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ABSTRACT

This field guide is the basis for a five-day, 1000-mile trip through six states and six geomorphic provinces. The trip and the pre- and post-trip exercises included in the guide constitute a three credit course at The Ohio State University entitled "Field Geology for Science Teachers." The purpose of the trip is to study the regional geology, which ranges from Quaternary glacial deposits through a folded and faulted Paleozoic terrane to an igneous and metamorphic terrane. Study of geomorphological features and the application of geomorphology to aid in understanding the geology are also important objectives of the field trip. The trip also provides the opportunity to observe and study relationships between the geology of an area, its natural resources, and the culture and life styles of the inhabitants. For teachers participating in the trip, it demonstrates the advantages of teaching a subject like geology in the field and the nature of field evidence. In addition to a road log and stop descriptions, the guide includes a very brief introduction to the geology of the Appalachian Highlands and the Interior Plains, a review of geological terms, concepts, and techniques, and notes on preparing for and running field trips. (JN)

FIELD GUIDE TO THE GEOLOGY OF PARTS OF THE APPALACHIAN HIGHLANDS AND ADJACENT INTERIOR PLAINS

by

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Dedicated to

Dr. Robert L. Bates who
developed the Appalachian Field Trip.

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PREFACE

This field guide is the basis for a 5-day, 1000-mile field trip through six states and six geomorphic provinces. The trip and the pre- and post-trip exercises constitute a three credit-hour course at The Ohio State University entitled "Field Geology for Science Teachers."

The main purpose of the trip is to study the regional geology, which ranges from Quaternary glacial deposits through a folded and faulted Paleozoic terrane to an igneous and metamorphic terrane. Study of geomorphological features and the application of geomorphology to aid in understanding the geology are also important objectives of the field trip.

This field trip course was developed in the early 1960s by Professor R. L. Bates and his colleagues in the Department of Geology for teachers participating in a National Science Foundation sponsored Academic Year Institute. The course was conducted annually from 1961 to 1971, after which NSF support was no longer available. Since 1973, it has most often been offered in alternate years by Professors G. D. McKenzie and R. O. Utgard of the Department of Geology and Mineralogy. Most of the participants in the last decade have been in-service teachers or students in science education. Some students in Natural Resources and some with a minor in Geology have also taken the course to provide important field experience in a wide range of geological environments.

The field trip also provides the opportunity to observe and study relationships between the geology of an area, its natural resources, and the culture and life styles of the inhabitants. For teachers participating in the trip, it demonstrates the advantages of teaching a field-based subject in the field and the nature of field evidence. Teachers also benefit from the opportunity to collect samples and do field exercises, both of use in their own courses.

The usual requirements for students include pre-trip discussions with assignments and exercises on general and Appalachian geology, completion of a field-mapping problem, and completion of related short exercises during the trip. Also required is a field-trip log describing the stops, concepts, and main ideas in a fashion that would be useful for future trips.

In addition to the road log and stop descriptions, the guide includes a very brief introduction to the geology of the Appalachian Highlands and the Interior Plains, a review of geologic terms, concepts and techniques, and notes on preparing for and running field trips. These additional materials should be of particular use to those who have never been on a field trip and to those with limited course work in the earth sciences.

Although the guide was prepared for students with only one or two courses in geology, it could be used by more advanced students, including graduate students, on a similar trip. For advanced students some stops could be omitted providing more time for discussion at other stops. More advanced exercises than those that we use in the field might also be appropriate for this group.

Garry McKenzie
Russell Utgard

Columbus, Ohio
February, 1985

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ACKNOWLEDGMENTS

We are indebted to the geologists who have provided, over many years, the current understanding of the geology of these provinces. They are too numerous to mention; however, many are cited in the references. We also thank Bob Bates for introducing us to the trip and providing a copy of his field guide. Other colleagues, Vic Mayer and Doug Pride and students, have worked with us on this and similar trips and we have benefited from their ideas, suggestions and reference materials. Stig Bergstrom and R. A. Davis kindly provided information on the Ordovician near Maysville. C. E. Corbato and G. E. Moore advised on map symbols and rock classification, respectively. We are grateful to those who have given permission for access to outcrops and sites: West Virginia Turnpike Commission, Mt. Airy Granite Corporation (David Vernon), Appalachian Power Company and the staff of the John Amos Power Plant (LeRoy Balding). We also thank the authors and publishers for permission to use their materials. We have modified material from brochures and reports, particularly those of the Ohio and other geological surveys and the U.S.G.S.; we are grateful to those who contributed these materials.

We appreciate the help of Reggie Brown and Marge Tibbetts of Orton Geological Library. Portions of this guide were typed by Elicia Finnell and Mary Hill; Helen Jones assisted with the illustrations. We have benefited from suggestions by Marylin Lisowski and Martha McKnight who reviewed parts of this manuscript.

1.0 INTRODUCTION

1.1 Overview

This short field course for science teachers has been offered in a variety of forms and under different titles for more than 2 decades. The basic objectives are to introduce you to regional geology, field methods that will improve your understanding of the science, and as many different aspects of geology as time and geography permit. As most of you are or will be teaching, we will try to develop your confidence in the field approach, where conditions are quite different from the classroom and where there is often something new and puzzling.

To meet these objectives, this itinerary guides us through six physiographic provinces that provide examples of igneous (intrusive and extrusive), metamorphic and sedimentary rocks; Quaternary and Eocambrian glacial deposits; folded, faulted and nearly horizontal rocks; Pennslyvanian plant fossils; and the fauna of some of the most fossiliferous rocks in the world — the Ordovician in southwestern Ohio. Basins and domes, cyclothems, unconformities and a cryptoexplosive structure round out the major features explored on the trip.

A brush with economic geology includes a granite quarry, an early 1900s mining district, and a roadside outcrop of barite-sphalerite veins. Environmental and engineering geology will be discussed at several of the many landslides en route and at a strip-mine area in southeastern Ohio. The relationship of the physical environment to the economy of a region is explored in the eastern coal fields and Blue Grass region of Kentucky.

On this trip transportation is usually by van. Accommodation at inexpensive motels or college dormitories is the rule. The trip is run during the OSU spring break (the last half of March), when few tourists are braving the snow and rain of backwoods Appalachia, and the outcrops are left to those who do not choose to migrate to the southern beaches.

Our preparation for the trip includes updating this field guide, obtaining reservations for lodging and vans, and requests for permission to visit some sites. As a student, a review of your introductory geology and readings on the physiography and general geology of the Appalachians is required. You should also read this guide and be prepared to discuss the geology at each of the planned stops.

1.2 Physiographic Setting

Physiography refers to the topographic expression and geology of a region. Topographic expression includes attitude, relief, and type of landforms (Thornbury, 1965). Geology includes the rock type and structure, and the geologic history. Topography is usually the first and most obvious clue to a physiographic unit.

The province is the basic unit of physiography; it is defined on the basis of topography and geology. Areas exhibiting uniformity are placed in a province. Provinces are grouped into Divisions and divided into Sections, and even Regions. Some areas may be nearly flat, as is the Till Plains Section in Central Ohio; other areas may be mountainous with a linear trend to the mountains as in the Valley and Ridge Province of the Appalachian Highlands.

The continental United States is divided into 8 Divisions and 25 Provinces. Other areas of North America, other continents, and even the submarine portions of the globe have been classified according to physiographic character -- their topographic expression and geology. These divisions provide a handy tool for description of areas of the earth by geologists and other scientists concerned with aspects of the physical environment. For those who know the physiographic provinces, mention of a province immediately conveys information on lithologies, topography, and geologic history of that province.

The division of the landscape into regions was formally done by committee in the early 1900s (Fenneman, 1917), but minor modifications have been suggested since then. This was not the first attempt to produce physiographic provinces; and even as late as 1965 Thornbury noted opportunities for additional details in constructing regional classifications.

Probably the first to write about geomorphic differences that existed in the eastern United States was R. Beverly (White, 1953). In 1856 J. P. Lesley (Thornbury, 1965) published the first American map showing the geomorphic provinces of eastern North America. Lesley was impressed with the 15-foot square map and is quoted (Thornbury, 1965), "I am surprised at the beauty of the whole representation now for the first time made to the eye. The correlation of parts was very fine in a geological sense." The important relationship between topography and geology had been recognized. Many of the same features appeared in school geography texts shortly after that discovery.

The first map and report that included the whole of the United States was by Powell (1895). Lobeck's Physiographic Diagram of the United States is given as Figure 1. In some areas the boundaries are distinct as between much of the Appalachian Plateau and the Ridge and Valley, but in other areas the boundaries interfinger or are not easily seen in the topography. For example, the general topographies of the Central Lowlands in southwestern Ohio and the Interior Low Plateaus near Lexington are essentially the same (Interior Lowlands in Figure 1). The difference, as noted by Thornbury (1965), is that the Central Lowlands have been glaciated.

Bloom (1978), Hunt (1967), Thornbury (1965) and maps by Erwin Raisz and A. K. Lobeck are all good references. Atwood (1940) is another source; however, according to Thornbury this work suffers from the geographical approach in which climate and vegetation are considered. A current list of provinces is given in Table 1.

Each physiographic province through which we will travel is marked by an asterisk in Table 1. You should be familiar with the topography, geology, and structure of these areas before leaving on the trip. You should also outline these provinces on a road map of the eastern United States. Subdivisions of the provinces (sections) should be added where possible.

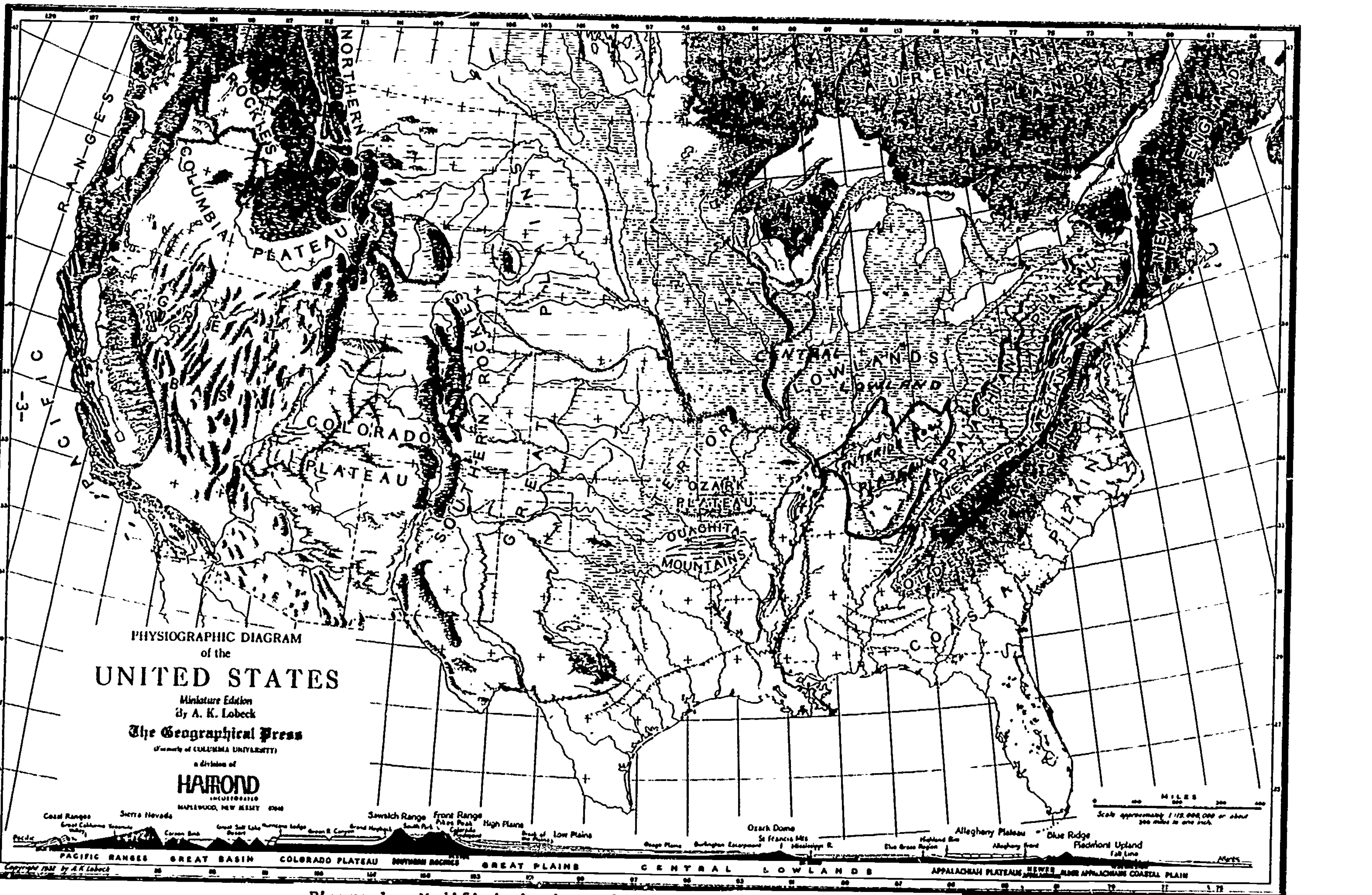


Figure 1. Modified physiographic diagram of the United States. (Reprinted with permission of Hammond Incorporated, Maplewood, New Jersey.)

