAYS  
DIVISION OF RESEARCH  
333 SOUTH LIMESTONE STREET  
LEXINGTON, KENTUCKY 40508  
Telephone 506-254-4475

H-2-16

MEMO TO: A. O. Neiser, State Highway Engineer  
Chairman, Research Committee

DATE: April 25, 1968

SUBJECT: Landslides: Geological Correlation

Research Report: "The Crab Orchard  
and Osgood Formations," R. C. Deen  
KYHPR-63-16; HPR-1(3), Part II

A conspicuous similarity between certain roadway slides which have occurred in our outer Bluegrass Area has emerged during the past two or three years. Searching inquiries have further disclosed a geological similitude--which associates the eastern Crab Orchard Formation with the western Osgood Formation. Academically speaking, we understand that fauna fossils do not correlate well (except in the Brassfield limestone, which comprises the basal layer both east and west); for this reason, geologists continue to identify them by separate names but imply an epochal relationship. The question concerning the possibility of former continuity of these strata across the Cincinnati Arch remains academic. From an engineering standpoint, they are materially and stratigraphically the same. Regardless of which series of names may be assigned, it appears that these greenish shales are untrustworthy in any conceivable form of roadway earthwork--including embankment foundations. Consequently, I asked Dr. Deen to compile the specific case histories and to document pertinent information for the benefit of Design, Construction, and Maintenance. His report is submitted herewith.

Borings are now being made at the site of the major slide west of Irvine (KY 52). Judging from new roadway excavation exposures to the immediate east and more remotely to the west, the Brassfield limestone lies perhaps 20 to 30 feet below the bottom-land level. If the roadway is reconstructed on the present line, it will have to remain perched on the Estill and Lulbeograd Shales. Benches may become slippery quite soon after they are stripped. We feel that this is a case where everything will worsen with time--that is to say, stability will decay through exposure, disturbance, and intrusion of ground waters. The Waco Limestone, if present, would provide the most favorable

April 25, 1968

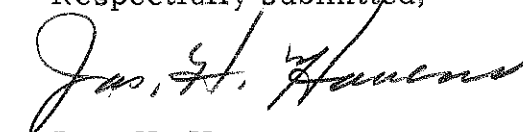
bench cap; even so, fissures and cracks or holes should be plugged. Thus far, borings have not revealed the presence of Waco ledges. These shales have developed some natural internal drainage in the form of piping or veins, and cutoffs should be constructed along the upper side of the road and transversely along the grade. Reconstruction will undoubtedly involve considerable risk. If the cost of relocating seems too great, I suggest that the reconstruction be staged or phased.

As a matter of parallel interest, a copy of an inter-office memorandum concerning the location of a new section of KY 10, in Lewis County, is attached hereto. This memo pertains to one of the case studies included in Deen's report.

These shales were encountered in the construction of I 75 north of Berea. They may have already been encountered on I 64 between Owingsville and KY 801. Maps indicate outcrops along I 71 in the vicinity of LaGrange. The only problem that has come to our attention in connection with these projects was just north of Berea. There, a silty soil--apparently deposited in a down-faulted zone--created a situation very much like that experienced in the western Kentucky silts. It appears that the silt overlaid the shale, and this caused a perched water table. The problem was that the silt could not be compacted. The material was removed (undercut) and refilled. In this case, the trouble was only indirectly attributable to the Crab Orchard Shales.

Deen's report fails to mention two earlier instances of embankment instability on KY 52 in the vicinity of Waco--which are quite similar to the slide on the Mountain Parkway (page 27 of the report).

Respectfully submitted,



Jas. H. Havens  
Director of Research

JHH/em

cc's: Research Committee

R. O. Beauchamp, Assistant State Highway Engineer  
W. B. Drake, Assistant State Highway Engineer  
J. T. Anderson, Projects Management Engineer  
K. B. Johns, Operations Management Engineer  
J. R. Harbison, Program Management Engineer  
C. G. Cook, Director, Division of Bridges  
G. F. Kemper, Director, Division of Construction  
R. Brandon, Director, Division of Data Processing

- E. B. Gaither, Director, Division of Design
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- J. M. Carigan, Director, Division of Photogrammetry
- J. W. Fehr, Director, Division of Planning
- C. H. Bradley, Director, Division of Right of Way
- K. C. Arnold, Director, Division of Roadside Development
- ~~E. Farmer~~, Director, Division of Service and Supply *Nancy Pleasant*
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District Engineers

- J. O. Gray, # 1, Paducah
- A. W. Clements, # 2, Madisonville
- H. J. Padgett, # 3, Bowling Green
- H. R. Ditto, # 4, Elizabethtown
- R. C. Aldrich, # 5, Louisville *Howard Hale*
- ~~C. O. Yochum~~, # 6, Covington
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- J. P. Noonan, # 8, Somerset
- S. B. Riddle, # 9, Flemingsburg
- B. A. Knight, # 10, Jackson *George W. Ashway*
- ~~E. V. Hilton~~, # 11, Manchester
- W. Bayes, # 12, Pikeville
- R. E. Johnson, Division Engineer, Bureau of Public Roads *ASSOCIATE*
- D. K. Blythe, Chairman, Department of Civil Engineering, ~~Assistant~~ Dean, College of Engineering, U. of Ky.

Attachments

MEMO TO: S.B. Riddle  
District Engineer  
Flemingsburg, Kentucky

FROM: Jas. H. Havens, Director  
Division of Research

DATE: March 25, 1968

SUBJECT: KY 10, Maysville-Vanceburg Road  
Lewis County, SP 68-114  
Sta. 291+00 to Sta. 651+97.02

At a design-construction meeting, March 1, 1968, which Messers Lukin, Dwyer, and Armitidge attended, I submitted a recommendation that proposed line drawn by the consultant for this section of road be shifted far enough to avoid the treacherous Crab Orchard formation which outcrops along the lower slopes of the hills. That line involves cuts and fills in and on this formation at several points. The matter was left to me to propose an alternate line or corridor--which is submitted herewith. It is my understanding that preliminary estimates of costs and feasibility will be made by your staff.

The alternate corridor lies wholly within the bottom lands; and the feasibility of this location is contingent, necessarily and principally, upon channel changes and the use of material from channel improvements to construct the roadway embankments. No additional bridges or culverts appear to be needed on the main line. The channels of Little Branch and Salt Lick Creek would remain on the south side of the roadway throughout. Abandoned channels on the north side might be re-filled in order to avoid impoundment of water; and, in any event, ditches should be constructed along the north side so as to empty at natural drainage points. The grade should be maintained well above flood level, and the amount of fill material needed may, therefore, determine the extent of channel improvements. Embankment slopes of 4:1 or even 6:1 seem desirable. Riprap may be needed at certain points.

The bottom location seems to be the only possible alternate. Modest fill-heights, wide embankment-slopes, and a reasonable distance between the embankment and the stream channel should minimize any risk of embankment failure due to subsurface conditions. Settlement should be expected; but



it is not likely to be any more severe than that which might be encountered at the two bridge sites on the consultant's line (Sta. 487+ and Sta. 510+). Improvement of drainage as necessary to construct the road may enhance the agricultural value of the bottom land along the route. Channel changes were required already at two sites along the consultant's line.

I am aware now that earlier re-construction on KY 10, west of the subject project, traversed the Crab Orchard shales; unfortunately, I had no opportunity or compelling reason to visit the project or to be familiar with the work; however, we would be very interested in knowing of any difficulties (slides) encountered there during construction or afterward.

We note that the Crab Orchard dips underground in the vicinity of Clarksburg; for some distance beyond there (toward Vanceburg), any future re-construction should be completely side-hill or bottom locations--that is, avoid locations at the toe of the hill--especially where portions of an embankment might rest on talus or alluvium.

In recent months, we have been able to correlate the occurrence of slides with the Crab Orchard formation to such a degree that it now seems imprudent to locate a road along its contacts.

The upper reaches of the offensive formation is shown by arrow points on the base map.

The line we have drawn is violable--as is the channel line, etc.

JHH:em

Attachments

cc: J.T. Anderson

E.B. Gaither

H.G. Mays



Research Report

THE CRAB ORCHARD AND OSGOOD FORMATION  
The Case For Slope Instability  
KYHPR-63-16, HPR-1(3)

by  
Robert C. Deen  
Assistant Director of Research

Division of Research  
DEPARTMENT OF HIGHWAYS  
Commonwealth of Kentucky

In Cooperation with the  
U. S. Department of Transportation  
Federal Highway Administration  
Bureau of Public Roads

The opinions, findings, and conclusions  
in this report are not necessarily those of  
the Department of Highways or the Bureau of  
Public Roads.

April 1968

THE CRAB ORCHARD AND OSGOOD FORMATIONS  
The Case for Slope Instability

For the past few years, the Division of Research, as a part of its continuing study of the occurrence of landslides in Kentucky, has reviewed and studied several sites in order to identify and delineate the geologic and soil formations which might be involved in the unstable earth masses. After a study of a number of landslides, it became evident that one particular material was highly susceptible to the development of landslides. This material, in Eastern Kentucky, is known as the Crab Orchard Formation and was deposited during the middle Silurian age. The Crab Orchard Formation, a deposit some 50 to 120 feet thick, is extensively mapped in the eastern portion of the State and correlates geologically with the Osgood Formation mapped in the western portion of Kentucky. The Crab Orchard and Osgood Formations are primarily shale deposits with some thin, discontinuous beds of dolomite. Soils which typically develop from these formations include the Rockcastle, Rarden, Fleming, and Fawcett series.

Experience over the past few years also suggests that certain formations of Pennsylvanian age, particularly of the Pottsville Series, are also highly susceptible to landslides. In Eastern Kentucky, a number of slides have occurred on highways from Bell County through Boyd County in the Breathitt Formation, a succession of shales and limestones. This particular formation often contains layers of coal and associated underclays, which are associated directly with the occurrence of these landslides. In Western Kentucky, the Tradewater Formation, also of the upper Pottsville Series has been identified as the troublesome material involved in slides on the Western Kentucky Parkway. The Tradewater is predominantly a shale formation with interbeds of sandstone and coal and associated underclays. The sandstones are subordinate and tend to be fine grained and shaley and are usually found in the lower part of the Tradewater.

At the base of the Crab Orchard Formation (see Figure 1) is the Plum Creek Member, a shale and dolomite deposit two to ten feet in thickness. The shale is a yellowish-green to grayish-olive, thin-bedded material which is very plastic and swells when wet. The dolomite is a light gray, weathering to yellowish-brown, fine- to medium-grained material. It occurs in discontinuous beds from 1/4 to several inches thick. The dolomite commonly is less than 20 percent of the member but locally may compose as much as 50 percent. The unit, when exposed, forms gentle slopes.

Above the Plum Creek is the Oldham Member, a dolomite and shale deposit ranging between 0 to 14 feet in thickness. The dolomite is a light gray, white-olive, or greenish-gray fine- to medium-grained material which weathers to a yellowish-brown or grayish-orange. The dolomite beds range