Table 1. Physiographic areas of the United States (modified from Bloom, 1978).

Division	Province	Sections Visited
Laurentian Upland	1. Superior	
Atlantic Plain	2. Continental Shelf	
	3. Coastal Plain	
Appalachian Highlands	* 4. Piedmont[a]	Piedmont Upland
	* 5. Blue Ridge[b]	Southern Section
	* 6. Valley and Ridge[c]	Tennessee Section
	7. St. Lawrence Valley	
	* 8. Appalachian Plateaus	Allegheny/Cumberland
	9. New England	
	10. Adirondack	
Interior Plains	*11. Interior Low Plateaus[d]	Bluegrass or Lexington Plain Highland Rim
	*12. Central Lowland[d]	Till Plain
	13. Great Plains	
Interior Highlands	14. Ozark Plateaus	
	15. Ouachita	
Rocky Mountain System	16. Southern Rockies	
	17. Wyoming Basin	
	18. Middle Rockies	
	19. Northern Rockies	
Intermontane Plateaus	20. Columbia Plateaus	
	21. Colorado Plateaus	
	22. Basin and Range	
Pacific Mountain System	23. Cascade-Sierra Mts	
	24. Pacific Border	
	25. Lower California	

* Provinces visited on field trip

Note: On Figure 1, provinces are shown as:

(a) Older Appalachians
(b) Blue R.
(c) Newer Appalachians
(d) Interior Lowlands

The physiography of each province is not described in detail here as this will probably be one of your pre-trip research projects.

1.3 Structural Geology

Structure in the geomorphic sense refers to the lithology and the lineations in a rock as well as the gross "structural" features such as the attitude of strata that may be deformed by folds and faults. On this trip we will see essentially flat-lying sedimentary rocks in Ohio, West Virginia and Kentucky, folded and faulted sedimentary units in Virginia and Tennessee, and igneous and metamorphic rocks in North Carolina and Virginia. We also will see major faults such as the Kentucky River fault, Copper Creek fault, and a series of faults at the Narrows of the New River. The folding of sedimentary units and the rather impressive change from nearly horizontal units to steeply dipping and even overturned units will be encountered along the Appalachian Structural Front. Much of the structure will be revealed through the geomorphic features of the landscape as the structure of the rocks has an influence on resultant landforms and the overall landscape of an area. Additional information on the structure, stratigraphy and geologic history of North America is available in Clark and Stern (1960) and King (1977).

Although part of the first day and all of the last day of the trip will be spent in the Interior Plains, the rest of the trip will be in the Appalachian System. In southeastern Ohio, southern Kentucky, and West Virginia we will traverse the Appalachian Basin, a negative structural element of North America (Figure 2) that accumulated sediments throughout the Paleozoic. The physiographic expression of this region is the Appalachian Plateaus, consisting of the Cumberland, Allegheny and Catskill Plateaus.

In Virginia, and parts of North Carolina and Tennessee the Appalachian System has undergone considerable deformation in the Valley and Ridge Province, the Blue Ridge, and the Piedmont. The latter two provinces consist mainly of greatly deformed Precambrian and Paleozoic sedimentary rocks and igneous intrusives. North of New Jersey they become one province extending into Newfoundland. They continue to the south and the Blue Ridge becomes the Great Smokies. The Appalachian System has been involved in several orogenies. Parts of the northern portion of the System were deformed during the Taconic Orogeny (end of the Ordovician). Evidence for this includes thrust sheets in the north; to the southwest across Pennsylvania folded Ordovician sediments occur beneath undeformed Silurian (King, 1977). The Taconic evidence fades in the southeast belts of the system or is sporadic. The Acadian Orogeny occurred at the end of the Devonian (Figure 3). In general, the times of orogenies in these crystalline rocks of the Older Appalachians (Piedmont/Blue Ridge) are not well known in the central and southern parts of the Appalachians; however, clastic wedges associated with such events are recognized. According to King, J. Tuzo Wilson, proposed a gradual close of the Atlantic in the last 2/3 of the Paleozoic. This might account for the sporadic nature of the evidence along an irregular suture.

In North and South Carolina, the boundary between the Piedmont and the Blue Ridge is the Brevard Zone. King (1977) describes this as a suture between two plates. Closure occurred along this zone. This was followed by strike-slip movement during the Late Paleozoic.

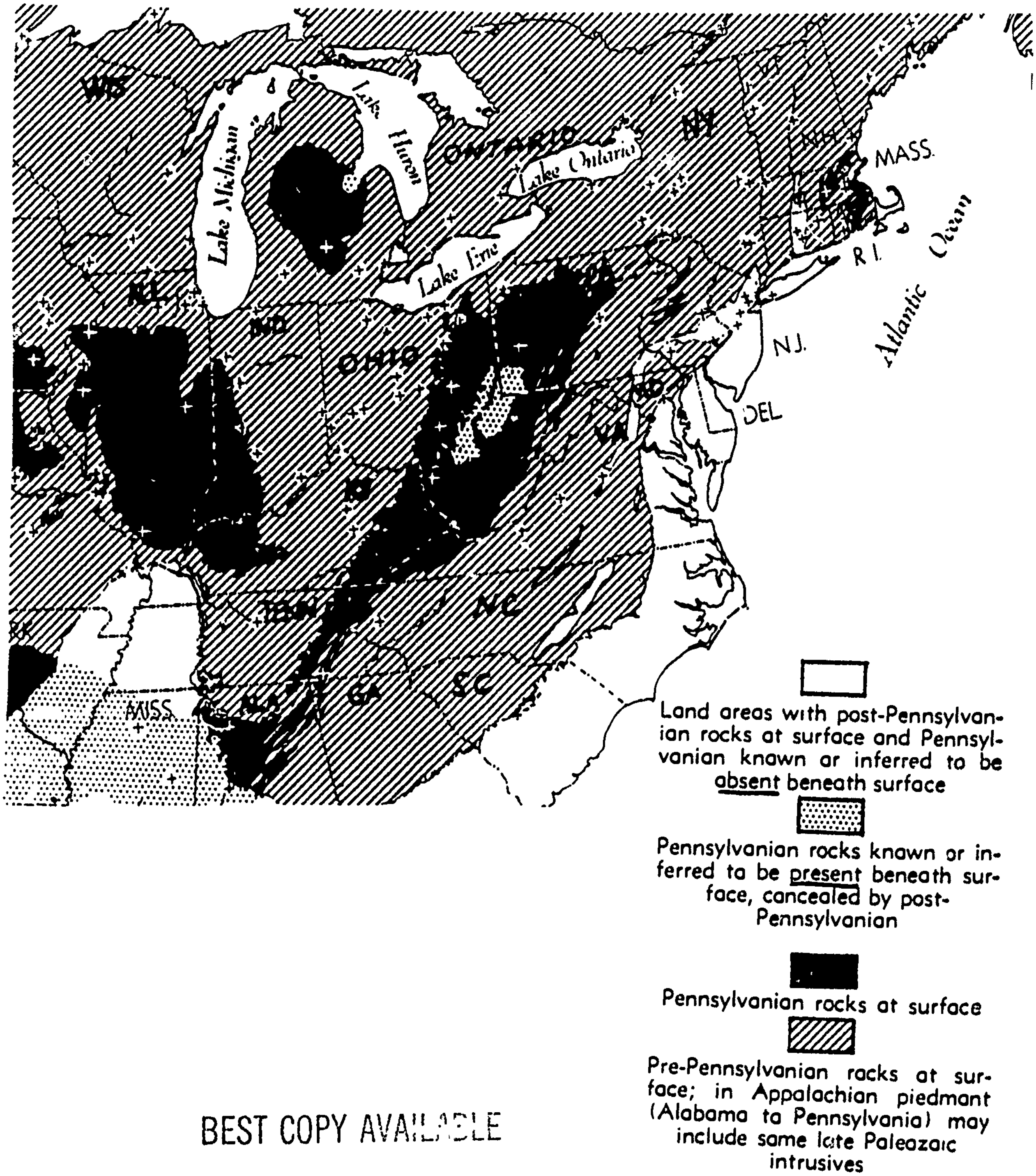
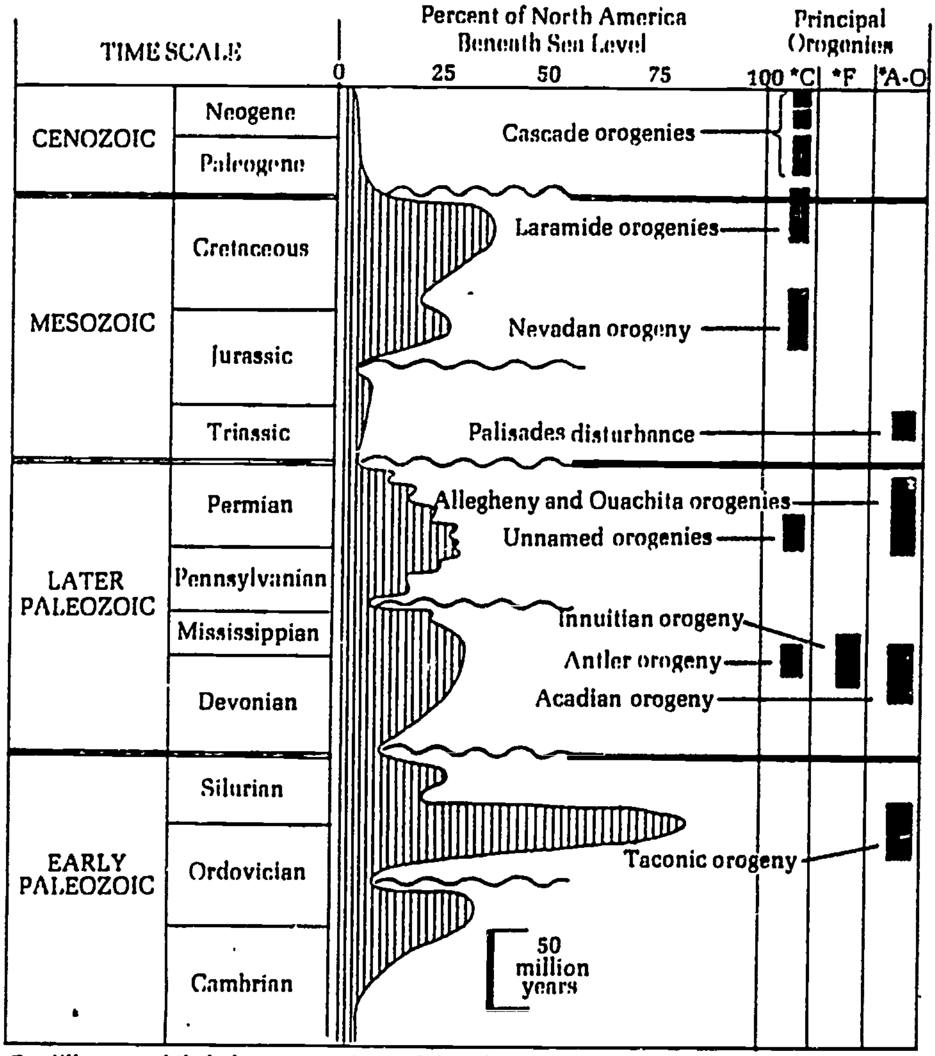


Figure 2. The Appalachian Basin. (Modified from Moore, R.C., Introduction to Historical Geology, copyright, 1958, McGraw-Hill. Reproduced with permission.)



*C Cordilleran mobile belt *F=Franklin mobile belt *A-O -Appalachian-Ouachita mobile belt

Figure 3. North American orogenies since the Precambrian. (From Bates, Sweet and Utgard, Geology: An Introduction, copyright, 1973, D. C. Heath and Company. Reprinted with permission.)

The Valley and Ridge Province consists of folded and faulted Paleozoic strata, with ridges of resistant rock forming the mountains and the less resistant rock of carbonates and shales forming the valleys. Nearly continuous sedimentation occurred from the Cambrian through Lower Permian, with some disconformities, but with no angular unconformities. The obvious structural grain of this province is northeast-southwest. This inner portion of the Appalachians (the Newer Appalachians) was deformed during the Allegheny Orogeny (late Early Permian or later) when folding and thrust faulting changed the structure up to and for some distance beyond the Appalachian Structural Front that separates the Valley and Ridge from the Appalachian Plateaus Province. The structures may have been developed earlier in the southern part than in the northwestern part. The structural trend of this area is shown in Figure 1. For more detail of the structures see Figure 4.3. In general the central part (as occurs in central Virginia) exhibits fold structures, while the southern part (as seen on this trip) contains a series of thrust faults.