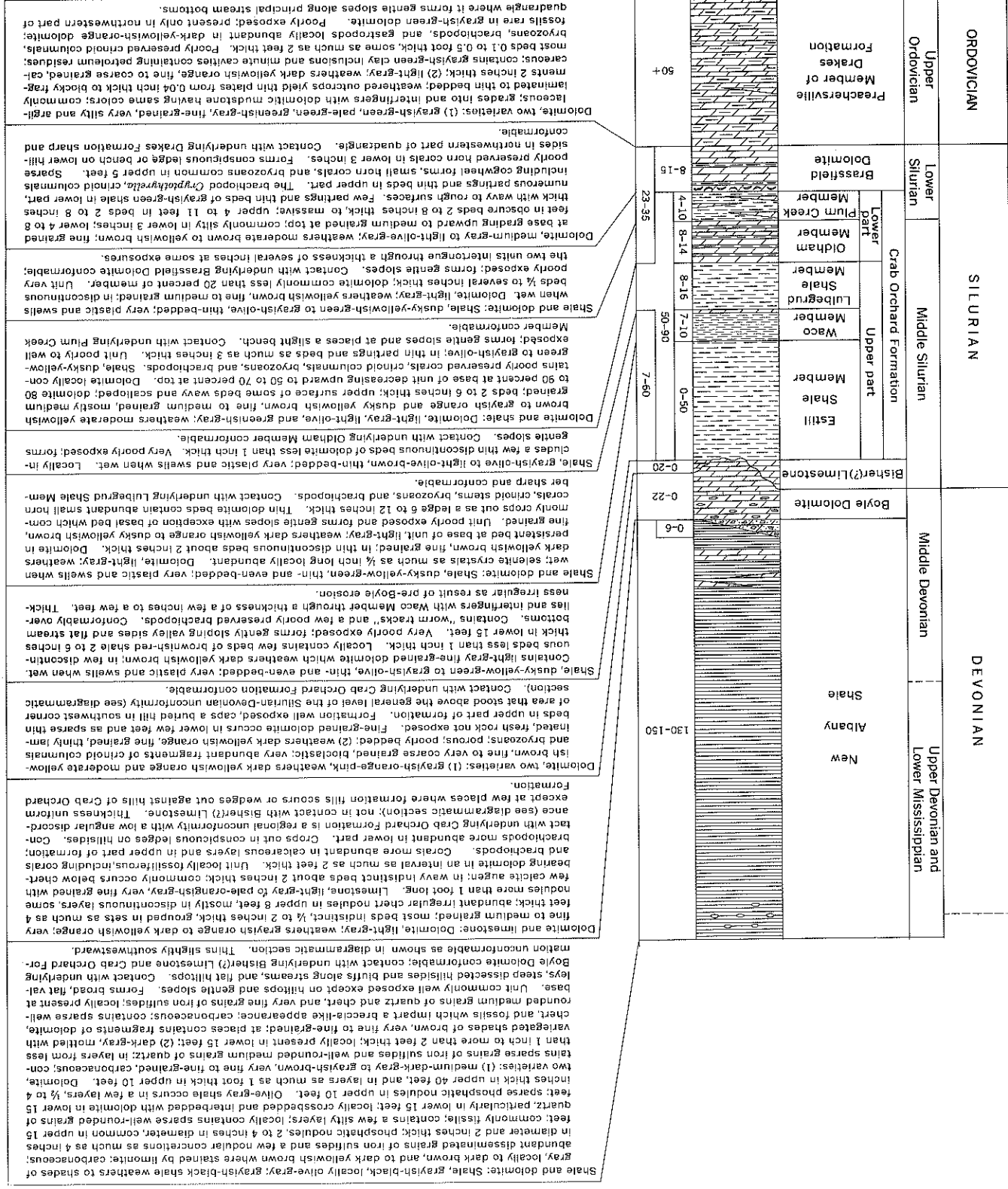


Figure 1. Generalized Columnar Section for Estill County, Kentucky (From "Geologic Map of the Clay City Quadrangle, Powell and Estill Counties, Kentucky, G.C. Simmons, US Geological Survey, 1967).

between two and six inches in thickness and comprises 80 to 90 percent of the member at the base of the unit and decreases toward the top of the unit to 50 to 70 percent. The shale, yellowish-green to grayish-olive, occurs in thin partings in beds as much as three inches thick. Where the Oldham Member outcrops, it forms gentle slopes and, in places, a slight bench.

The next member of the Crab Orchard is the Lulbegrud Shale, a deposit ranging up to 18 feet in thickness. This shale is a grayish-olive to a light olive-brown, thin-bedded material. Locally the member includes a few discontinuous beds of dolomite less than one inch in thickness. The shale is very plastic and swells when wet. The material, when exposed, forms gentle slopes.

The Waco Member overlies the Lulbegrud. The Waco is a deposit ranging up to ten feet in thickness and forms gentle slopes, with the exception of the basal dolomite which commonly crops out as a ledge six to twelve inches thick. The dolomite is light gray, weathers to a dark yellowish-orange to yellow-brown, and is a fine-grained material. In the upper portion of the member, the shale is a yellowish-green, thinly and evenly bedded material with discontinuous beds of a light gray dolomite about two inches thick. This dolomite weathers to a dark yellowish-brown, fine-grained material. The shales are very plastic and swell when wet.

The top member of the Crab Orchard Formation is the Estill Shale, a deposit ranging up to 60 feet in thickness. This shale is a yellowish-green to a grayish-olive, thinly and evenly bedded material. It contains a few discontinuous beds less than one inch thick of light gray, fine-grained dolomite which weathers to a dark yellowish-brown. Locally the member contains a few beds of a brownish-red clay two to six inches thick in the lower 15 feet. A bed of slightly resistant gray shale, one to three inches thick, occurs from zero to three feet above the base of the member. The shale is very plastic and swells significantly when wet. The member forms gently sloping valley sides and flat stream bottoms (see Figure 2). The thickness of this member is extremely irregular as a result pre-Boyle erosion.

In the western portion of the State, the material which correlates geologically with the Crab Orchard Formation is mapped as the Osgood (see Figure 3). The Osgood Formation consists of at least 50 percent of greenish-gray shale composed predominately of silty dolomitic clay. The lower part of the formation contains pale red, oxidized zones. Commonly the basal one to two feet of shale is greenish-gray and the overlying two to three feet is the pale red. The unit weathers to plastic clays and in many places underlies nearly barren, badly gullied slopes at the base of escarpments in the overlying dolomites. The dolomites of the formation occur as thin interbeds with the shale near the top and base of the unit. The Osgood Formation may be as thick as 50 or 60 feet in the western portion of the State and is generally mapped as a single unit, not being subdivided into various members as is done in the eastern portion of the State.

In both Western and Eastern Kentucky, the Crab Orchard and Osgood Formations are underlain by the Brassfield Dolomite (see Figure 4), a deposit of lower Silurian age, ranging between 8 and 30 feet in thickness, being



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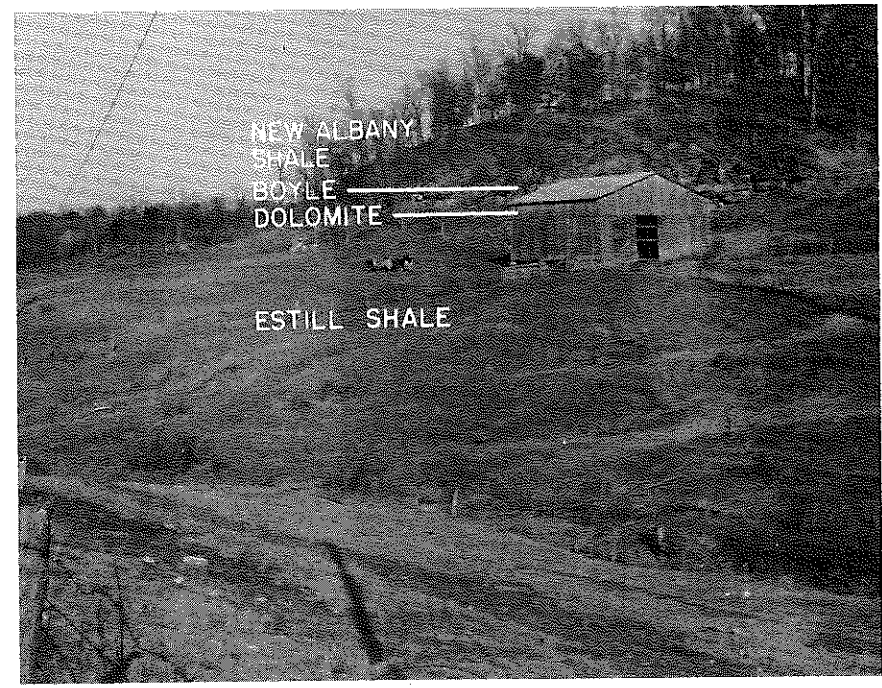


Figure 2. Gentle Slopes in the Estill Shale at the Base of the Boyle Dolomite Escarpments (KY 89, Estill County).

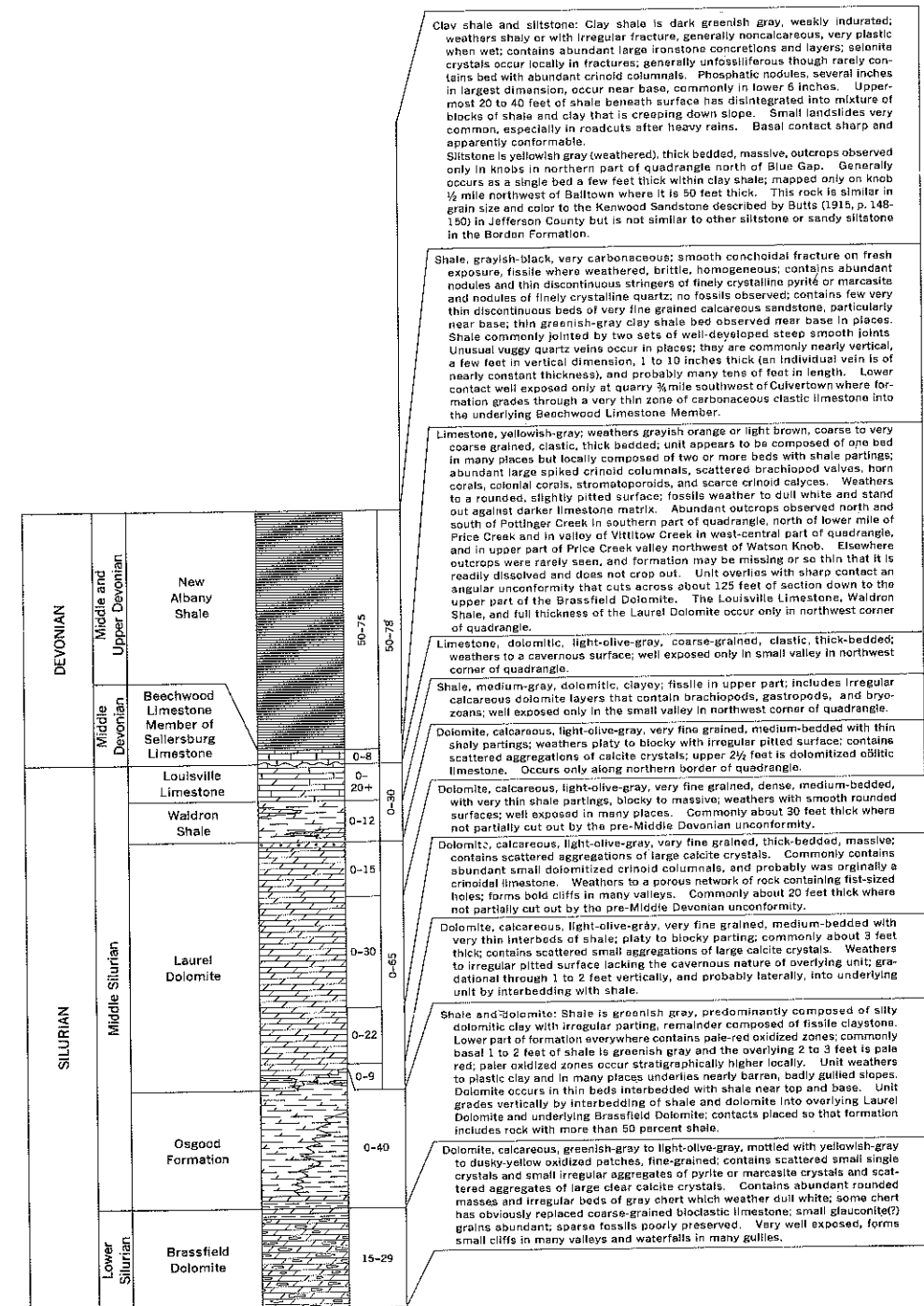


Figure 3. Generalized Columnar Section for Nelson County, Kentucky (from "Geologic Map of the New Haven Quadrangle, Nelson and Larue Counties, Kentucky," W. L. Peterson, US Geological Survey, 1966).



somewhat thicker in Western Kentucky. The Brassfield is a calcareous, greenish-gray to light olive-gray, fine- to medium-grained dolomite. The deposit is more generally fine-grained near the bottom becoming medium-grained at the top. The deposit is thickly to massively bedded with a few partings of thin beds of a grayish-green shale in the lower portion of the formation, the partings becoming more numerous and thinner in the upper part. The Brassfield Dolomite weathers to a moderate brown to yellowish-brown and often contains abundant rounded massive and irregular beds of gray chert, which weathers dull white. Where the Brassfield Dolomite outcrops, it forms small cliffs in many of the valleys and waterfalls in many gullies. Its outcrops are conspicuous as ledges or benches on the lower hillsides and its contact with the underlying Drakes Formation, a formation of the upper Ordovician age, is sharp and conformable.

In Western Kentucky, the Osgood Formation is overlain by the Laurel Dolomite, a thick- to medium-bedded calcareous dolomite ranging up to 65 feet in thickness. Near the middle portion of the Laurel, the deposit is thick-bedded and massive and weathers to a porous network of rock. In the lower portion of the unit, the Laurel lacks this cavernous nature of weathering and contains a number of very thin interbeds of shale. Above the Laurel are thin beds of the Waldron Shale, up to 12 feet of medium-gray dolomitic, clay shale. Above the Waldron Shale is approximately 20 feet of the Louisville Limestone, a light olive-gray, coarse-grained, clastic, thick-bedded limestone which weathers to a cavernous surface. The Louisville Limestone represents the upper most formation of the middle Silurian age in those areas in which the Osgood Formation is found. Portions of the Sellersburg Limestone, a deposit of middle Devonian age, overlays the Louisville Limestone in thickness up to eight feet. This limestone is yellowish-gray and weathers to a grayish-orange or light brown. It is coarse- to very coarse-grained, clastic and is thick-bedded. The unit often appears to be composed of a single bed in many places but locally it is composed of two or more beds with thin shale partings. The Sellersburg Limestone, the Louisville Limestone, the Waldron Shale, and the Laurel Dolomite locally may be entirely missing due to erosional processes. Above the Sellersburg Limestone are the thick, 50 to 75 feet, deposits of the New Albany Shale. This is a grayish-black, very carbonaceous shale and outcrops extensively in the areas in which the Osgood Formation is found.

In Eastern Kentucky, the Estill Shale Member of the Crab Orchard Formation is overlain by the Bisher Limestone, which apparently correlates with the Louisville Limestone of Western Kentucky. The Bisher is 0 to 20 feet in thickness and is a grayish-orange-pink dolomite which weathers to a dark yellowish-orange and moderate yellowish-brown. It is a fine- to very coarse-grained, bioclastic which is porous and poorly bedded. Above the Bisher is the Boyle Dolomite, ranging up to 22 feet in thickness (see Figure 5). The Boyle correlates with the Sellersburg Limestone of Western Kentucky and is an interbedding of light gray dolomite and light gray to pale orangish-gray limestone. The dolomite is fine- to medium-grained and the limestones are very fine-grained and commonly occur below the chert-bearing dolomite in beds as much as two feet thick. Outcrops of the Boyle and Bisher in Eastern Kentucky and the Sellersburg and Louisville Limestones in Western Kentucky are conspicuous as ledges on hillsides and often form

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Figure 4. Brassfield Dolomite (KY 52, Estill County).



Figure 5. Boyle Dolomite and New Albany Shale (KY 52, Station 230, Estill County).

the cliffs of many of the hills. Many of the hills in the Crab Orchard Formation are capped by the New Albany Shale, which may be as thick as 130 to 150 feet.

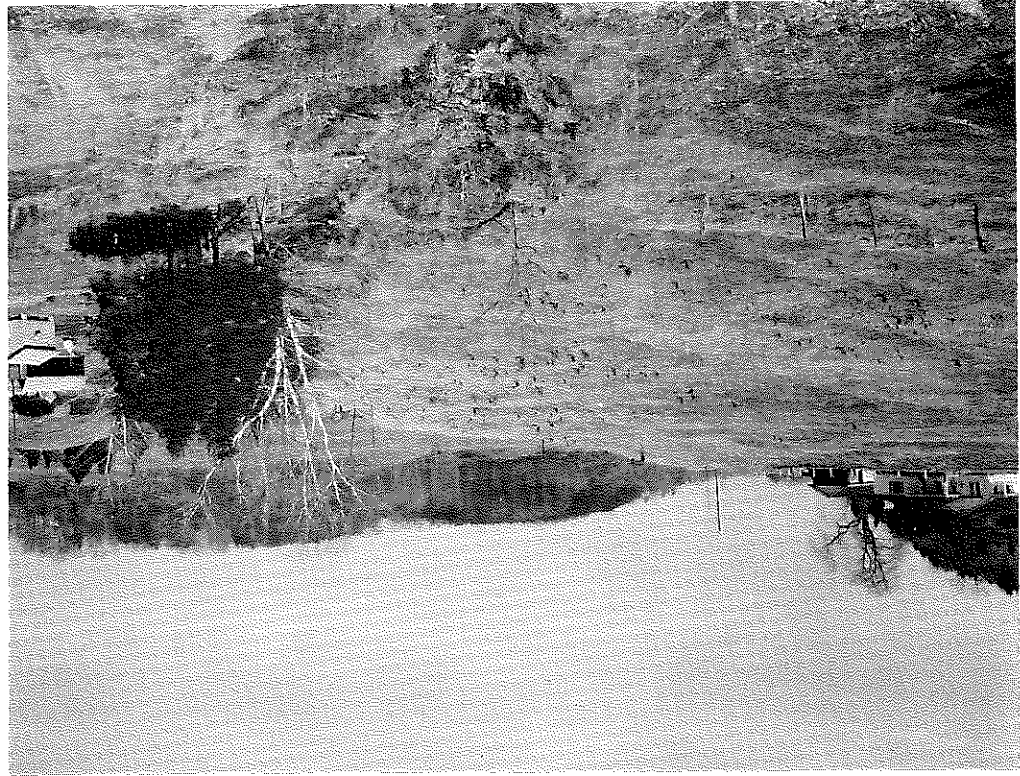
Shales of the Crab Orchard Formation, particularly the Estill Shale and Lulbegrud Shale members, and the Osgood Formation readily weather to very plastic clays that slump when moist. Shales of the Estill Member are particularly susceptible and small slumps and slides are noted even in natural slopes (see Figure 6). Construction on these clays should have suitable foundations and drainage, or the clay should be completely removed and replaced by stable material. Clay derived from the weathering of the Lulbegrud and Estill Members of the Crab Orchard Formation are suitable for the making of brick and drain tile. In Eastern Kentucky, the Crab Orchard Formation may yield small quantities of highly mineralized ( $\text{CaSO}_4$ ) water from wells in valley bottoms.

To indicate the extent to which the Crab Orchard and(or) the Osgood Formations are susceptible to slope instability, a number of case histories which have been observed during the past four or five years will be cited. In each of these instances it has been very definitely established, by reference to geologic and soils maps and reports and interviews with personnel of the U. S. Geological Survey and the Kentucky Geological Survey, that the materials involved in the unstable earth masses were of the Crab Orchard or Osgood Formations.

Because of the experience with the Crab Orchard and(or) the Osgood Formations, as illustrated by the following examples, it can be generally said that special engineering considerations should be involved in the design and construction of engineering facilities in areas where the materials are encountered. Since these particular formations often are exposed with a distinctive color of green or greenish-gray, it might in general be said that if the material is green, it should be wasted. Clays derived from the Crab Orchard are not suitable as fill material or as a foundation. To illustrate the importance of this, the following is quoted from "Geology of the Charters Quadrangle, Kentucky" by Robert H. Morris ( U. S. Geological Survey, 1965):

"...An unfavorable economic aspect of these clays, however, is their tendency to slide or slump, which in turn causes pavement failures in the roads.... The movement is generally by a series of almost imperceptible slips along ruptures over a long period of time, and it is likely to be increased during seasons of unusually heavy precipitation. Where the natural slope of the ground has been oversteepened during road building, slumping is more imminent and common...."

Figure 6. Slumps in Natural Slope in Estill Shale (KY 52, Estill County).



KY 52, Estill County  
SP-33-83, S 616(13)

The attention of the Division of Research was directed to a landslide, which was developing on KY 52 in Estill County approximately four miles west of Irving, by personnel of the Division of Construction. The Division of Research, as a part of its continuing studies of the occurrence of landslides in Kentucky, undertook a review of the situation in order to identify and delineate the geologic and soil formations involved in the unstable earth mass.

During the 1967 construction season (November, 1967), a slide began to develop near Station 241+00 on a side-hill fill situation. The fill was not particularly high, being only twenty feet at the deepest point (see Figure 7). However, the additional loading due to the fill was sufficient to cause significant movement, first noted in the original ground some 20 or 30 feet below the limits of construction, to develop in the foundation material (see Figure 8). Movement continued and construction in the immediate area was postponed. Movement of the unstable soil mass has continued and the slide now (February, 1968) extends at least from Station 239+00 to 254+00 (see Figures 9, 10 and 11).

A critical review of geologic maps for the Estill County area and interviews with the U. S. Geological Survey personnel working in that area revealed that the unstable material was a portion of the Crab Orchard Formation. The unstable material involved in the slide at Rice's Station is the Estill Shale Member, a yellowish-green to grayish-olive, thinly and evenly bedded shale which weathers very readily to plastic clays that slump when moist. X-ray analysis (see Figure 12) of the clays from the landslide site and several other points on KY 52 in the general vicinity indicate the presence of illite, chlorite, and some bentonite clays. Table 1 summarizes the engineering characteristics of the Estill Shale clays.

At the landslide site, the Estill Shale is overlain by the Boyle Dolomite. This dolomite can be seen outcropping in a cliff (see Figure 13) just to the north of the roadway construction and is the significant material contributing to the formation of the ridge to the north of the highway. Above the Boyle Dolomite is the New Albany Shale (also known as the Ohio Shale and the Chattanooga Shale), primarily a grayish-black shale 80 to 120 feet thick in the area (see Figure 14). The deep cut (Station 230) just to the west of the landslide site exposes the New Albany Shale and the Boyle Dolomite.

In places, the Estill Shale is underlain by the Waco Member, a shale and dolomite formation. The Waco may, in places, be sufficiently strong to



Figure 7. View of Landslide Site on  
KY 52, Estill County (December 1967).



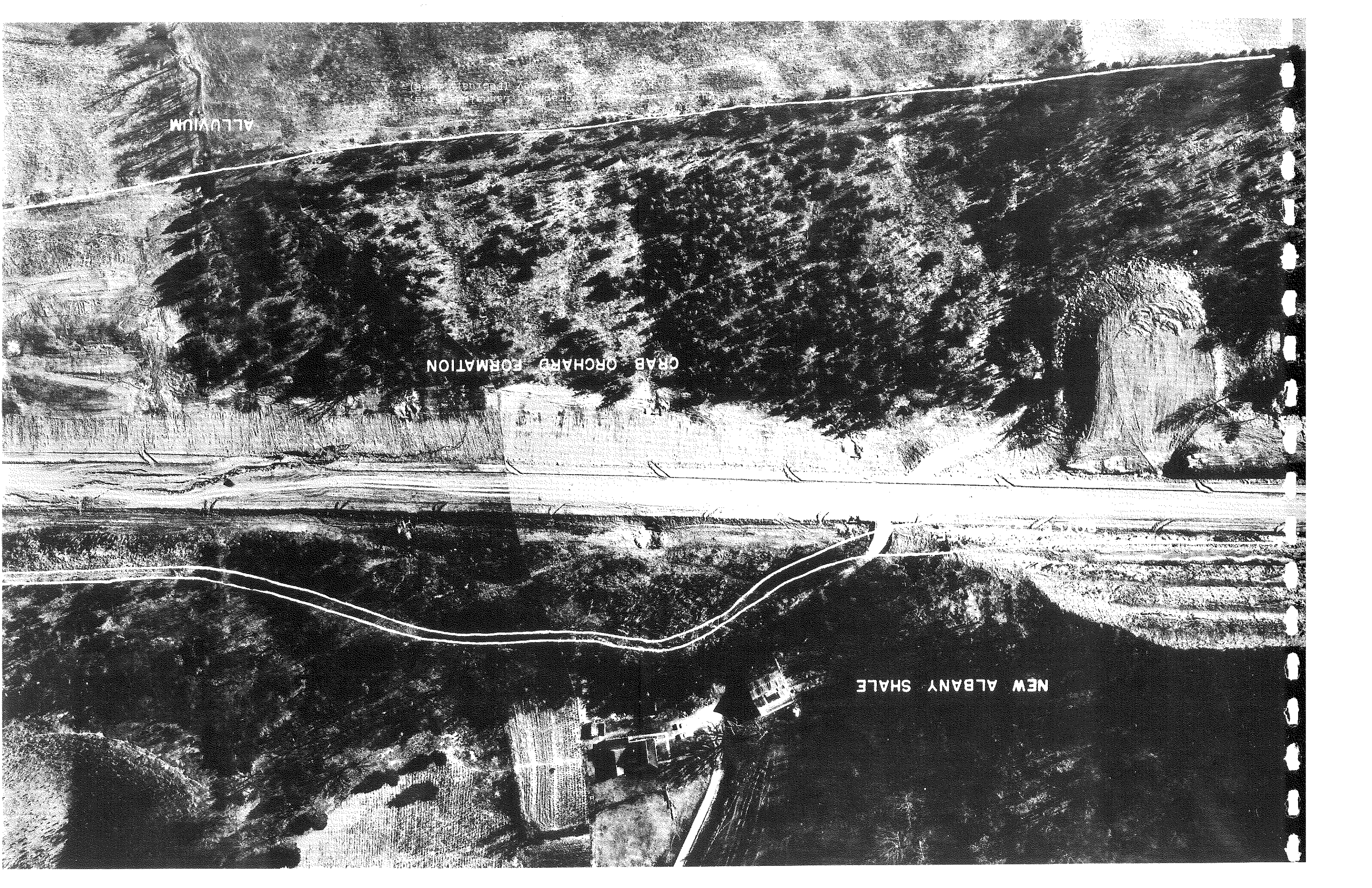
Figure 8. Distress in Embankment on  
KY 52, Estill County (December 1967).