On the northwest edge of the Appalachian System in Kentucky lies the Interior Low Plateaus. This includes a domal structure -- the Jessamine Dome -- centered on Lexington, Kentucky. This positive structure was active through part of the Paleozoic as a high area and affected the pattern of sedimentation around it. Extending to the north into the Central Lowland Province, the dome becomes the Cincinnati-Findlay Arch with a northeast-southwest trend. This is also a positive element. It has controlled the sedimentation and erosion patterns over this portion of western Ohio and is reflected in the pattern of rock types on the surface in Ohio (Figure 4). It is also apparent in the geologic cross section of the state (Figure 4).

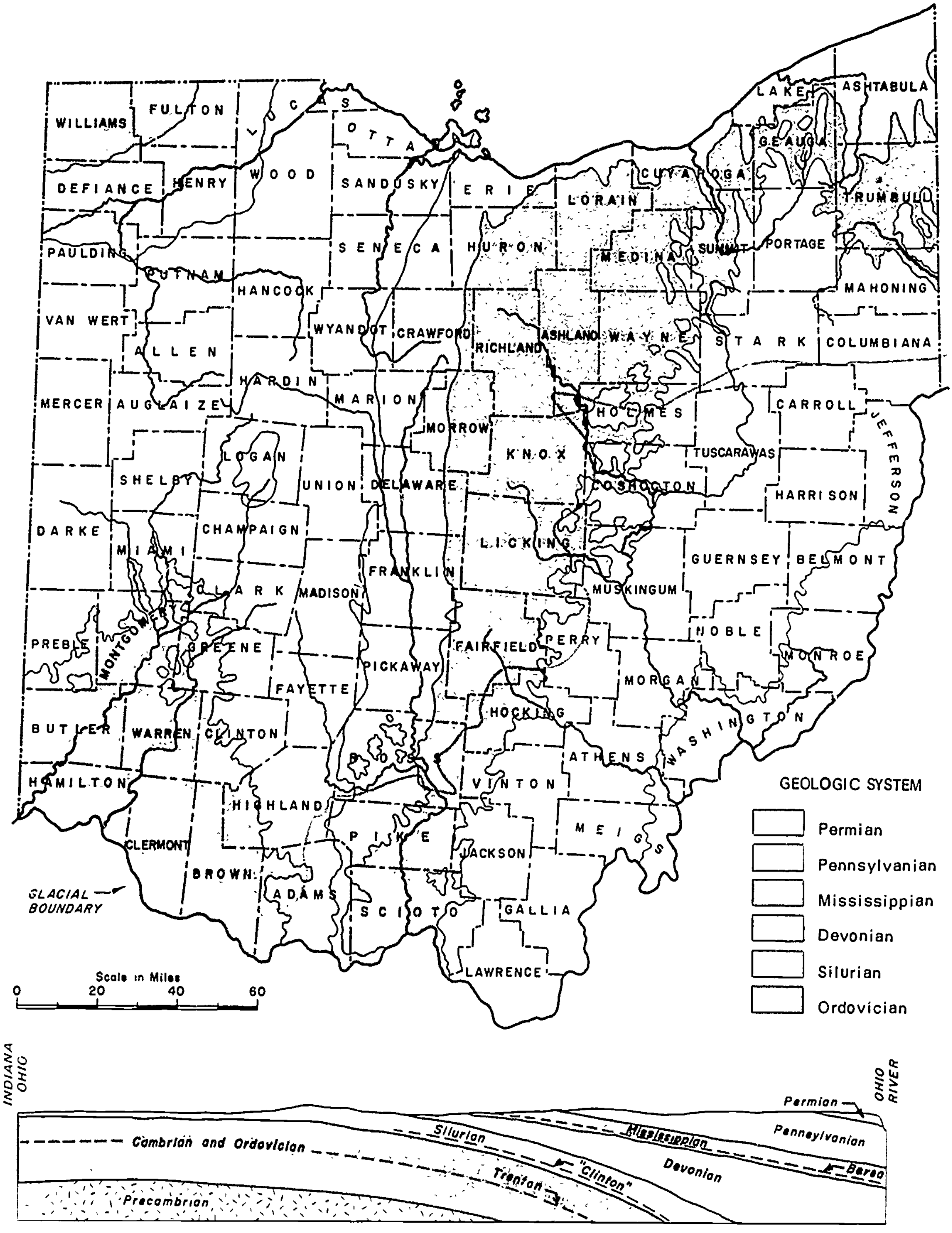
In preparation for the trip, it is necessary to review structural geology and the symbols that are used to identify structural features on maps. Some of these symbols are found in textbooks on field geology such as Barnes (1981), Compton (1962), Moseley (1981), and Tucker (1982) or on geological maps. A summary of some of these map symbols is given in the Appendix.

1.4 Stratigraphy

Geologic formations -- identifiable, mappable units -- constitute the basis for stratigraphic columns in a region. A formation is well-defined in the area where first described and at its "type section" which is named for a nearby geographic feature. In central Ohio the Olentangy Shale, probably named for the Olentangy River, occurs between the Ohio Shale and Delaware Limestone (Table 2). It is recognized on the basis of its lithologic characteristics. This formation, consisting a of specific rock type and age does not extend around the globe, but it is limited in areal extent because of erosion and non-deposition. Sometimes similar formations in adjacent states or regions have different names because they were mapped by different geologists. This explains why some "formation" names change at political boundaries.

Sets of formations with similar characteristics are often placed in a Group (Table 2).

At the same time that sediments of the Olentangy Shale were being



OHIO DIVISION OF GEOLOGICAL SURVEY

GEOLOGIC MAP AND CROSS SECTION OF OHIO

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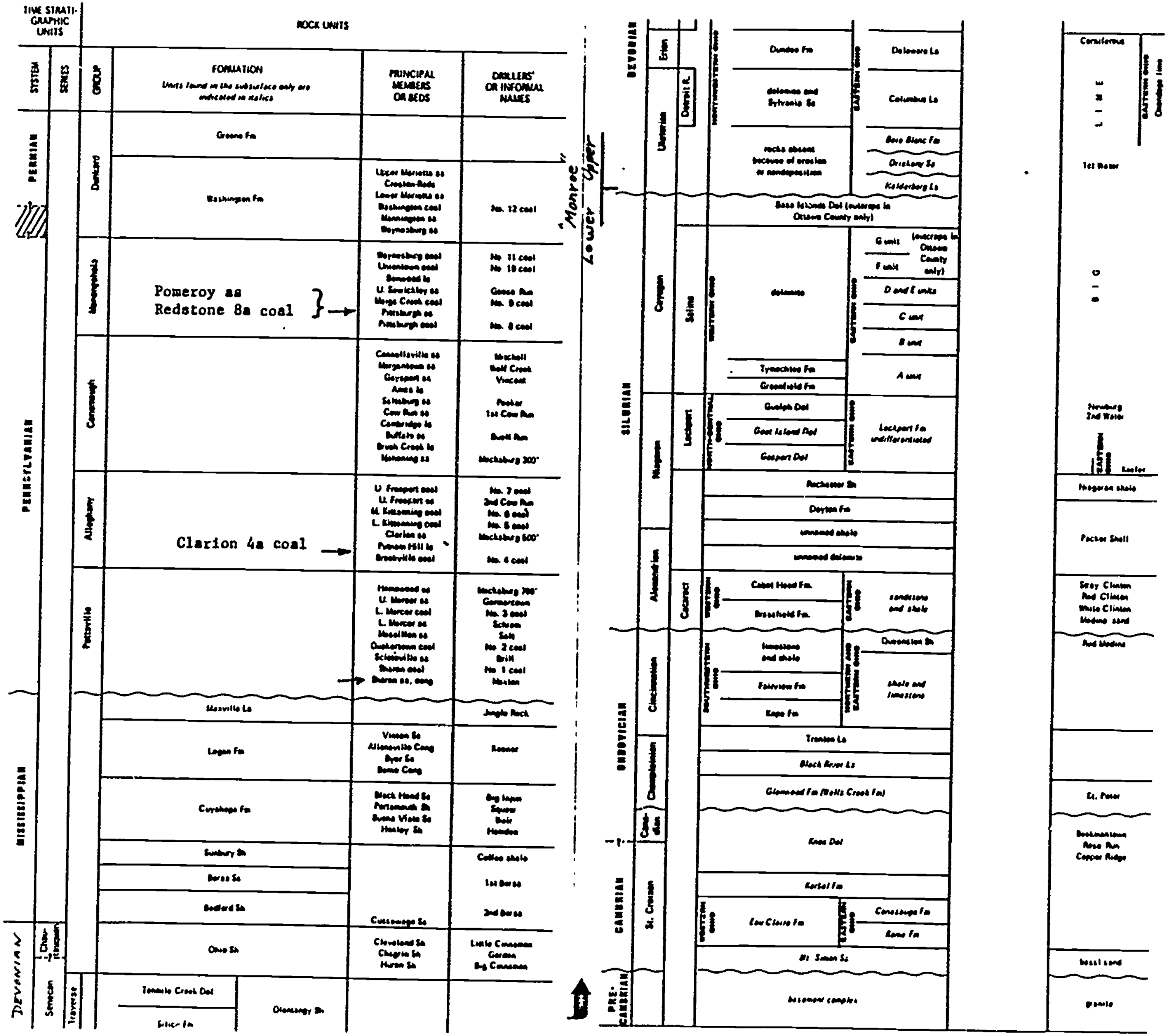
TABLE 2 GENERALIZED ROCK COLUMN FOR OHIO. (Modified from Ohio Geological Survey, Janssens' 1972 revised edition)



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formed in central Ohio, other sedimentary types (lithofacies) were forming in adjacent areas (see lithofacies and iopach maps, Figure 5). The knowledge that the rocks were forming at the same time is derived from the fossil record which is used to subdivide the rock record into zones. A zone represents the same time unit wherever it occurs and is the basis for correlation of stratigraphy.

Matching the units on the basis of lithology is not enough, however, as many depositional environments occur at one time in a region and formations are often time-transgressive. Thus time must be used as the basic control in correlating the stratigraphy from one region to another and in building up a correlation chart for a multi-state region. Correlation charts may be found in regional geological reports and in texts on historical geology. These correlation charts, which aid in constructing the regional history of an area, can be used to identify events such as erosion, deposition, onlap, offlap, and assist geologists in understanding the geologic setting in areas where they may not have first-hand experience.

The correlation charts and and stratigraphic columns in this guide (see Figures 1.7 and 2.1, for example) may need to be supplemented by additional material.

Glacial deposits constitute the uppermost portion of the stratigraphic column in the Central Lowlands. This drift (general term for glacial deposits) is mainly glacial till, but also includes ice-contact deposits and outwash. In Central Ohio, the average drift thickness is about 100 feet, with about 50 feet over buried uplands and 200 feet over buried valleys (VerSteeg, 1933). At Cleveland the drift thickness in some places is more than 700 feet. The age of the exposed drift is mainly Wisconsinan, with some Illinoian and older deposits on the margins.

The bedrock beneath the drift in Central Ohio is made up of Paleozoic sediments. At Columbus Devonian shales and carbonates occur; to the southeast in the Appalachian Plateaus Province, mainly Mississippian and Pennsylvanian clastics with coal beds occur. These deposits lie in a large northeast-southwest trending basin, with the thickest and youngest deposits (Permian) midway through our 200-mile traverse of this basin. In the southeastern edge of the Appalachian Plateaus Province, Mississippian clastics appear at the surface. Here the regional dip of bedrock is to the northwest, while near Columbus it was to the southeast. Throughout the province the dips are very gentle, on the order of a few feet per mile. To the southwest within the Plateaus, the province narrows, and where we traverse it on our way north it is about 50 miles wide.

The Valley and Ridge Province consists of sedimentary rocks ranging in age from Cambrian to Mississippian, but are generally of early Paleozoic age. These highly folded and thrust-faulted rocks include carbonates, shales, sandstones and very dense sandstones. Differential erosion of these folded units has produced the striking topography with anticlinal and synclinal valleys and ridges. The ridge-forming units in the northern part of the Ridge and Valley Province include the Pottsville Ss (Penn.), Pocono Ss (Miss.), Oriskany and Chemung Ss (Devonian), and the Tuscarora and Oswego Ss (Sil.). In the southern part of the province, additional ridge formers include the Ft. Payne chert (Miss.), the Clinch Ss and Rockwood (Sil.),

Mississippian

Limestone

Shale and Sandstone

Sandstone

Pennsylvanian

Sandstone and Conglomerate

Isopach (interval = 1000 feet)

Figure 5. Isopach and lithofacies maps of the Mississippian and Pennsylvanian Systems of Eastern United States. (Modified from Bates, Sweet and Utgard, Geology: An Introduction, copyright, 1973, D. C. Heath and Company. Reprinted with permission.)

and sometimes the Knox Dolomite (C-Ord.). Carbonates and shales underly the valleys. The eastern part of the province consists of a low, 1200-mile long valley known as the Great or Appalachian Valley. It varies in width from 2 to 50 miles and in elevation from 400 to 2400 feet (Thornbury, 1965).