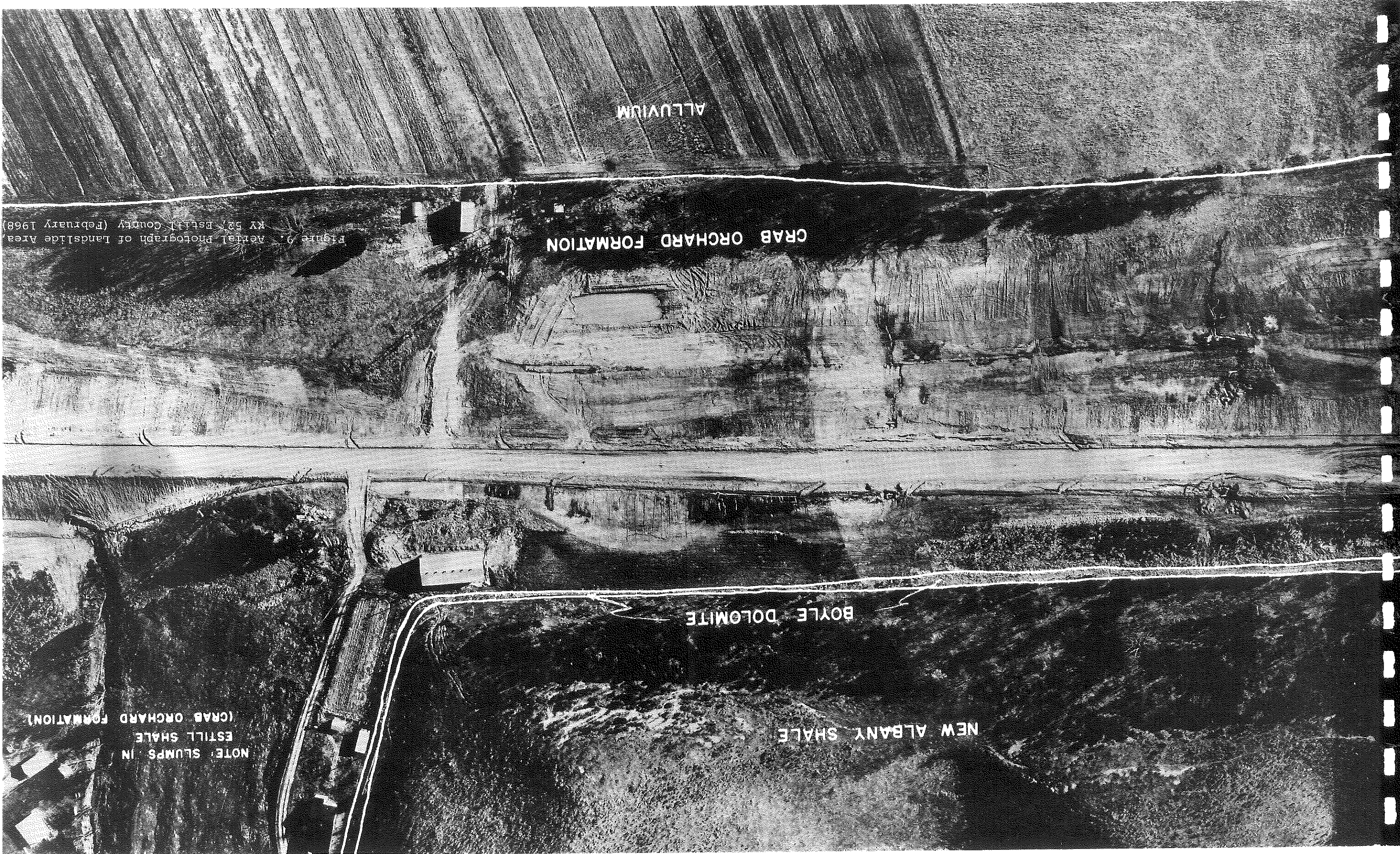
ALUVIUM

CRAB ORCHARD FORMATION

NEW ALBANY SHALE







ALLUVIUM

CRAB ORCHARD FORMATION

BOYLE DOLOMITE

NEW ALBANY SHALE

NOTE: SLUMPS IN  
ESTILL SHALE  
(CRAB ORCHARD FORMATION)

Figure 9. Aerial Photograph of Landslide Area  
KY 52, Estill County (February 1968)





Figure 10. Distress in Embankment on KY 52,  
Estill County (February 1968).



Figure 11. Distress in Embankment on KY 52,  
Estill County (February 1968).

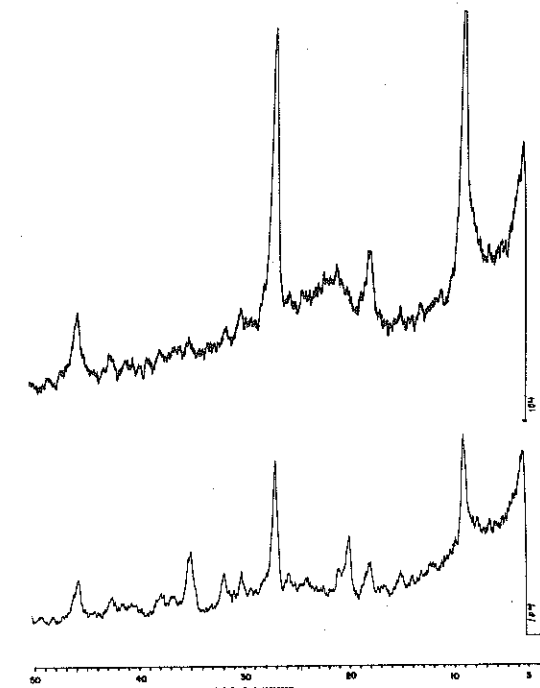


Figure 12. Typical X-Ray Diffraction Patterns of the Estill Shale.

Table 1. Summary of Engineering Characteristics of Estill Shale Clays

GRAIN SIZE DISTRIBUTION (ASTM D 422-63)		
Coarse Sand (-#10 sieve, +#40 sieve)		6%
Fine Sand (-#40 sieve, +0.05 mm)		10%
Silt (-0.05 mm, +0.005 mm)		32%
Clay (-0.005 mm)		52%
Colloids (-0.001 mm)		24%
ATTERBERG LIMITS (ASTM D 423-61T and D 424-59)		
Liquid Limit		47%
Plasticity Index		23%
SPECIFIC GRAVITY (ASTM D 854-58)		
		2.78
MOISTURE-DENSITY RELATIONSHIP (ASTM D 698-58T, Method A)		
Maximum Density	112 Pounds Per Cubic Foot	
Optimum Moisture Content	16.4%	
CBR (Kentucky Method)		
Minimum Laboratory CBR	0.4	
Dry Unit Weight After Compaction	119.7 Pounds Per Cubic Foot	
Moisture Content After Compaction	14.7%	
Dry Unit Weight After Swell	94.1 Pounds Per Cubic Foot	
Moisture Content After Swell	27.7%	
Percent Swell	20.6%	
CLASSIFICATIONS		
AASHTO		A-7-6(15)
Unified		CL
Textural (US Bureau of Soils and Mississippi River Commission)		Clay
MINERALOGY (X-Ray Diffraction)		
		Illite, Bentonite, Chlorite

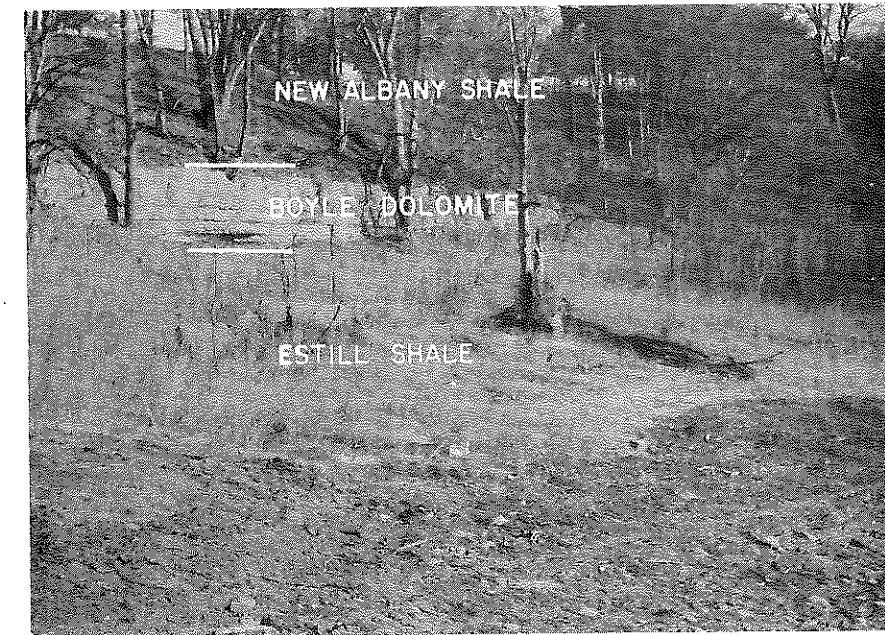


Figure 13. Cliffs of Boyle Dolomite on  
KY 52, Estill County.



Figure 14. Exposures of Estill Shale, Boyle  
Dolomite, and New Albany Shale  
(Ohio Shale or Chattanooga Shale)  
on KY 52, Estill County.

support a highway. However, it should be pointed out that the Waco Member is often missing entirely. The Lubegrud Shale Member underlies the Waco and, in the absence of the Waco, lies directly under the Estill Shale. The Lubegrud is just as bad a material as the Estill and thus the highway at this particular site is probably located over plastic and swelling clays, all which may be as thick as 60 to 80 feet at the landslide site.

It is interesting to note that extensive areas of the ridges lying to the west of Irvine are covered by the Irvine Formation, a terrace deposit of silt, clay, sand, gravel, sandstone, and conglomerate. Along the route of KY 52, where it cuts the ridge tops, significant quantities and depths of the reddish-brown sand are encountered. At places there has been significant drainage of water from these sands and it is anticipated that the cut slopes will be highly susceptible to surface and groundwater erosion.

The alluvial clays which occur in the Irvine Formation, the Quarternary terrace deposits of the Kentucky River and its tributaries, are often suitable for pottery making. This clay occurs as lenses that are interbedded with impure clays, silt and sand. Much of the clay forming from the Estill Shale and the Lubegrud Shale of the Crab Orchard Formation is suitable for making bricks.

Statements from the recently published geologic maps for the general area indicate that numerous small, soft water springs are often observed in the Irvine Formation. It has also been noted that perennial springs are particularly common at or near the base of the Boyle Dolomite. Remember that the Boyle Dolomite is underlain by the Estill Shale, the unstable material which is causing the slide.

It is extremely unfortunate that the centerline of the relocation of KY 52 parallels the strike of the outcrops of the Estill Shale for approximately one to two miles in the landslide area. The shale is so unstable that landslides often occur in the natural slopes. The minimum amount of construction activity in the material is sure to result in some difficulties in the future. Since the undesirable materials are so thick in the area, the most feasible method of minimizing landslide occurrences and to correct the existing ones is to relocate the highway in such a way that the poor materials are crossed as quickly as possible and in such ways that earth movements are minimized. This suggests a relocation of the highway, crossing the Estill Shale at right angles to its strike, and placing the highway in the "V" of the stream valleys.

Bluegrass Parkway, Mile Post 20  
Nelson County

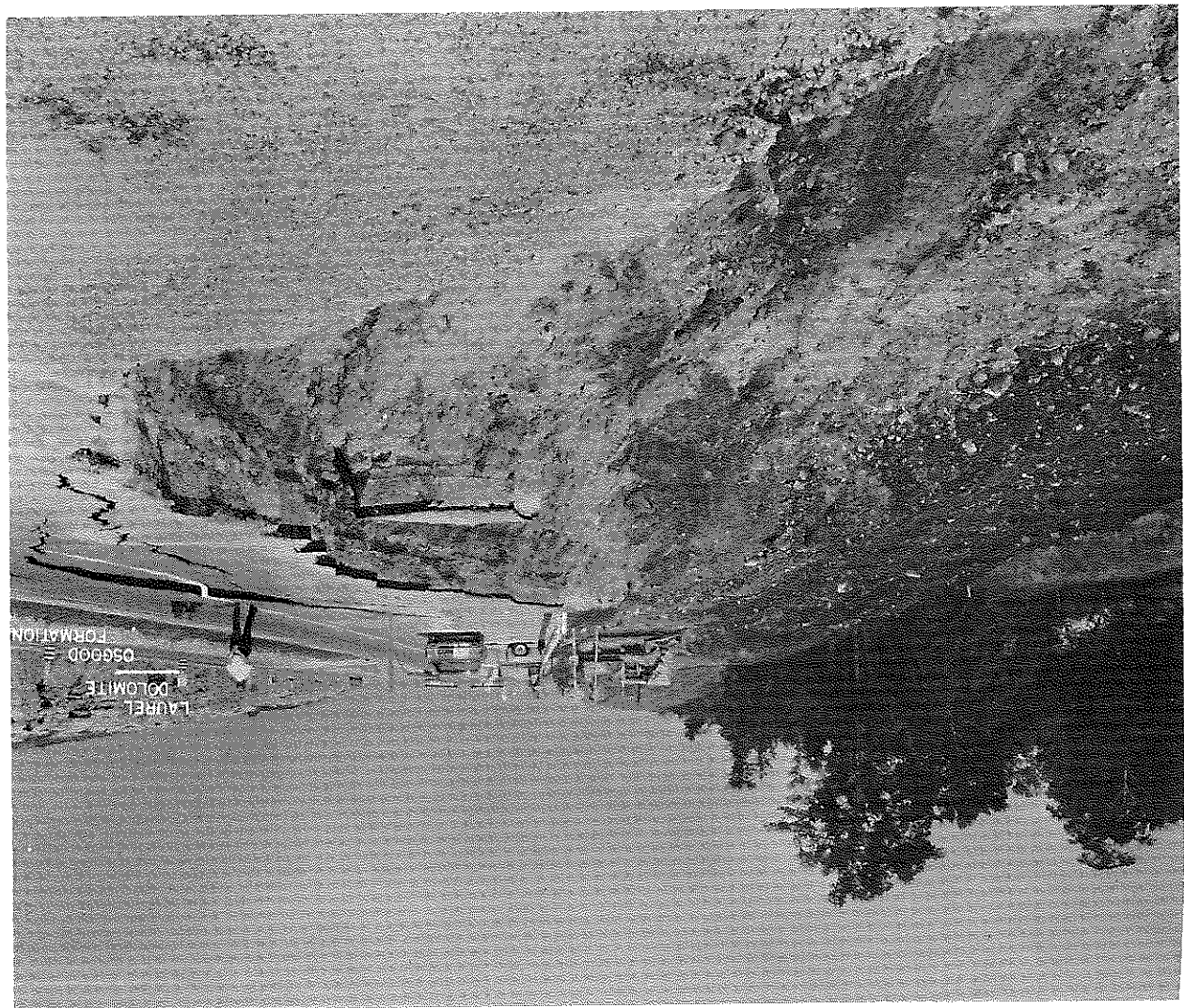
Just prior to the completion of construction, a slide occurred in the eastbound lane of the Bluegrass Parkway approximately 1.5 miles west of the US 31E interchange. The pavement, which was damaged, was patched just before the Parkway was opened to traffic. Movement continued in this area until the eastbound lanes had to be closed to traffic. A detailed discussion of the site and of the corrective measures have been reported previously ("Stability Analyses of Earth Masses" by R. C. Deen, G. D. Scott, and W. W. McGraw, September, 1966).

It is interesting to note that two other slips have occurred on the Bluegrass Parkway within two miles of the US 31E interchange. Both of these slips, as the one at Mile Post 20 described above, first occurred during the construction period, and the material was removed and replaced at that time. Since the Parkway has been opened to traffic, there has been no serious inconvenience to the public at these two slides. However, there has been indications of continuing movement manifested by cracked shoulders and settlement of the guardrails and the pavement.

The material involved in the unstable masses at three landslide sites have been identified as portions of the Osgood Formation. These landslide sites are side-hill cut-fill sections. Outcrops of the thinly bedded Osgood Shales (Figure 15), known to be paths along which subsurface water seeps, have been covered with the embankment portion of the section. It is felt that subsurface seepage has been dammed by the embankment--the embankment becoming saturated and loosing strength and therefore slipping down the original slope. It should be pointed out that the original material was also extremely weak and had tendencies within itself to become unstable and to slip down slope when wet.



Figure 15. View of Slide Area, Looking West, at Mile Post 20 in Late July, 1966.



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KY 89, Clark County

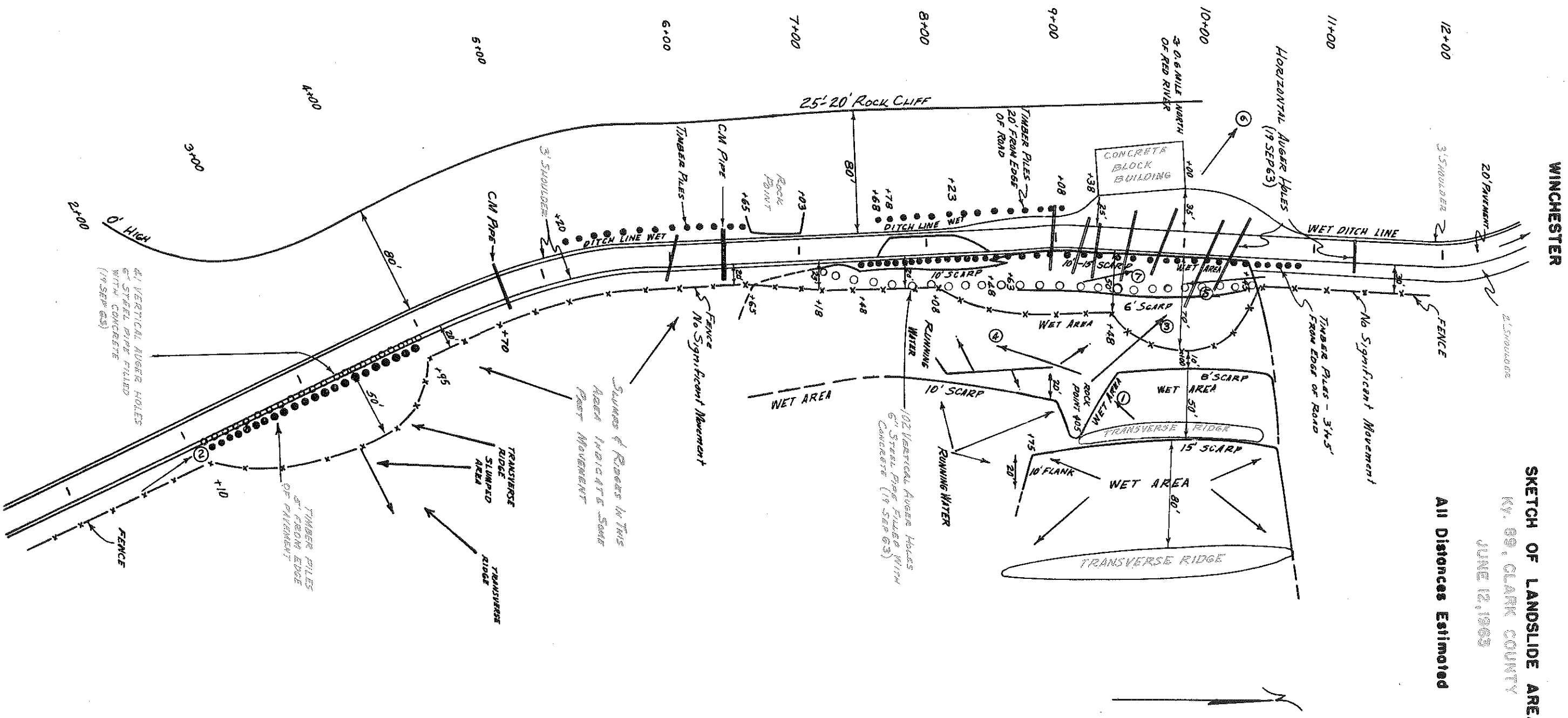
A large landslide, which has been causing difficulty for the Maintenance Division for several years, is located on KY 89 in Clark County, approximately 0.6 miles north of the Clark-Estill County line (Red River). This particular landslide was brought to the attention of the Division of Research by the Maintenance Division in early summer, 1963. A sketch (see Figure 16) of the landslide area made on June 12, 1963, illustrates the extent of this slide, probably one of the largest to be observed in the area. The slide is located on a steep slope above the point where the Red River approaches most closely KY 89. The extent of lateral displacement, for example, is illustrated in the sketch by the movements of the fence lines (see Figures 17 through 21).

A review of geologic maps and reports indicate that the location of KY 89 in this particular area parallels the outcrops of and is located on the Estill Shale, a member of the Crab Orchard Formation. To the west of and paralleling the roadway is a 20- to 25-foot cliff formed by the Boyle Dolomite (see Figure 22). Above this dolomite and forming the rounded portion of the ridge is the New Albany Shale. At the foot of the Boyle Dolomite cliff are the gentle slopes formed by the Estill Shale. This slope steepens significantly to the east of the roadway as the topography drops sharply to the Red River valley. The highway through this particular location is a side-hill cut-fill section and the construction activity was probably sufficient to initiate significant movements in the area. It should be pointed out, however, that there are indications that the natural slope in the area had been moving for a long time. During different inspections of the site, there had been numerous indications of large amounts of seepage water, which of course contributes to a loss of stability of the material.

Again, it is interesting to note that the development of major distress in a highway location was observed where the highway crossed the Estill Shale more or less parallel to its outcropping. A study of the location of KY 89 from Winchester to Irving has a lesson to teach. The route of KY 89 between these two termini crosses into and out of the Crab Orchard Formation throughout the entire length. The only area in which significant landslide difficulties have been encountered is the site approximately 0.6 miles north of the Red River. At other places where the highway must cross the Estill Shale, it is noted that it crosses more or less at right angles to the strike of the beds and, more often as not, is located in the bottom of the "V" of the valleys, where the highway construction is more or less "wedged in" (see Figure 23).

In September 1963, the Division of Maintenance installed a number of concrete-filled, 6-inch steel pipe piles in the slide area in Clark County (see Figure 24). These piles were placed to depths of some 60 to 80 feet and apparently penetrated into stable material sufficiently to stabilize the slope. According to comments made by local people in February 1968, there has been no significant movement of the area for a couple of years.

Figure 16. Sketch of Landslide Area, KY 89, Clark County



WINCHESTER

SKETCH OF LANDSLIDE AREA

KY. 89, CLARK COUNTY

JUNE 12, 1963

All Distances Estimated





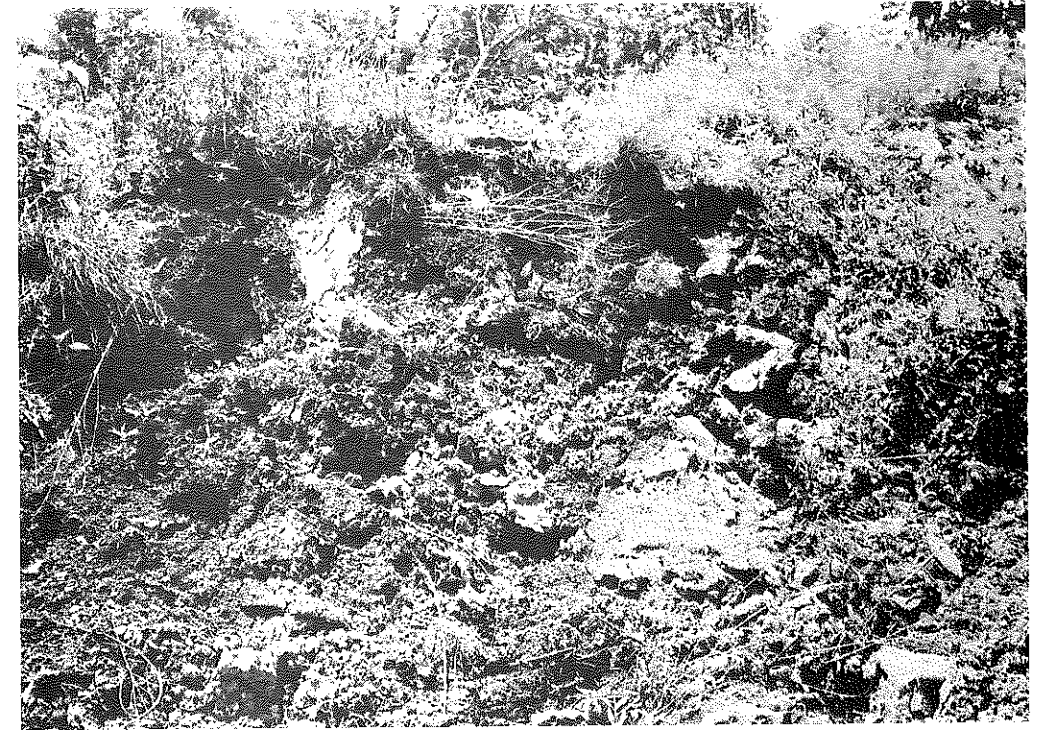


Figure 17. Photograph 1 (See Figure 15) Showing Saturated Slope Material, KY 89, Clark County.