Southeast of the Ridge and Valley Province lies the Blue Ridge, consisting of Upper Precambrian and Lower Cambrian metasediments and Precambrian gneisses and plutonic igneous rocks. The metasediments are mainly on the western side of the province, with the plutons mainly on the eastern side. The metasediments include conglomerates, sandstones, slates and graywackes. They can be placed in a reasonable stratigraphic order; however, this is not so easily done for the metasediments of the Piedmont.

Southeast of the Blue Ridge lies the Piedmont. They are separated from each other by the Blue Ridge Front or Escarpment. The Piedmont consists of Paleozoic and Precambrian metasediments, Paleozoic intrusions, and Triassic sediments (Fig. 6). The Carolina Slate belt in the southeastern part of the province actually consists of moderately metamorphosed slate and volcanics. The widest part, 125 miles, is at the Virginia/North Carolina border.

The Interior Low Plateaus Province is the sixth physiographic province visited. Bedrock ranges in age from Ordovician to Cretaceous, although in the area traversed it consists of lower Paleozoic carbonates and clastics. The oldest rocks are over the domes and at the Jessamine dome Middle Ordovician carbonates and some shales are exposed. The carbonates have given rise to karst terrane in places. Cryptovolcanic structures have been identified at several places in this province -- Jeptha Knob, Muldraugh Dome and Versailles in Kentucky, Flynn Creek and Wells Creek in Tennessee (see Figure 4.7). Serpent Mound in Adams County, OH is in the Central Lowland Province; the Middlesboro, Kentucky structure is in the Appalachian Plateaus Province.

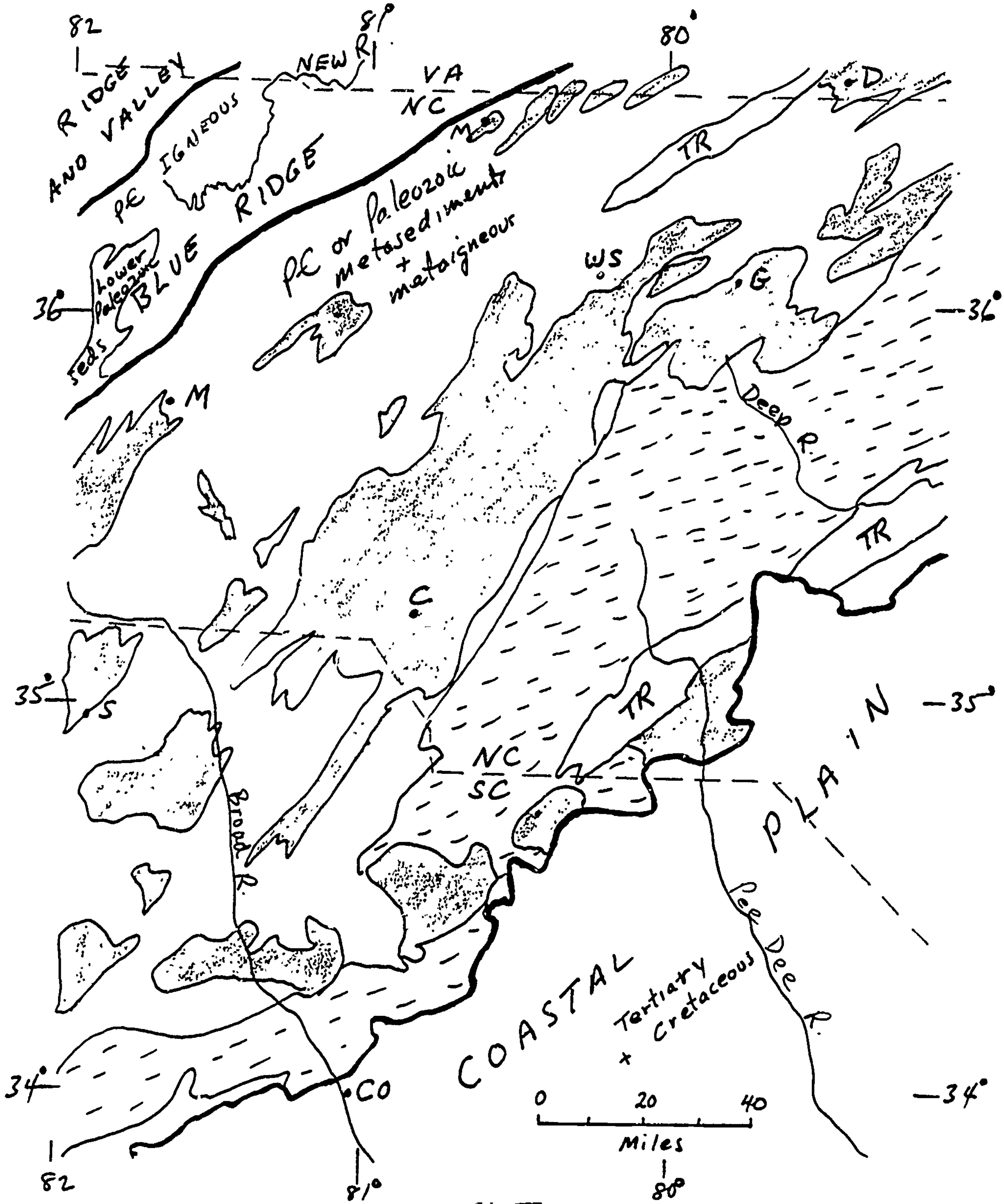


Figure 6. Geology of the Piedmont Province. (Modified from Thornbury, 1965, after King, 1955. Original figure copyright 1965 by McGraw-Hill. Used with permission.)

C = Charlotte, CO = Columbia, WS = Winston-Salem, G = Greensboro, D = Danville, S = Spartanburg, M = Mt Airy.

TR = Triassic sedimentary; = "Carolina Slate Belt"; Paleozoic Intrusives

2.0 INTRODUCTORY GEOLOGY — A REVIEW

Only a brief review of some very basic ideas on minerals, rocks, structures, maps and fossils is presented here to help you in the field. For more detail consult standard textbooks such as Stokes, Judson and Picard (1978), Birkeland and Larson (1978), and Press and Siever (1982). Parts of geology lab manuals may also be useful. (See Hamblin and Howard, 1980, and Zumberge, 1973). A handy paperback textbook that covers most of the basic ideas encountered on the trip is by Foster (1985). For more advanced information the AGI Data Sheets (American Geological Institute, 1982) are recommended. Classification schemes for rocks and a sheet of map symbols are found in the Appendices.

2.1 Minerals and Rocks

Definitions for minerals vary (even from the glossary to the body of one book), but generally contain the following points (although they are sometimes qualified). A mineral is a naturally-occurring, inorganic solid (crystalline) substance (element or compound) with definite and characteristic internal structure and composition (or range of compositions). Glass is a noncrystalline solid; the atoms are not arranged in a symmetrical pattern. Therefore, it is considered as a viscous liquid and not a mineral. Organic substances such as coal, amber, and oil are not considered to be minerals—although legally they may be classified as mineral fuels. The mineral calcite is usually formed by organic processes, but it is still a mineral.
A mineral may occur as a crystal — with an internal structure in a regular pattern — that exhibits crystal faces that are smooth planes with sharp edges. There are more than 2500 minerals, but knowledge of several dozen suffices for most geologists. Field identification of minerals depends upon the physical properties. These properties, plus composition, are used in the laboratory.

The commonly used physical properties are:

Color	- on a fresh surface
Streak	- the powdered color
Luster	- the way light is reflected: metallic and nonmetallic. The nonmetallic are dull, waxy, silky, etc.
Crystal Form	- 6 systems, differentiated by symmetry of the crystal. Crystals exhibit "constancy of interfacial angles."
Cleavage	- breakage of minerals along definite planar surfaces. Cleavage exhibits definite and constant angles with respect to crystal axes. Up to 6 directions.
Fracture	- irregular break.
Hardness	- resistance to abrasion. Recall Mohs scale, but more useful in the field is the following information:

Fingernail	- 2.5	Glass	- 5.5
Penny	- 3.0	Steel file	- 6.5
Knife	- 5.0	(hardness on Mohs Scale)	

Specific Gravity - ratio of weight of mineral to the weight of an equal volume of water. Quartz and orthoclase are 2.6; calcite is 2.7.

Rocks are natural aggregates of minerals -- usually. Sometimes they are described as appreciable parts of the earth's crust (Foster, 1985), and this allows rocks to include materials that don't fit as minerals such as obsidian and organics. Rocks are classified as to origin using some general rock characteristics. The characteristics include bedding, sedimentary structures, textures, mineral assemblages, and foliation. The three groups are igneous, sedimentary and metamorphic. Igneous rocks form from a melt or magma during cooling; sedimentary rocks form from deposition of weathering products of other rocks and sediments. Metamorphic rocks are changed within or on the crust by pressure and temperature. Recall the rock cycle.

2.2 Igneous Rocks

Igneous rocks are classified by composition and texture. They consist of silicate minerals, both light colored (light weight too) and dark colored (higher specific weights, often containing iron and known as the ferromagnesians). Quartz, orthoclase or K-feldspar, and minor ferromagnesians (biotite and hornblende) make up granites; plagioclase and augite make up basalt. These rocks are the two end members in the range of compositions of common igneous rocks. With variation in texture (grain size) other igneous rocks are recognized. Obsidian is at the granite end of the compositional spectrum, even though it is dark colored. Common textures are:

phaneritic - minerals seen with unaided eye (coarse grained)
aphanitic - microscopic minerals (fine grained)
vesicular - with many small cavities
glassy - glass-like
porphyritic - larger crystals in a finer groundmass

Consult the Appendix for the classification of igneous rocks.

2.3 Sedimentary rocks

Sedimentary rocks form from the weathering products of other rocks. Some of these products travel as fragments or clasts. The clastic particles are named according to size range (Figure 7). After deposition lithification may occur to form indurated rocks. The lithification may include cementation from ions in solution (silica, calcite and iron oxides are common), compaction, and recrystallization.

Soluble weathering products also make sedimentary rocks when these ions are precipitated chemically or biochemically.

Several classifications of sedimentary rocks are used; however, most include clastic and or chemical categories. As with igneous rocks, composition and texture are important, but structures are also considered. It is usually layering or stratification that is the most diagnostic feature of a sedimentary rock. A chemical classification is difficult because of the wide variety of materials supplied from pre-existing rocks. The main materials found in sedimentary rocks are: silica, carbonates, clay minerals, evaporites, and rock fragments. Feldspars and other minerals and organic materials complete the list. Textures often provide clues to the depositional history of the rock.

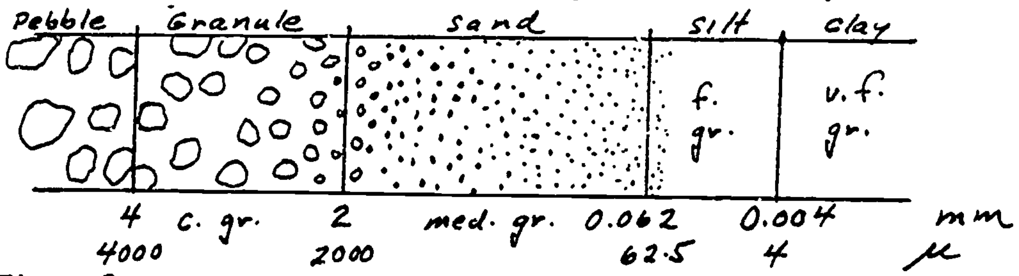


Figure 7. Particle sizes for classification of sedimentary rocks.

Much of the clastic material found in sedimentary rocks is derived from or formed on the land, and the term terrigenous detritus (land-derived rock debris) is applied. Other clastic rocks are derived from precipitates and are known as precipitated clastics (sometimes the term organic detrital is applied here because of the biochemical clastic source -- usually shell fragments). Precipitated nonclastics also occur and are sometimes referred to as inorganic chemical precipitates; however, some of these may be biochemical in origin too.

Some systems divide sedimentary rocks into only two groups, the clastic and nonclastic. In these schemes, the clastic group is subdivided by grain size and the nonclastic group is subdivided by composition; however, this is too simplified because it fails to account for the large portion of clastic carbonate rocks. One scheme is given in the Appendix; you might want to consult others.

2.4 Metamorphic Rocks

Metamorphic rocks are changed rocks. Heat from a nearby magma may produce recrystallization or chemical recombination of the country rock. Gases and solutions from the magma may also cause chemical replacement in the country rock. Also, in areas of regional metamorphism, where significant directed pressures exist, physical changes are produced in the rock. A parallel fabric or structure often results where recrystallization and flow of minerals has occurred. Not all metamorphic rocks show this structure known as foliation or rock cleavage. Foliation or its absence is the basic criterion that is used in classification of metamorphic rocks. The degree of recrystallzation and rearrangement is known as grade of metamorphism.

Classifications are based on structure (foliated or non-foliated , i.e.

massive), texture and mineralogy. Foliated rocks have textures that vary from fine to coarse (slaty cleavage to gneissic); massive rocks have a wide range of textures. The ultimate name of the rock depends on its mineralogy (mica schist; marble or quartzite, etc.).

2.5 Structural Geology

Understanding the geologic history of an area requires knowledge of the structural aspects of the rocks. Usually this is shown in the erosional landforms, and thus a geomorphic analysis of the region will provide clues to the underlying structure and rock types.

The position in space or the three-dimensional orientation of a rock unit is known as the attitude. Recall the terms strike and dip as they are used to define the attitude of a rock layer. Strike is the bearing of the line formed by the intersection of an inclined plane with a horizontal plane; dip is the bearing and angle of inclination, measured perpendicular to the strike.

Rock layers are usually not perfectly horizontal as they often form with a slight depositional dip. Folding and faulting are other ways to produce dipping layers.

The parts of a fold are shown in Figure 8. Plunging folds show convergence of limbs and produce a zig-zag pattern in outcrop. Non-plunging folds show parallel patterns. Faults record rock failure in which differential motion has occurred on either side of the fracture surface. In normal faults the hanging-wall block moves down relative to the footwall block. The reverse is true for reverse or thrust faults. Other fault types include flat faults, tear faults, and strike slip (including transform) faults. Fault terms are shown in Figure 9. Selected map symbols for the above features are given in Figure 10. Additional features are shown in the Appendix.

2.6 Topographic Maps

Topographic maps differ from planimetric maps by showing elevation as well as direction and distance. Elevations are shown by contour lines -- all points on the line being at the same elevation above or below sea level. Figure 11 illustrates the interpretation of contours.

Locations on a topographic map are given by latitude and longitude. The OSU Oval is at 40 00' 00'' north latitude and 83 00' 54'' west longitude. Sometimes grid coordinates or rectangles are used to locate specific points on a map. In the latter case, features may be noted as occurring in the West Central (WC) Rectangle or in the NWR (for north west rectangle).

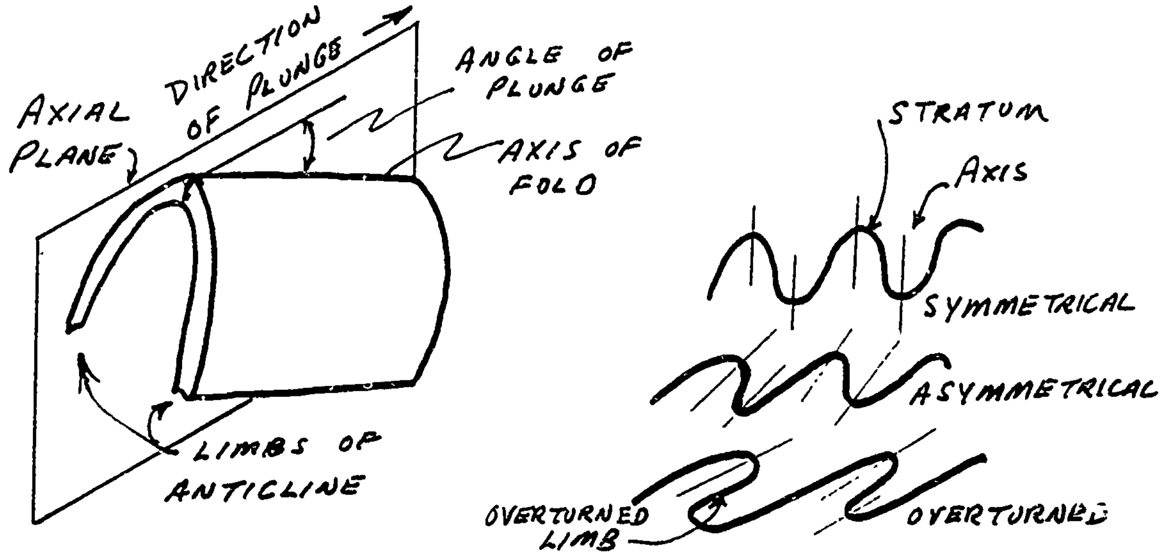


Figure 8. Fold terminology.

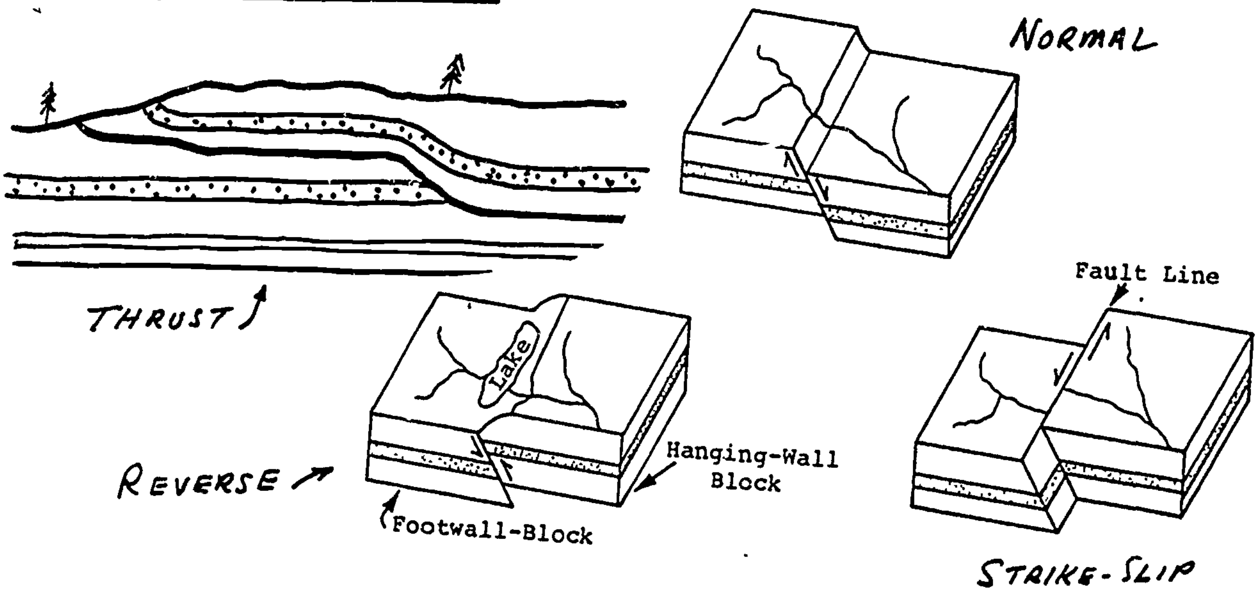


Figure 9. Fault terminology.

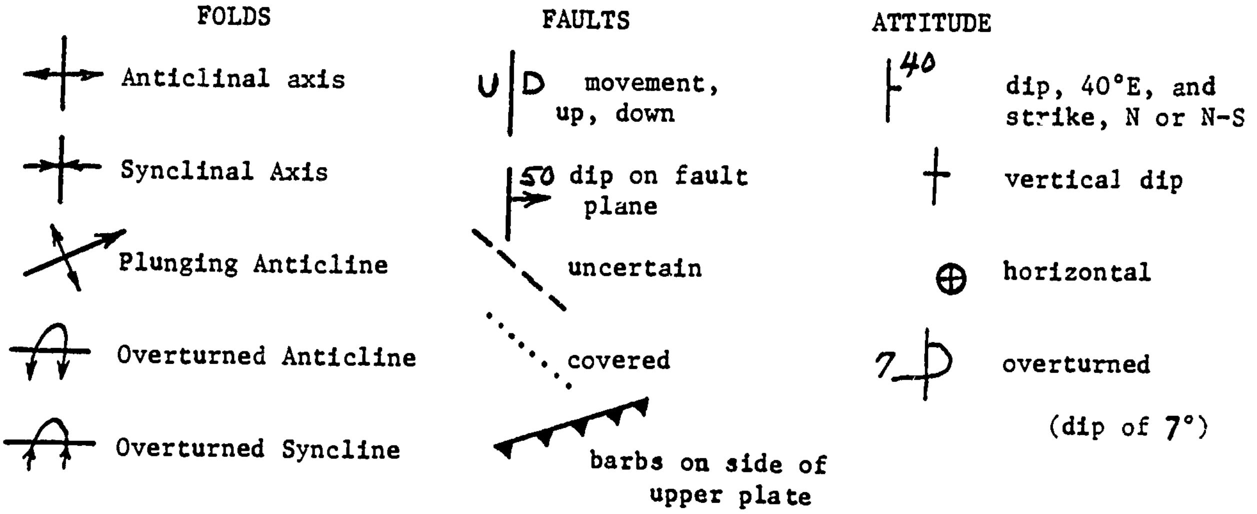
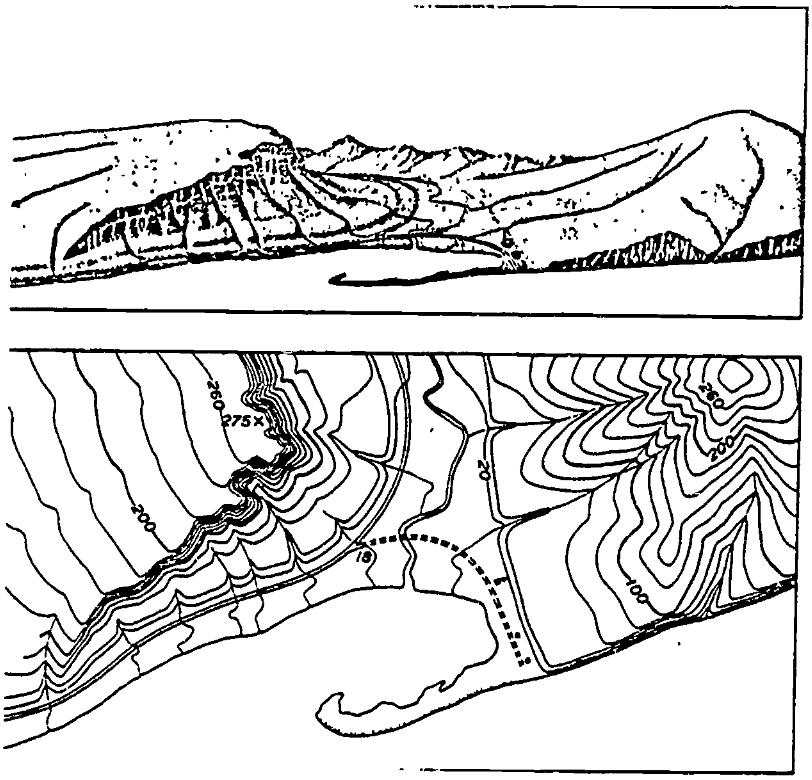


Figure 10. Structural symbols



THE USE OF SYMBOLS IN MAPPING

These illustrations show how various features are depicted on a topographic map. The upper illustration is a perspective view of a river valley and the adjoining hills. The river flows into a bay which is partly enclosed by a hooked sandbar. On either side of the valley are terraces through which streams have cut gullies. The hill on the right has a smoothly eroded form and gradual slopes, whereas the one on the left rises abruptly in a sharp precipice from which it slopes gently, and forms an inclined tableland traversed by a few shallow gullies. A road provides access to a church and two houses situated across the river from a highway which follows the seacoast and curves up the river valley.