Figure 18. Photograph 2 (See Figure 15) of Slide Area, KY 89, Clark County.



Figure 19. Photograph 3 (See Figure 15) of Slide Area, KY 89, Clark County.

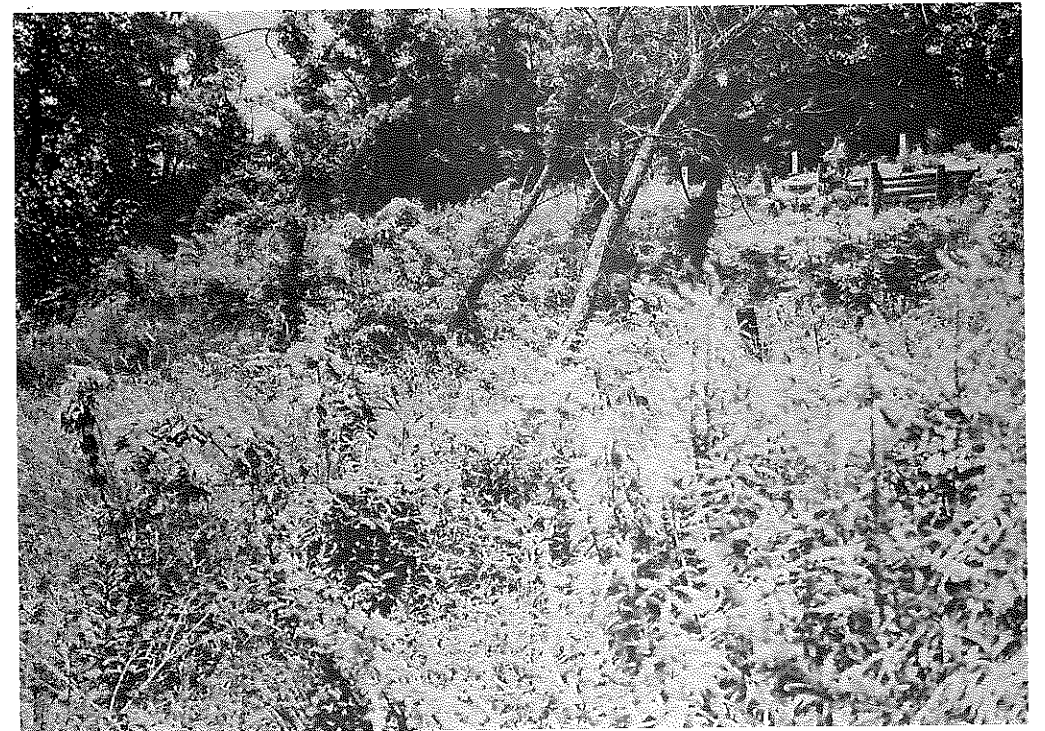


Figure 20. Photograph 4 (See Figure 15) of Slide Area, KY 89, Clark County.



Figure 21. Photograph 5 (See Figure 15) of Slide Area, KY 89, Clark County.

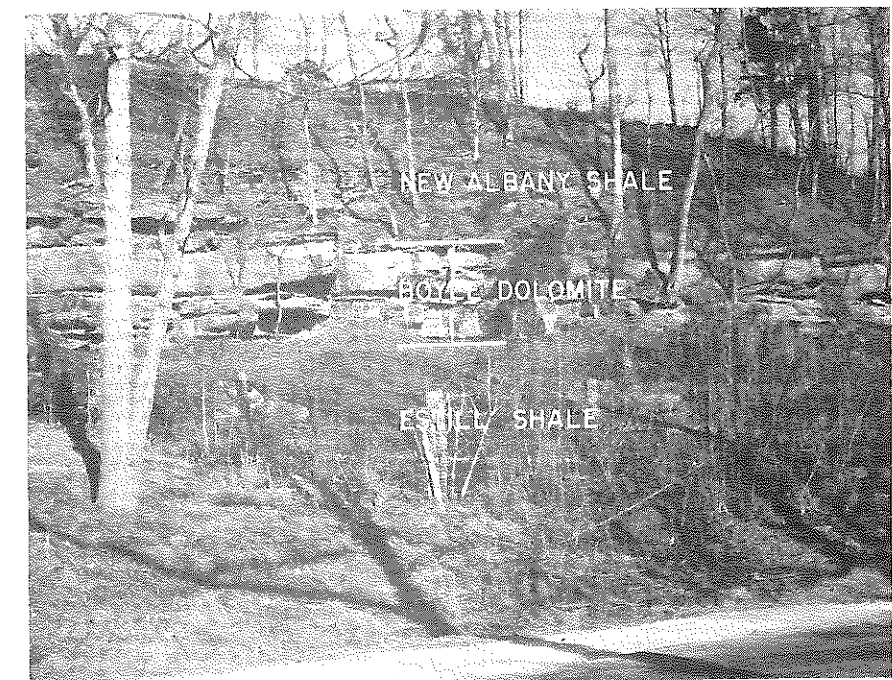


Figure 22. Boyle Dolomite Cliff, KY 89, Clark County, Photograph 6 (See Figure 15).



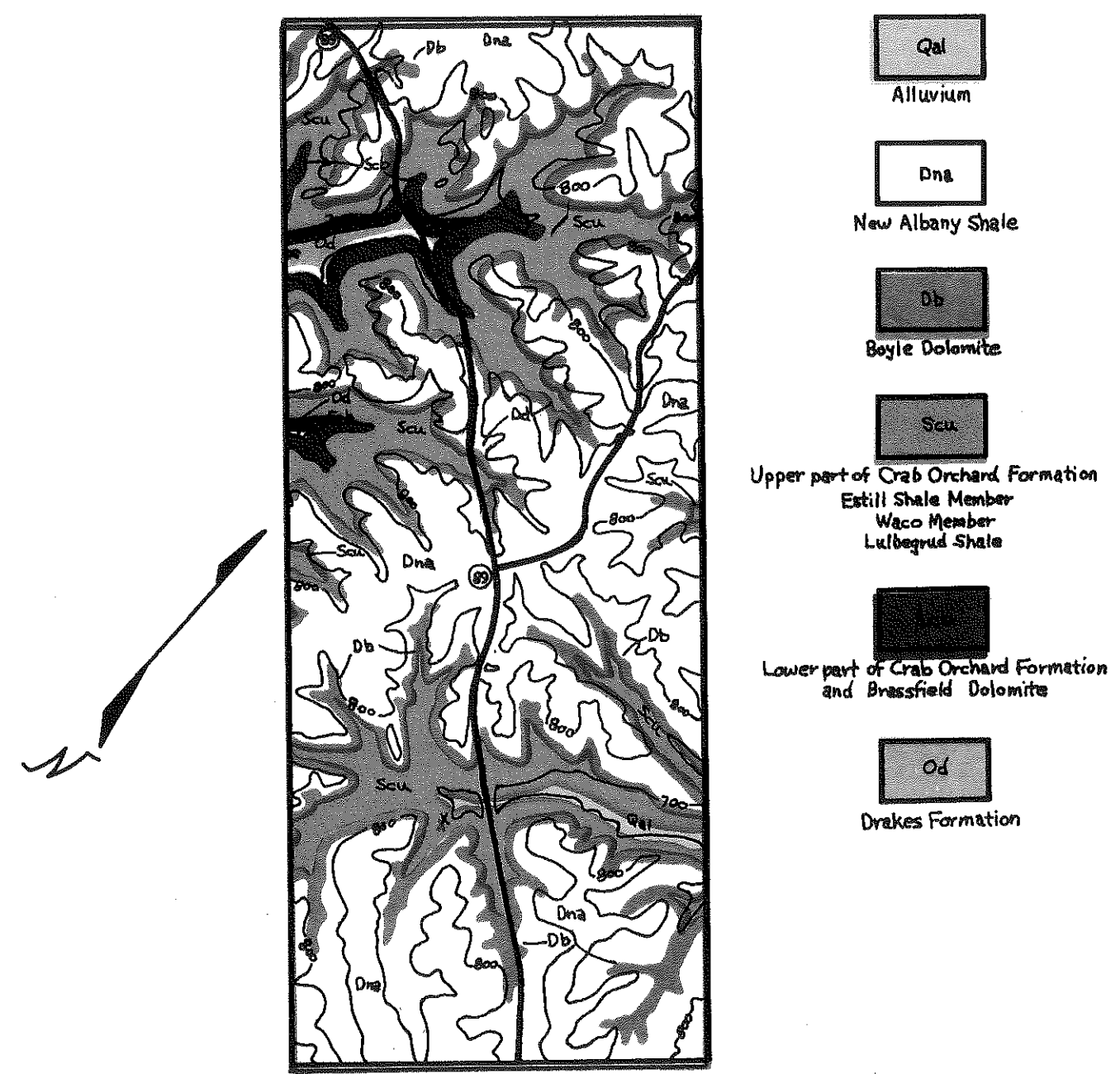


Figure 23. Illustration of Most Advantageous Location of Highways in Estill Shale.

Figure 24. Concrete-Filled Pipe in Place, KY 89,  
Clark County, Photograph 7 (See Figure 15).



Significant difficulties were encountered with slides during the construction of KY 1840 in the area where it junctions with KY 89, approximately 1-1/2 miles north of Irving. This county road was built along a line parallel to the contours of the ridge and more or less parallel to the outcrops of the Estill Shale. The road was built at the base of the Boyle Dolomite cliff which was overlain by the New Albany Shale (see Figure 25).

In order to correct the landslide situation, the location of the road was abandoned and relocated in the bottom of the "V" of the small valley between the two ridges. Even though the roadway crossed the Estill Shale, this particular location was the most advantageous. The crossing is made at right angles to the strike of the outcropping and the roadway is "wedged in" the bottom of the small valley. In this manner, the likelihood of a landslide was minimized. To date (February 1968) there has been no significant difficulty with the relocated section of KY 1840 where it crosses the Estill Shale.



Figure 25. Landslide Area, KY 1840, Estill County.

Mountain Parkway, Clark County

The Division of Research has been observing a slide on the Mountain Parkway in Clark County between Stations 633+00 and 635+00 in conjunction with research on methods of tracing seepage water in unstable slopes. The slide is located on a short fill section near the Powell County line. Soon after the project was opened to traffic, a 50-foot section of the right (eastbound) shoulder subsided slightly (see Figures 26 and 27). Since that time the area of subsidence has increased during periods of wet weather so that both right (eastbound) traffic lanes, and to a lesser extent the left (westbound) traffic lanes, have been involved. Maintenance operations have included mudjacking and patching to maintain the proper grade.

During all the inspections of the landslide site, numerous areas of significant groundwater seepage were noted in the fill area. A suspected source of this water was thought to be water coming down the ditches and rock subsurface through the cut to the west of the site. In September 1966, hydrated lime was placed just below the ground surface at the median inlet and two ditch inlets at Station 625+00, where water was observed disappearing into the ground. Water samples were obtained from drill holes, which had been installed during the summers of 1965 and 1966, at frequent intervals over a period of several months and tested in the laboratory for ph, conductivity, calcium content, etc. Analyses of these water samples did not indicate any change due to the lime, indicating that the suspected source of seepage was not actually a major factor and that this water probably finds its way to the spring box at Station 631+80, which, as indicated by the large flow, is functioning properly. With the most obvious source being eliminated as a prime suspect, observations of water elevations in the drill holes were made at frequent intervals for several months in an effort to detect other possible sources of seepage water into the slide area. The results of this data are presented in the form of water-table contours in Figure 28. These water-table contours show a mound of groundwater between Stations 633+50 and 634+00 and extending the entire width of the roadway. The contours indicate that the water is draining from the embankment in a southerly direction. The groundwater low point is in the eastbound lane at Station 633+00, which places the drainage outlet in the vicinity of the 48-inch concrete culvert. Water was noted to be continually entering the culvert through the tops of open joints, a further indication that the culvert serves as an outlet.