The lower illustration shows the same features represented by symbols on a topographic map. The contour interval (the vertical distance between adjacent contours) is 20 feet. (USGS)

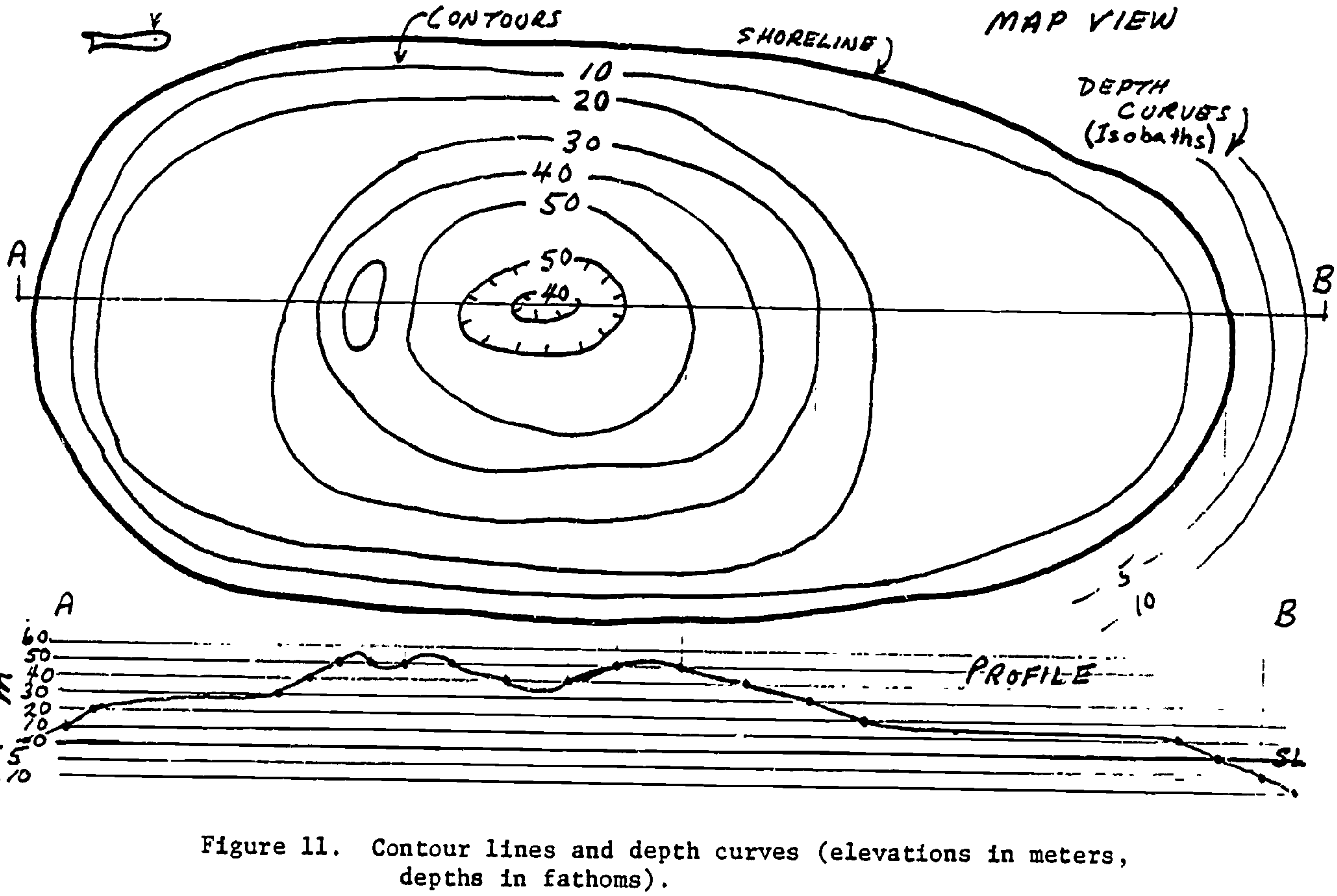


Figure 11. Contour lines and depth curves (elevations in meters, depths in fathoms).

Distances on a map are given by a scale; the easiest to use is the bar scale. Use a piece of paper or a ruler to determine the distance between two points on a map, then compare that distance with the bar scale on the map. All maps should have scales and a north arrow or other indication of direction.

Topographic map symbols and scale information for USGS maps are given in the Appendix.

2.7 Geologic Maps

Geologic maps are usually produced on topographic bases and include the features and rock types. The basic unit on most maps is the formation — an identifiable, mappable rock unit. It may consist of several different rock types. See the formation description in Table 4.

The key to understanding the geologic map is in the explanation on the margin of the map. These explanations read from oldest at the base to youngest at the top. Cross sections are often included to assist in understanding the third dimension in the region. On some geologic maps the geologic history of the region is described; however, by reading the explanation at the side, you should be able to interpret the geologic history yourself. The symbols used on maps are given in the Appendix. Consult also the symbols for the structural features described above. An example of a geologic map with a block diagram is given in Figure 12. A more complicated geologic map is shown in Figure 13.

2.8 Fossils

Fossils are important indicators of paleoenvironment and tools by which we tell time. Thus they are often very important in the interpretation of the geologic history of an area with sedimentary units. Identification of most fossils is best done by experts; however with some training and the proper reference books, one can "key out" (work through a key to identify a specimen) fossils found in the field. For our trip three references are particularly useful (Castor et al., 1961; Gillespie, et al., 1966; La Rocque and Marple, 1962). A simple key for identification to phyla and class is given in the Appendix. This key is based upon symmetry (asymmetrical, bilateraly symmetrical, and radially symmetrical), solitary or colonial growth, and the number of pieces in the skeleton.

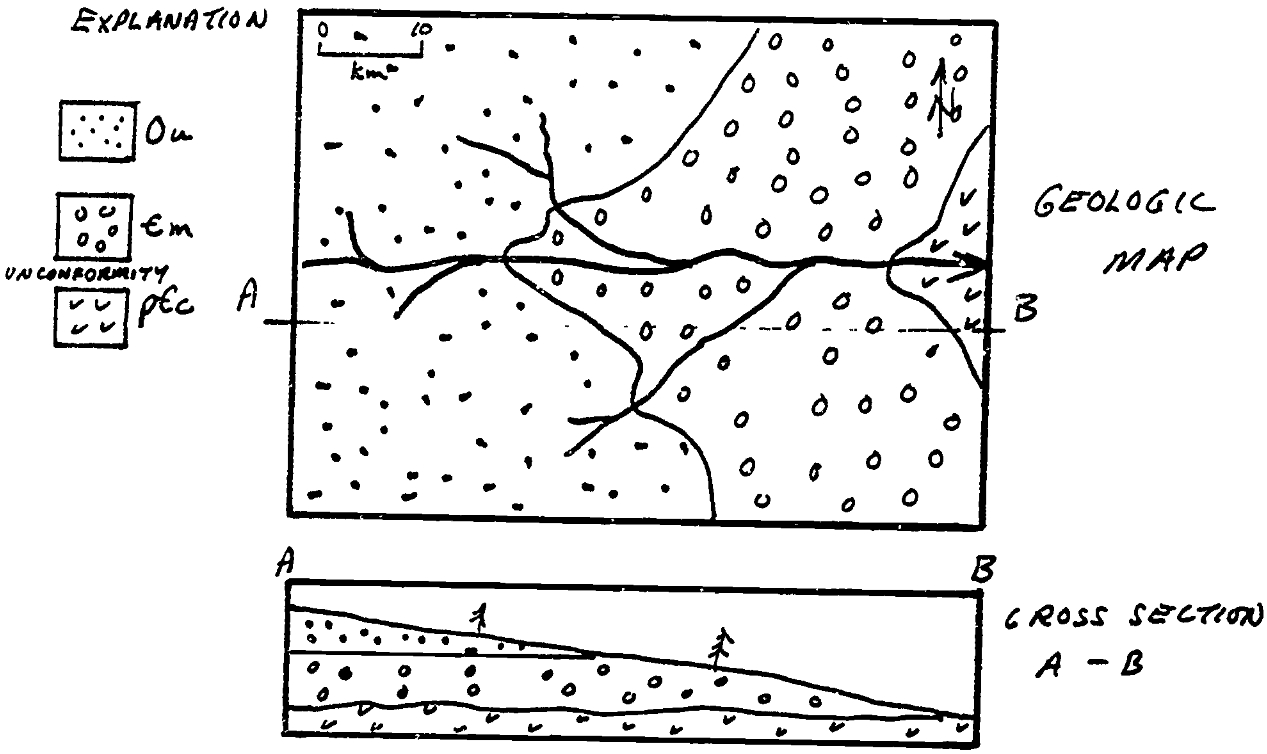


Figure 12. Geologic map and section -- horizontal strata.
In the explanation, pЄc = Precambrian crystallines, Єm = Cambrian McKenzie Formation, and Ou = Ordovician Utgard Formation.

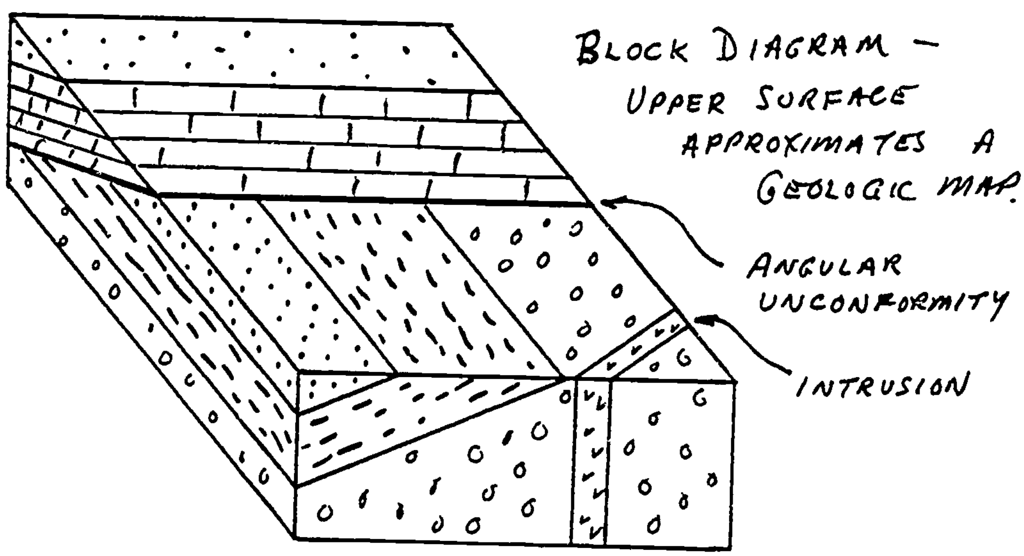


Figure 13. Block diagram showing inclined strata, angular unconformity and intrusion.(modified from Thomas, 1977).

3.0 FIELD TRIPS

3.1 Philosophy/Format

Field trips provide a nearly ideal medium for teaching some geoscience concepts, but field-oriented courses usually require different approaches than those used in the classroom. Our standard multi-media classroom lectures and discussions (Lovenburg, 1967), under ideal acoustic and visual conditions, must be modified in the highly variable and serendipitous field environment (Lokke, 1965a, 1965b). In spite of this, the field still remains one of the best places to teach geology (Thrift, 1975) if we are willing to plan trips carefully and capitalize on opportunities as they arise.

The basic purposes for a field trip are to teach subject matter and techniques. For most of the geosciences, the field setting provides the ultimate laboratory--one in which a true appreciation and understanding of the science can develop. Generally, field study will clarify concepts and examples that have been described in textbooks and explored in the classroom, but "textbook examples" will not be everywhere in the field. Some students will be uncomfortable in the field environment because of this plus the sometimes difficult or unpleasant field conditions. For those students exploring a career in geology, an early field experience and preferably an extended field trip, is particularly useful.

Another reason for field trips is to demonstrate the scope and fun of learning geology. Field activities motivate students and produce more interest and enjoyment in learning (Kern and Carpenter, 1984). Learning extends beyond the classroom and is a life-long process. The joy of learning and teaching in the field, in less formal situations where spontaneity and discussion are important factors, is another good reason for field trips.

Field trips should not be used as an excuse to leave the classroom or to do something different. They should have a very specific purpose. Many administrators find it difficult to understand the need for field activities and are usually concerned about safety. Actually, for well-planned programs, field trips have produced no more liability cases than classroom activities (Mauldin and Ashton, 1981). For more information on liability consult current educational journals, your professional organizations, and Spence and Medlicott (1982).

Field trips range in length from an hour to weeks, and in distance from 100 m to thousands of kilometers. Time and resources dictate the magnitude of the trip. Usually the most exciting and interesting field sites are far away, but not always, and with a little research an exciting urban trip can be had through graveled parking lots, small creeks, road cuts, and excavations.

For any trip the objectives are important. A plan is also needed and for longer trips; this usually takes the form of a guidebook. Field guidebooks usually contain an overview of the topic with a discussion of the general geology of the region and references, maps and figures, a road log, and stop descriptions. Many guidebooks are available in geological libraries at major universities.

Almost any geoscience topic will suffice to generate a group of geologists primed for a field discussion. Such basic topics as the Geology of the Blue Ridge or as far out as the Ground Water Geology of Waterloo will be guaranteed participants.

At the professional level, the field trip is a useful vehicle for continuing education, for making new friends, and for discussing potential or on-going research. For the field trip leader, this assembly of geologists provides a test of the field research that the leader has completed in the area.

3.2 Materials

For almost any field trip the following materials should be carried or available.

1. Pencils (2H and 3H) and stiff-cover notebook. A waterproof book is useful for many field situations. Hard pencils are useful for clean copy on good paper, but will tear wet paper. Erasers are useful.
2. Clipboard or plastic pouch with firm back is useful for carrying maps and air photos.
3. Hand lens
4. Pocket knife (or small sheath knife for study of soil profiles and unconsolidated material)
5. Ball point pen
6. Marking pencils for marking specimens; chalk for marking outcrops
7. Sample bags (paper, cloth, or plastic); newspaper for wrapping delicate specimens
8. Measuring tapes; scale with inches and cms
9. Topographic, geologic, and road maps
10. Field trip guides or reports on the area
11. Hammer (and trenching shovel for unconsolidated materials)
12. Camera
13. Small backpack or collecting bag
14. Calculator
15. Colored pencils
16. Triangles or set squares
17. Protractor
18. Chalk

For other trips more and specialized equipment will be added. A soil auger might be included for mapping surficial materials; a copy of the AGI Data Sheets (American Geological Institute, 1982) might prove useful in many situations.

3.3 Clothing and Personal Gear

Personal gear will vary with the individual's needs, but usually less is needed than normally taken while traveling. Suits are not necessary unless you are travelling where you expect to be dining in the evening!