The water appears to be entering the unstable embankment from the east. To the northeast about 100 feet is a pond with water at a normal pool elevation of 705 feet. Thus, the pond is a likely source of seepage and should be drained. It is possible, however, that the pond is not the source of seepage but, rather both the pond and the embankment may be feed by

SKETCH OF LANDSLIDE AREA

MOUNTAIN PARKWAY  
CLARK COUNTY

JUNE 17, 1963

All Distances Estimated

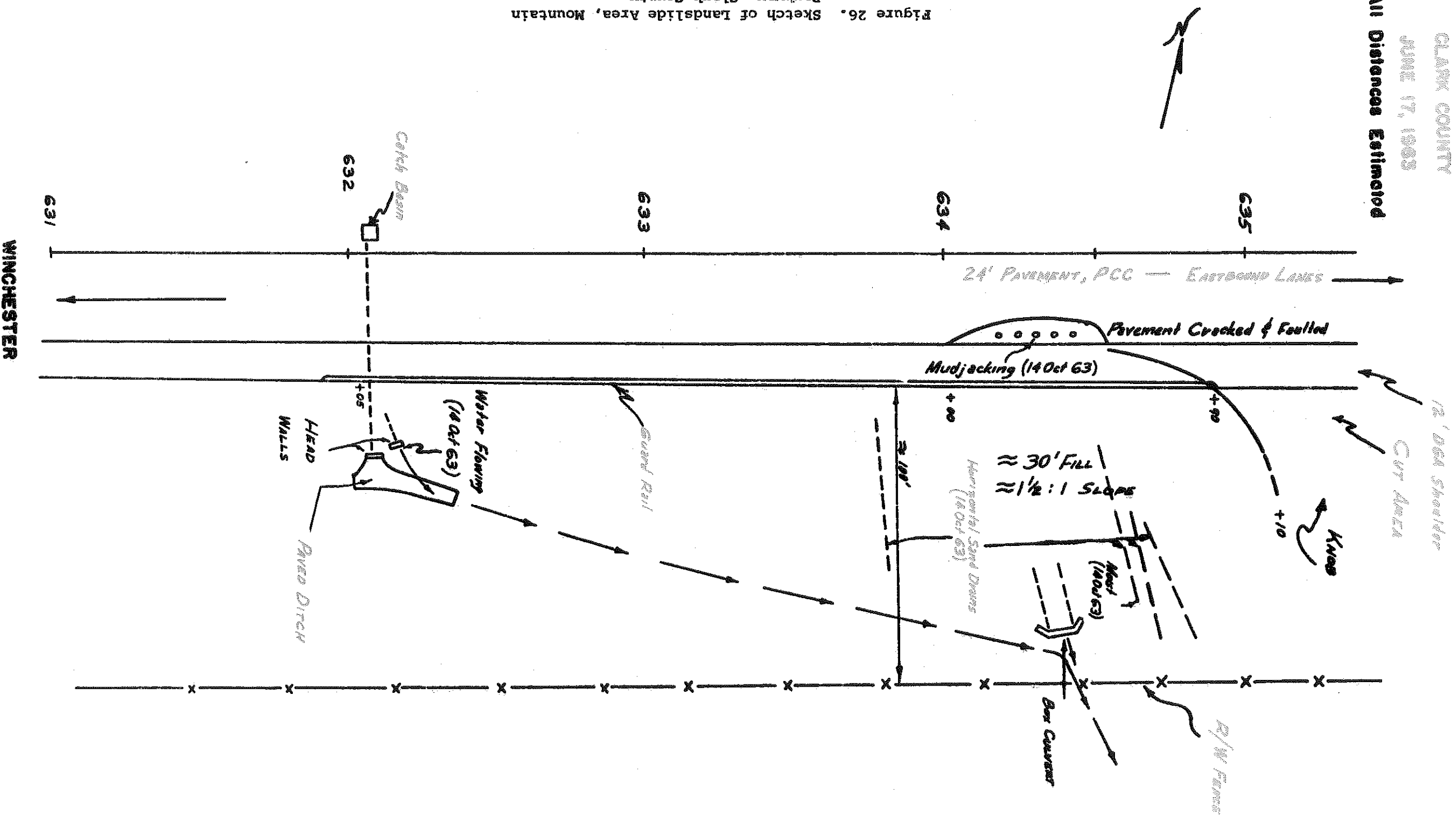


Figure 26. Sketch of Landslide Area, Mountain Parkway, Clark County.



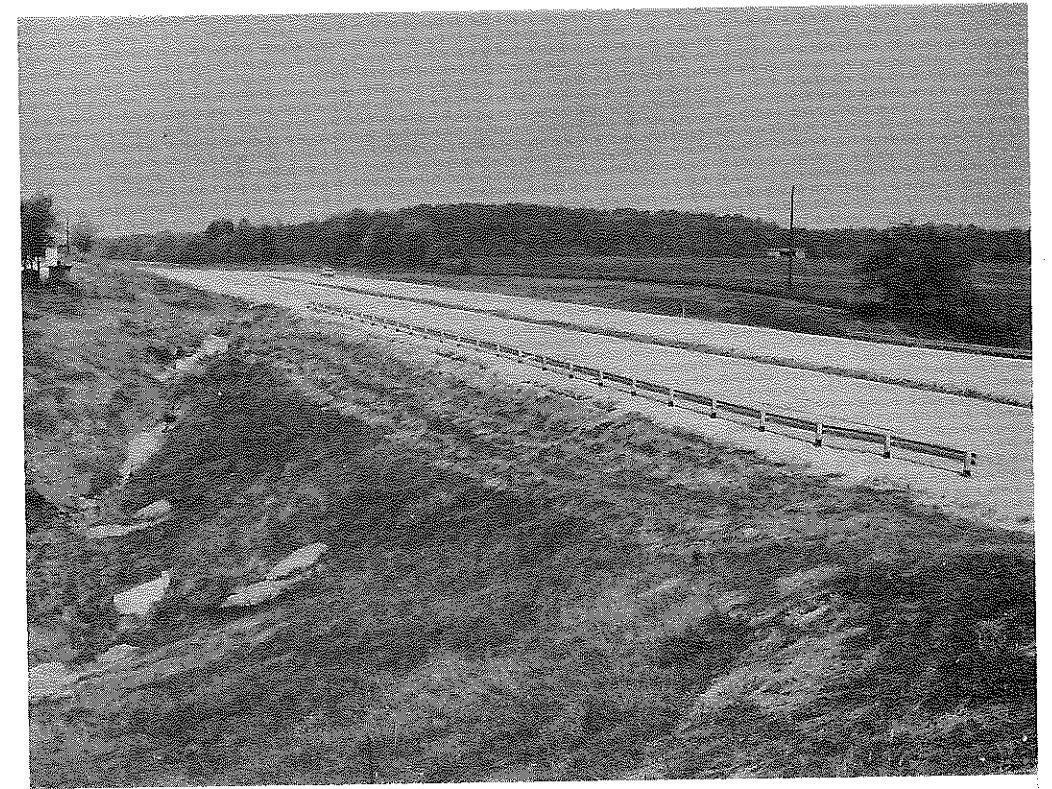


Figure 27. Landslide Area, Mountain Parkway,  
Clark County.

groundwater. Regardless of the ultimate source, it is likely that an interceptor trench about 10 feet deep and extending from approximately Stations 633+50 to 635+00 in the left ditch line would cut off the flow of water to the fill. Such a ditch 10 feet deep would have its bottom near elevation 700 which is well below the top of a green shale, thought to act as a barrier to the vertical seepage.

The embankment is founded on a greenish shale which weathers readily into a plastic clay. The green shale appears to be 15 to 20 feet thick in the vicinity of the slide with its top at an elevation of 705 feet. This green shale is mapped geologically in the area as the upper part of the Crab Orchard Formation. The New Albany Shale (also known as the Ohio Shale and the Chattanooga Shale) is observed (see Figure 29) on the ridge tops above an elevation of approximately 715 feet. Between the black shale and the green shale of the Crab Orchard Formation are layers ranging from dolomite to a sandy limestone. The lower part of the layer is composed of a hard limestone bioclastic over a cherty limestone, both about eight inches thick. These are probably the Bisher Limestone and the Boyle Dolomite. The top portion of the layer is a sandy limestone, which is thought to be the Duffin layer, a massive sandy, gray dolomitic limestone. This particular layer is often found interbedded with the basal 9 to 15 feet of the New Albany Shale and for this reason is often regarded as the basal member of the New Albany Shale rather than a part of the Boyle Dolomite. The geologic strata in the vicinity of the slide apparently dip slightly from the southeast to the northwest (to the direction of decreasing stations).

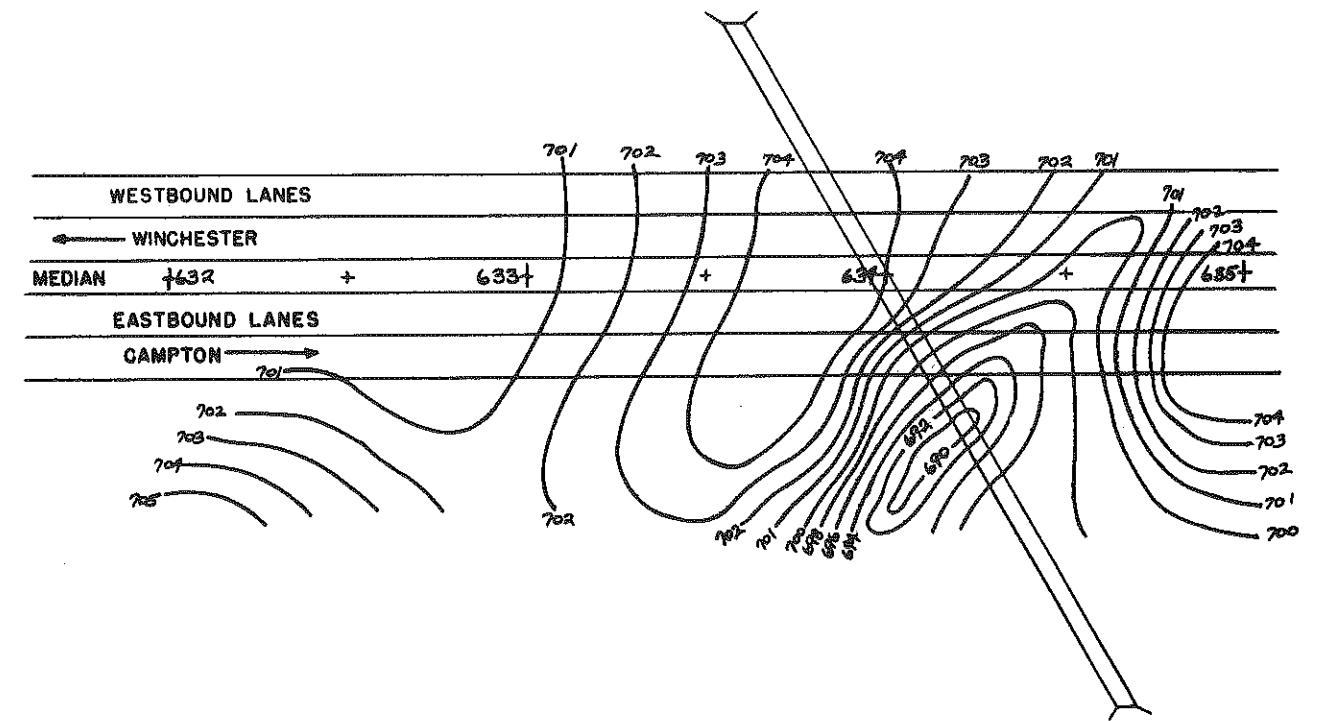


Figure 28. Water-Table Contour Map of Slide Area, Mountain Parkway, Clark County.



Figure 29. Slide Area, Mountain Parkway, Clark County.