The amount and type of clothing and gear depends on the climate, season, length and objectives of the trip and the nature of transportation. The

following list (Table 3) is quite comprehensive--not all of this gear would be useful on our 5-day Appalachian Trip; however, the list may assist you in planning the trip and it may be useful for other trips. It has been compiled from several sources including reports from expeditions and the mining industry (Safety Committee, 1982) and from Fletcher (1969). For Appalachia in March you should be prepared for rain or snow and warm or cold conditions.

Table 3. Clothing and personal gear

Field boots	Sunglasses
Running shoes or casual shoes	Spare eyeglasses
Socks	Flashlight
Underwear	Water bottle
Shirt	Binoculars
Sweater	Sleeping Bag
Long pants	Camera and equipment
Belt	Film
Rain gear or foul weather gear	Maps
Jacket	Compass
Hat	Watch
Bathing Suit	Keys
Gloves/Mits	Wallet
Suitcase/Duffel bag/Backpack	Money
Also	
Toothbrush and paste	Hand Lotion
Comb, soap	First-Aid Kit
Footpowder	Needles and Thread
Suntan Oil	Insect Repellant
Lip Salve	

3.4 Field Notes

Taking field notes is something of an art, but one must be methodical in approach or important observations will not be made or recorded. Also, ideas may be confused with facts. For information on taking field notes for a geological survey see Barnes (1981), Compton (1962), Moseley (1981) or Tucker (1982). For field trip purposes we need not be so rigorous in our approach, but many ideas are useful and should be applied.

A hardback waterproof notebook is preferred by many geologists, particularly when a map clipboard is not used. Others prefer to use separate sheets in a clipboard, thus minimizing risk of loss of all the notes, improving the ease of drying and inserting pages and preparing larger uniform field sketches. On this field trip the blank facing pages of the guidebook could be used for field notes.

The notes are not used to supplement memory--often they must be used by others--but must be accurate and clear accounts of the facts. Ideas and hypotheses should be identified; sketches, maps and cross-sections may be used to clarify information in the notes. Photographs and collected specimens should be numbered and noted.

The style of notes varies, but printing and careful use of abbreviations will aid clarity. The top of each page (if loose pages are used) or at the start of each day's notes (if a book is used), should contain the date, location or stop, name of notetaker, and page number. Weather and time may also be noted to aid recall.

At the end of each day, notes should be reviewed with important observations being circled or underlined (Moseley, 1981) and cross-references made to similar features elsewhere. A summary may be useful.

The descriptions made will depend on the nature of the investigation and the importance of the stop. In mapping and studying glacial deposits, not only the material, but also notes on topography and landforms will be a very important part of the observations. In the beginning of any type of study it is often useful to make observations of features that may possibly be related to the main purpose of the study. These notes may provide important clues later, when new hypotheses have been developed. The detail and focus of notes will change after familiarity with the area is obtained.

The following items should be considered when describing the rocks and exposures in the field. It is modified from Compton (1962).

1. Rock type or unit name
2. Nature of the exposure (cut, quarry, etc) A sketch is often useful to show the outcrop, the covered areas and the gross structure and layers.
3. Main rock types present
4. Structures with shape and thickness of beds, major sedimentary features of the unit (cross-bedding), cleavage
5. Description of rocks: type, color (fresh and weathered), grain size, grain shape, sorting and orientation, nature and amount of cement and groundmass, porosity, and percentage of different grain types.
6. Fossils: types, distribution, condition, position and associated rock types.
7. Contacts of units

In describing a fold, the axis with trend and plunge, and the strike and dip of the axial plane should be noted. Sketches of the folds, with secondary folds and cleavages are useful here.

On a quick trip through an area, it will be impossible to obtain the detailed notes that a field geologist would obtain. Often the geologist will have many hours to study an important outcrop and will see features and relationships clearly in related outcrops that are not available to us while on a field trip. Even viewing an outcrop in different light and with different moisture conditions may provide clues not seen before. Also, some geologists are better able to see features (from training, experience, or by using a working hypothesis) that others would miss or not expect. Also on a field trip, part of the time at a stop will be used for taking notes from the field trip leaders who are describing the important features of the stop.

In general, location (with numbers that correspond to the map and the field guide), exposure type, the formation and age of the units, and a description of the rocks including fossils and structure are basic details that should be recorded at a stop. Sketches are particularly useful.

3.5 Field Maps

When mapping in the field, base maps are used for the geology. These base maps map be planimetric, if suitable landscape and cultural features are available for locating the features being mapped. Topographic maps are preferred, if available, and photographs may also be used. When using air photographs the mapping may be done on the photo or it may be done on a transparent overlay to preserve the photograph. As photographs show details not on topographic maps, they are preferred; however, the geologic data on the photos usually must be transferred to a topographic map for the final report.

Usually two copies of the base map--one for the camp or office and one for the field--are used. The main features to place on the map are the geologic units, that is the formations or larger units and the contacts between the different units. Also important are the structures depicting the folds and faults and the strike and dip of the units. Key beds and the strike and dip of contacts are also recorded on the maps.

Establishing the contact between formations is relatively easy when formations are distinctive and where they are well exposed. By simply walking out the contact it can be mapped or easily seen on an air photograph for mapping. In many areas the vegetation or colluvium covers the rock and contacts must be inferred from the attitude and distribution of beds at scattered outcrops. Sometimes the approximate contact can be determined by changes in vegetation, slope, and the character of the colluvium (boulders of bedrock).

The units are shown on the map using rock symbols, abbreviations, or colors, or a combination of these. The lithologic symbols used in mapping and the symbols used to record folds and faults are given in the Appendix.

To determine where a feature should be placed on a map, several techniques may be used. Often the easiest is by inspection. If the mapper is familiar with the scale of the map and there are enough features in the area that can be identified on the map, this is the fastest method. Other approaches include pacing from a known feature to the outcrop, by intersection to known points, and by use of an altimeter with a topographic base map. More than one method may be used on a map and several techniques may be combined. Geologists often use traverses to obtain the necessary information. This involves walking through the area using a compass for direction and pacing for distance so that the outcrops and features can be located on the map.

3.6 Samples

For field trips, the objectives of those collecting samples are different from the field geologist. But one factor remains constant--the samples are usually useless if they have not been labeled. We usually collect rocks and fossils for further study, for teaching purposes or because they are interesting or beautiful. Loss of interest in a specimen or completion of study may occur in a day, by the end of the trip, in several months, or many years later. (Many rocks go into the trash at the end of a field trip).

Collecting rocks can be dangerous. Hard rocks should not be hit with a hammer while others look on; pieces of metal and rock can fly off and injure observers. There is also a danger to the person with the hammer. It is wise to shield your eyes with glasses or your forearm when hitting hard rocks.

In a field mapping program the geologist collects rocks for further study--to check on the field identification using lab techniques, to further describe in detail the rock and its features and to compare the sample with others from the same area. For these purposes, samples should be representative and show fresh rock material. Hand size specimens are usually taken, unless larger samples are needed to study special features or for subsampling.

Fossils are usually collected to determine age and correlation of the unit. Collection from the outcrop is important; samples found in loose rock may have been transported some distance (even many miles from another outcrop!). Often loose rock provides good fossil specimens because they are exposed on weathering. These specimens should be saved. They often give clues where to find fossils in place in the outcrop. Stop location should be recorded for these specimens also.

Complete fossil specimens are rare in the field. Additional cleaning of specimens should be done in the lab -- there seems to be a law that if a rock is hit with a hammer it will fracture through the best fossil specimen in the rock. Fragile specimens should be wrapped in soft paper to protect them. In some cases shellac and other cementing agents are used in the field to protect valuable fossils. Carbonaceous films are particularly difficult to protect.

Any rock or fossil sample should be labelled. This can be done with a felt-tip pen or with paper or tape on the sample. Various schemes are used indicating collector, location of stop, and place or sample number at the stop. Thus JR2-1b, might be used for the second sample (b) collected by James Rock, on Day 2 at Stop 1. Other codes may be devised.

Samples should be cross-referenced to field notes and the map. At the end of the day they should be checked for correct labels and a list of samples should be made.

3.7 Field Etiquette

The following is reprinted from Haney (1984).*

A code for field work

Recent letters to *Geotimes* have deplored instances of vandalism at classic outcrops. And last month, we commented on the desirability of more active participation by geologists in local environmental and conservation societies. Both concerns are well covered, we think, in *A code for geological field work*, issued by the Geologists' Association, London, and called to our attention by a colleague who believes that it deserves wider circulation. The *Code* is reprinted here by permission of the Association (omitting only a short section referring to the British *Health and safety at work act*).

•••

A geological 'code of conduct' has become essential if opportunities for field work in the future are to be preserved. The rapid increase in field studies in recent years has tended to concentrate attention upon a limited number of localities, so that sheer collecting pressure is destroying the scientific value of irreplaceable sites. At the same time the volume of field work is causing concern to many site owners. Geologists must be seen to use the countryside with responsibility; to achieve this, the following general points should be observed.

1. Obey the Country Code, and observe local byelaws. Remember to shut gates and leave no litter.
2. Always seek prior permission before entering private land.
3. Don't interfere with machinery.
4. Don't litter fields or roads with rock fragments which might cause injury to livestock, or be a hazard to pedestrians or vehicles.
5. Avoid undue disturbance to wildlife. Plants and animals may inadvertently be displaced or destroyed by careless actions.
6. On coastal sections, consult the local Coastguard Service whenever possible, to learn of local hazards such as unstable cliffs, or tides which might jeopardise excursions possible at other times.
7. When working in mountainous or remote areas, follow the advice given in the pamphlet *Mountain safety*, issued by the Central Council for Physical Education, and, in particular, inform someone of your intended route.
8. When exploring underground, be sure you have the proper equipment, and the necessary experience. Never go alone. Report to someone your departure, location, estimated time underground, and your actual return.
9. Don't take risks on insecure cliffs or rock faces. Take care not to dislodge rock, since other people may be below.
10. Be considerate. By your actions in collecting, do not render an exposure untidy or dangerous for those who follow you.

Sheer collecting pressure is destroying the scientific value of irreplaceable sites. At the same time the volume of field work is causing concern to many site owners.

Collecting and field parties

1. Students should be encouraged to observe and record but not to hammer indiscriminately.
2. Keep collecting to a minimum. Avoid removing *in situ* fossils, rocks or minerals unless they are genuinely needed for serious study.
3. For teaching, the use of replicas is commended. The collecting of actual specimens should be restricted to those localities where there is a plentiful supply, or to scree, fallen blocks and waste tips.
4. Never collect from walls or buildings. Take care not to undermine fences, walls, bridges or other structures.
5. The leader of a field party is asked to ensure that the spirit of this Code is fulfilled, and to remind his party of the need for care and consideration at all times. He should remember that his supervisory role is of prime importance. He must be supported by adequate assistance in the field. This is particularly important on coastal sections, or over difficult terrain, where there might be a tendency for parties to become dispersed.

Visiting quarries

1. An individual, or the leader of a party, should have obtained prior permission to visit.
2. The leader of a party should have made himself familiar with the current state of the quarry. He should have consulted with the Manager as to where visitors may go, and what local hazards should be avoided.
3. On each visit, both arrival and departure must be reported.
4. In the quarry, the wearing of safety hats and stout boots is recommended.
5. Keep clear of vehicles and machinery.
6. Be sure that blast warning procedures are understood.
7. Beware of rock falls. Quarry faces may be highly dangerous and liable to collapse without warning.
8. Beware of sludge lagoons.

Research workers

1. No research worker has the special right to 'dig out' any site.
2. Excavations should be back-filled where necessary to avoid hazards to men and animals and to protect vulnerable outcrops from casual collecting.
3. Don't disfigure rock surfaces with numbers or symbols in brightly coloured paint.
4. Ensure that your research material and notebooks eventually become available for others by depositing them with an appropriate institution.
5. Take care that the publication of details does not lead to the destruction of vulnerable exposures. In these cases, do not give the precise location of such sites, unless this is essential to scientific argument. The details of such localities could be deposited in a national data centre for geology.

Societies, schools and universities

1. Foster an interest in geological sites and their wise conservation. Remember that much may be done by collective effort to help clean up overgrown sites (with permission of the owner, and in consultation with the Nature Conservancy Council).
2. Create working groups for those amateurs who wish to do field work and collect, providing leadership to direct their studies.
3. Make contact with your local County Naturalists' Trust, Field Studies Centre, or Natural History Society, to ensure that there is coördination in attempts to conserve geological sites and retain access to them.

•••

* With permission of GEOTIMES.

3.8 Planning a Field Trip

The amount of planning will depend on the complexity of the trip as determined by the length of time, distance, number and age of participants and the modes of travel. For a local trip of several hours with a few students the task is relatively easy; for several weeks in the mountains or on an island, the task is more difficult. No good book on planning field trips is readily available; however, several organizations provide services to teachers for planning and running field trips (e.g. International Field studies, Columbus OH and Educational Field Expeditions, Birmingham, AL). These and other organizations have guidelines, including information on liability and insurance, for running field trips (International Field studies, 1981, and Spence and Medlicott, 1982). The following comments are from several sources including those above and will provide many of the important points to be considered in planning for field trips.