KY 10, Lewis County

KY 10 in Lewis County traverses another area of the state in which the Crab Orchard Formation outcrops extensively. KY 10, from the vicinity of Tollesboro to Clarksburg, lies almost entirely in the upper portion of the Crab Orchard Formation. In an area with a radius of approximately two miles around Tollesboro, the upper portion of the Crab Orchard Formation is the only material which outcrops except in the lower reaches of some of the small stream valleys. The outcrop of the Crab Orchard Formation, particularly, the upper portion, occurs in a topographic region of very little relief, the area being relatively flat (see Figure 30). This probably explains the relative success of highway construction in this area. Even though the roadway of KY 10 is founded almost entirely upon the Estill Shale of the Crab Orchard, there appears to have been very little difficulty in the area with slides simply because the area is flat and there is therefore no opportunity for landslides to develop. Eastward from Cabin Creek, the relief becomes significantly greater. Many of the hilltops (Knobs) are capped by the Bisher Limestone; the higher Knobs are capped by the Ohio Shale (see Figure 31) and occasionally by the Berea Sandstone (see Figures 32 and 33). The performance of KY 10 from Cabin Creek to Clarksburg is relatively satisfactory even though the relief is somewhat greater. However, the satisfactory performance may be due to the location of the highway on the very lowest outcroppings of the Estill Shales where the slopes again are relatively flat. It is interesting to note, however, that where the new location of KY 10 crosses Herron Hill, there have occurred three small landslides within a length somewhat less than one mile. It is noted that the new location of KY 10 in this area is much higher upon the slopes where the outcrops of the Estill Shale are much steeper and therefore the likelihood of landslides is increased. The old location of the highway is lower in the valleys and often on the alluvium plains of Bethel Creek and Little Branch.

References to clays of the Crab Orchard Formation in recent geological reports for the area indicate that such clays may be useful as lining material for farm ponds where leakage through porous soils or slow seepage through bedrock is a problem. Clays from the upper portion of the Crab Orchard Formation and the lower 10 to 15 feet of the Borden Formation have also been indicated as being possibly suitable for the manufacture of common brick and tile. Geologic reports further point out that material of the Crab Orchard Formation has a low permeability and springs are common at the upper contact. It further states that the material is unstable even on low slopes and that numerous landslides have been observed in roadway cuts.

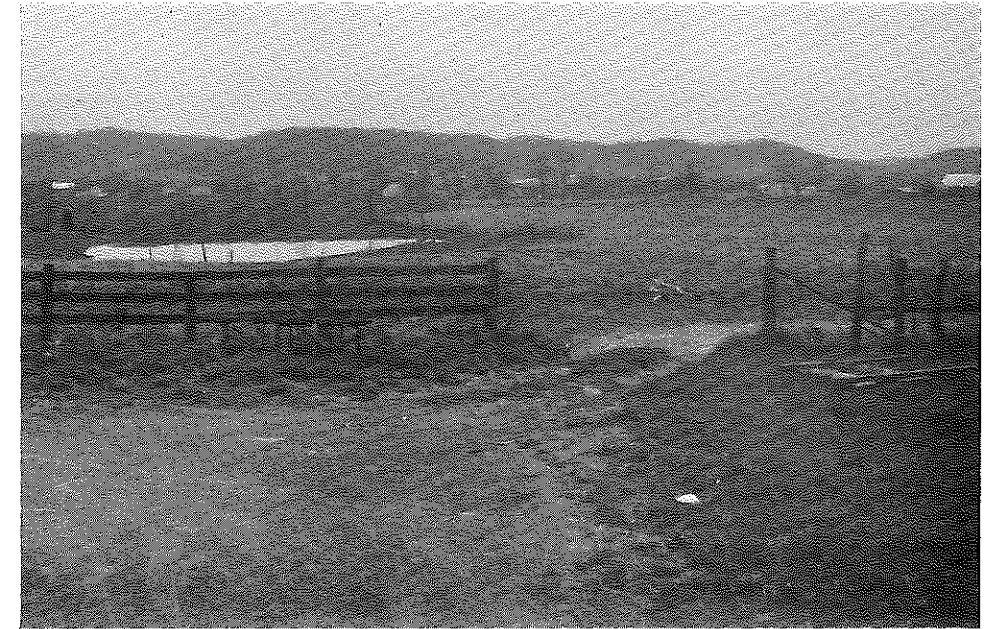


Figure 30. View of Crab Orchard Outcropping in Vicinity of Tollesboro. Note Ohio Black Shale Knobs in Background.

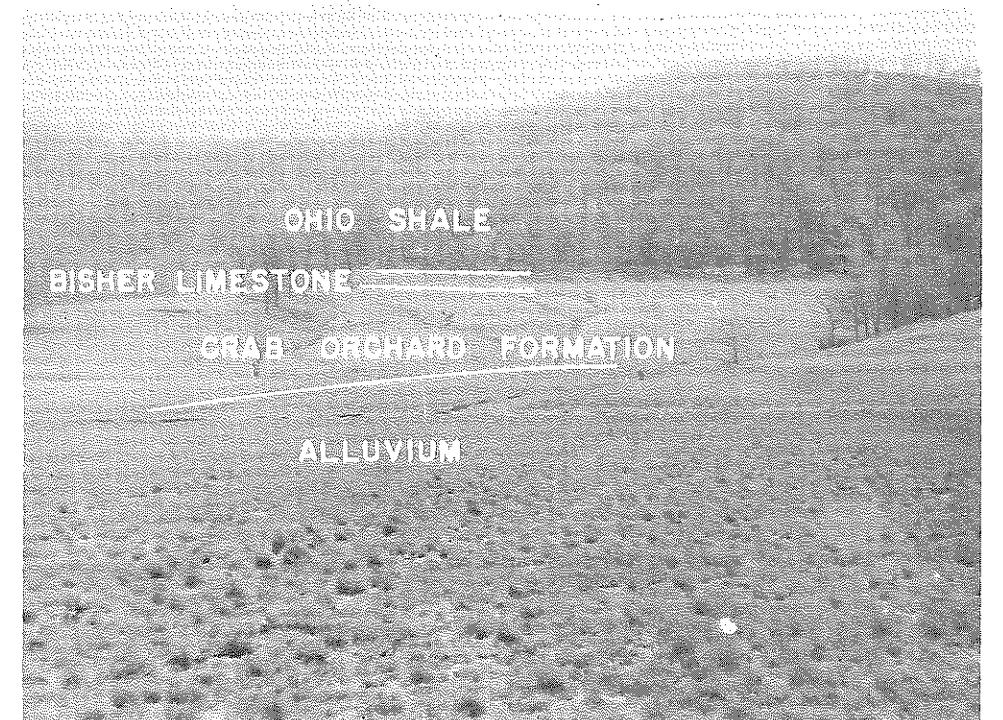
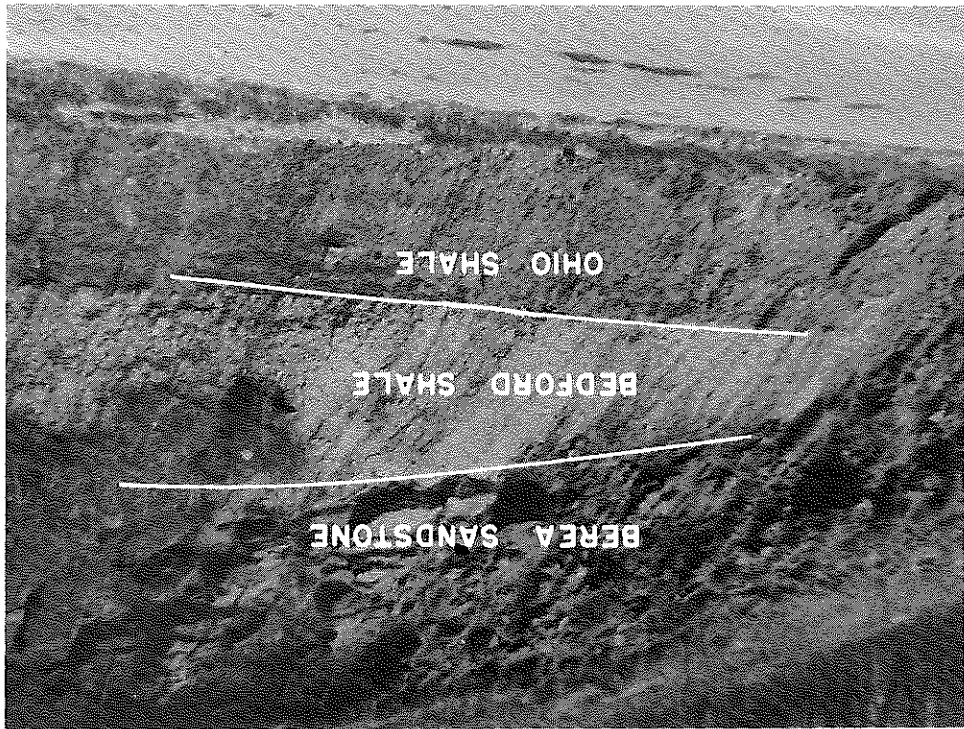


Figure 31. View of Bethel Creek Valley.



Figure 32. Outcrop of Berea Sandstone at Herron Hill.



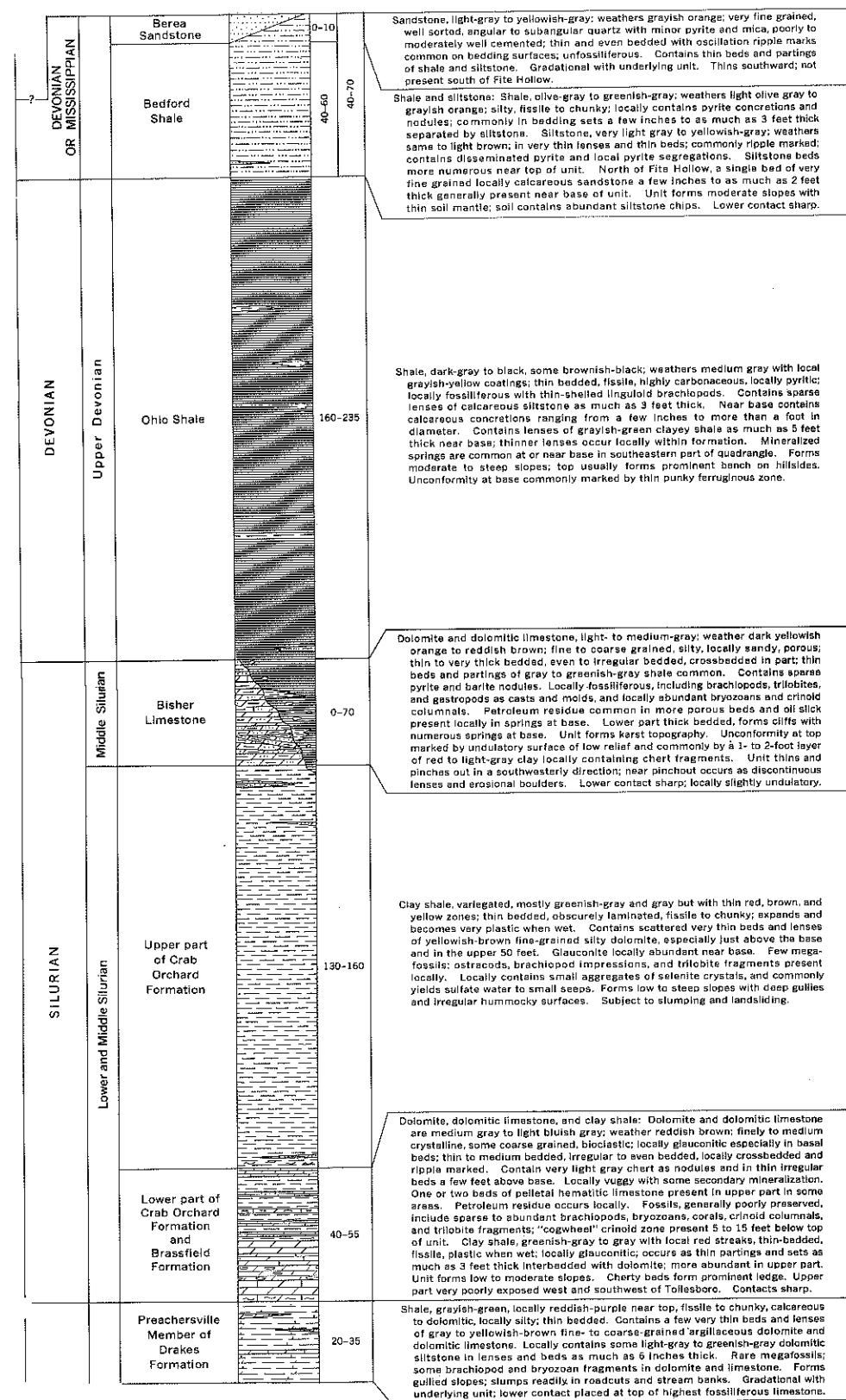


Figure 33. Columnar Section for Lewis County, Kentucky. (from "Geologic Map of the Tollesboro Quadrangle, Lewis and Fleming Counties, Kentucky," J.H. Peck, U.S. Geological Survey, 1967).