Before The Trip

1. Determine the purpose of the trip and the educational goals of the trip.

2. Select the destination, sites, and route of travel. Sites should meet the educational objectives of the group, but should also be available and safe. Weather and local conditions may dictate the time of year or even time of day a site is visited.

3. Determine the instructors needed and any sources of local assistance.

4. Pre-run the trip if you have not been over it before.

5. Select equipment and transportation needs. Make reservations for vehicles early.

6. Advertise the trip with an announcement and possibly a meeting. Details of the trips should be available in a fact sheet that includes an itinerary and objectives of the trip. Prospective participants should return a personal information sheet.

7. At a meeting of those persons who are committed to the trip, provide special intructions on clothing, equipment, and references or textbooks. Participants should be told what to bring and how to prepare for the trip--assume that they have never traveled before. Complete registration, obtain medical history and medical consent forms (if necessary). Make assigned readings.

8. Develop a field guide for the trip if appropriate. This may be nothing more than an expanded itinerary, or it may contain references and exercises.

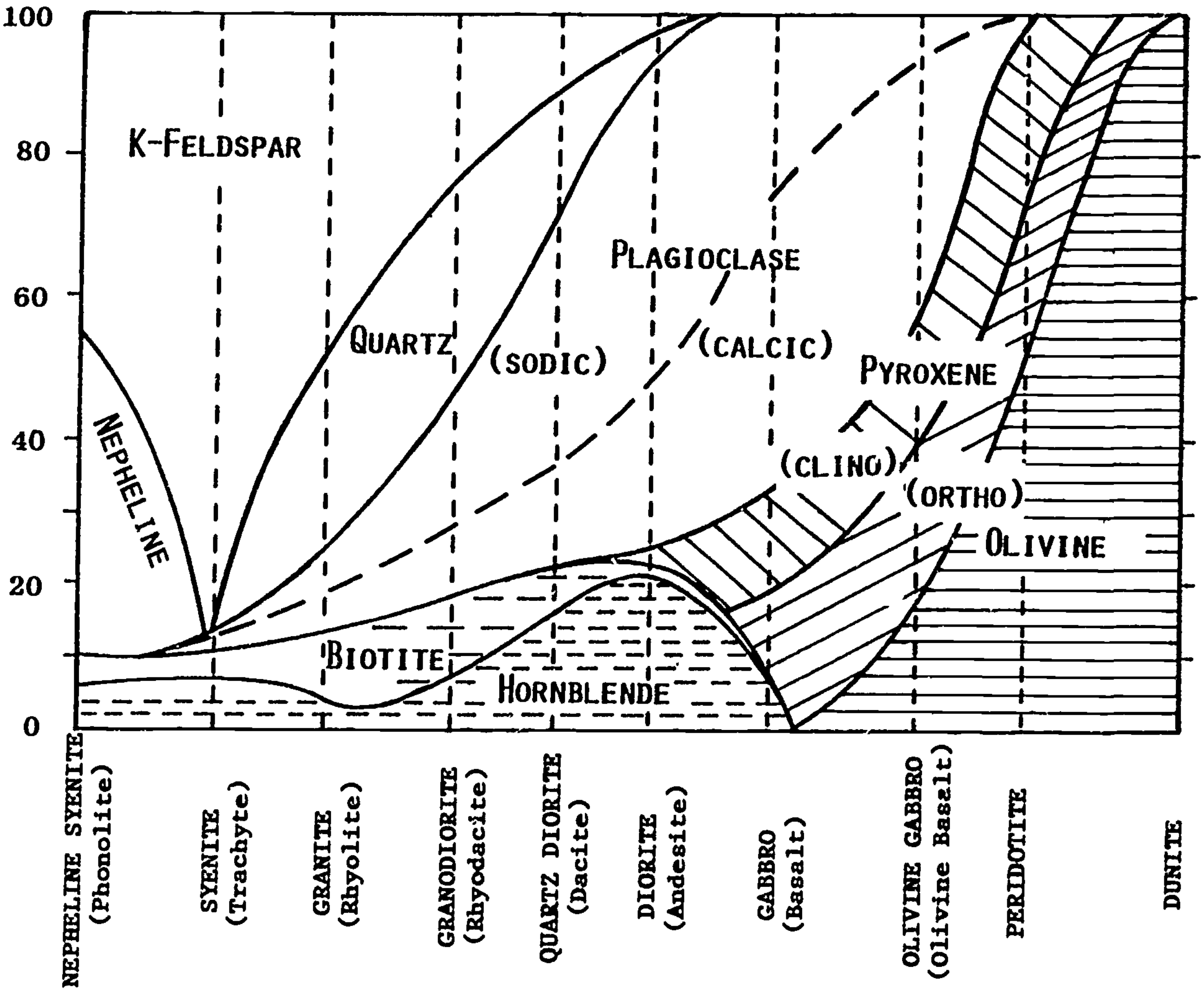
During The TRIP

1. Stick to the plan--no surprises.
2. Have an emergency plan. Phone numbers and contacts should be carried for each participant.
3. Call ahead when necessary.
4. Avoid horseplay and athletics that could result in injury.
5. Stay on schedule, but be prepared to be flexible should field situations or the condition of the participants dictate it.
6. Show concern for the welfare of the participants and be alert to any developing problems.
7. Use common sense.

After The Trip

1. At post-trip meetings.
   - return money not spent, completed exercises, and any lost belongings.
   - reports by participants on post-trip projects.
   - review of trip and summary of accomplishments.
   - field trip and course evaluation by participants.
2. Do preliminary revisions to the course. Include revisions to planning format, announcements, exercises, reference list, and guidebook.

APPENDICES



APPENDIX A CLASSIFICATION OF IGNEOUS ROCKS. Extrusive equivalents in parentheses.

APPENDIX A CLASSIFICATION OF METAMORPHIC ROCKS (modified from Foster, 1985).

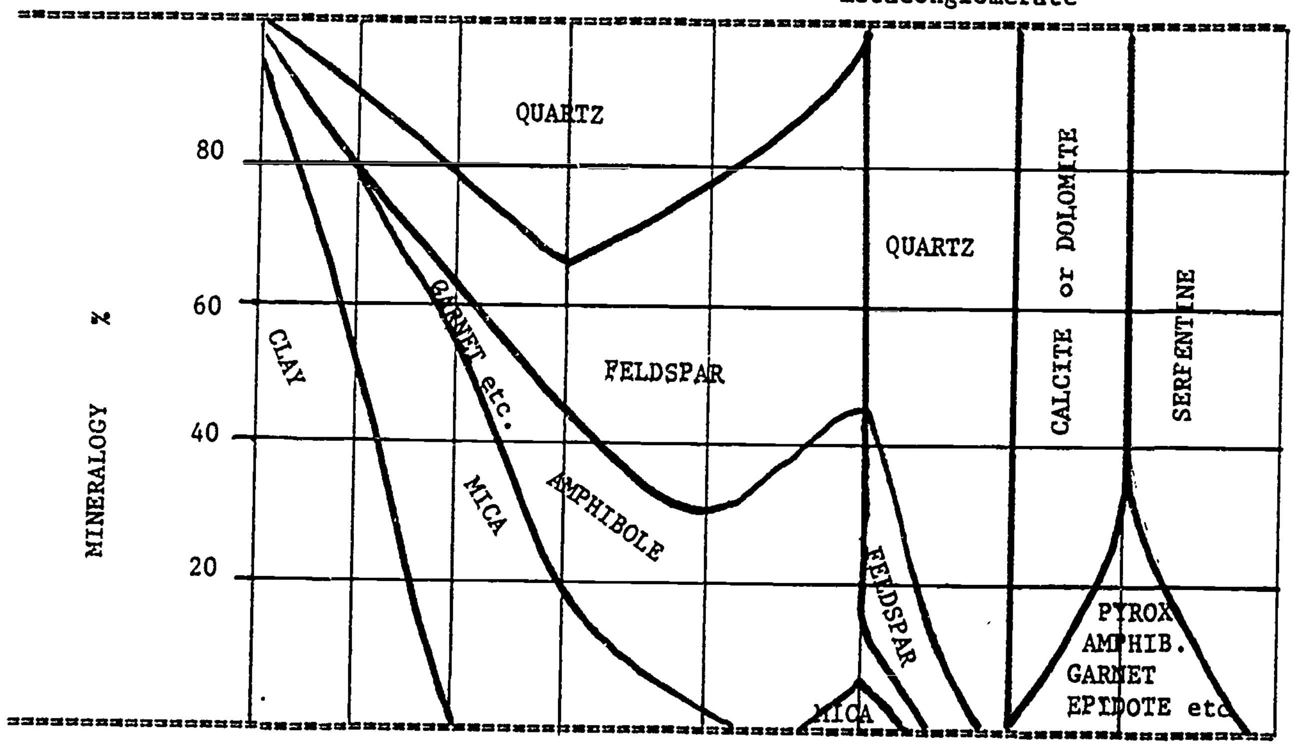
FOLIATED

Nonlayered
- v. f. gr. slate
- f. gr. phyllite
- med./c. gr. schist amphibolite

Layered
- c. gr. gneiss

NONFOLIATED

- f. gr. ←hornfels→ serpentinite
- f./c. gr. quartzite marble
- c. gr. metaconglomerate



APPENDIX A CLASSIFICATION OF SEDIMENTARY ROCKS (modified from Hamblin and Howard, 1980).

CLASTIC (or Terrigenous Detritus)

TEXTURE	COMPOSITION	SEDIMENT	SEDIMENTARY ROCK
coarse gr. > 2 mm	rounded grains, any type, quartz dominant	gravel	conglomerate
	angular frags.		breccia
variable	variable	diamicton/till	diamictite
medium gr. 2 - 1/16 mm	qtz w/ access.	sand	quartz sandstone
	qtz w/ > 25% feldspar	sand	arkose
	qtz w/ rock frags. and much clay	loam/diamicton	graywacke
fine gr. 1/16 - 1/256 mm	quartz and clays	silt/loess	siltstone
v. f. gr. < 1/256	qtz and clays	clay	shale/mudstone

INORGANIC CHEMICAL (or Precipitated Nonclastics)

TEXTURE	COMPOSITION	ROCK TYPE
f - c x'line	NaCl (halite)	rock salt
f - c x'line	$CaSO_4 . 2H_2O$ (gypsum)	gypsum
crypto x'line	$CaCO_3$	nonfossiliferous limestone
banded	$CaCO_3$	tufa/travertine
crypto x'line	SiO_2 (silica)	chert/flint/chalcedony/jasper

ORGANIC CHEMICAL (BIOCHEMICAL) (incl. Precipitated Clastic or Organic Detrital)

micro shells+ clay	$CaCO_3$	chalk
abundant foss. in $CaCO_3$ matrix	$CaCO_3$	fossiliferous limestone
fossils + foss. frags.,	$CaCO_3$	coquina
aggr.of oolites	$CaCO_3$	oolitic limestone
abundant-micro shells	SiO_2 (silica)	diatomite
abundant-micro shells	SiO_2 (silica)	radiolarian chert
fibrous	organic matter	peat
granular/uniform banded	carbon + volatiles + clays	coal

APPENDIX B TOPOGRAPHIC MAP SYMBOLS

- Hard surface, heavy duty road, four or more lanes
- Hard surface, heavy duty road, two or three lanes
- Hard surface, medium duty road, four or more lanes
- Hard surface, medium duty road, two or three lanes
- Improved light duty road
- Unimproved dirt road and trail
- Dual highway, dividing strip 25 feet or less
- Dual highway, dividing strip exceeding 25 feet
- Road under construction

- Railroad, single track and multiple track
- Railroads in juxtaposition
- Narrow gage, single track and multiple track
- Railroad in street and carline
- Bridge, road and railroad
- Drawbridge, road and railroad
- Footbridge
- Tunnel, road and railroad
- Overpass and underpass
- Important small masonry or earth dam
- Dam with lock
- Dam with road
- Canal with lock

- Buildings (dwelling, place of employment, etc.)
- School, church, and cemetery — Cem
- Buildings (barn, warehouse, etc.)
- Power transmission line
- Telephone line, pipeline, etc. (labeled as to type)
- Wells other than water (labeled as to type) — Oil, Gas
- Tanks; oil, water, etc. (labeled as to type) — Water
- Located or landmark object; windmill
- Open pit, mine, or quarry; prospect
- Shaft and tunnel entrance

Horizontal and vertical control station:

- Tablet, spirit level elevation — BM△5653
- Other recoverable mark, spirit level elevation — △5455

Horizontal control station: tablet, vertical angle elevation — VABM△9519

- Any recoverable mark, vertical angle or checked elevation — △3775

Vertical control station: tablet, spirit level elevation — BM×957

- Other recoverable mark, spirit level elevation — ×954

Checked spot elevation — ×4675

Unchecked spot elevation and water elevation — ×5657

- Boundary, national
  - State
  - County, parish, municipio
  - Civil township, precinct, town, barrio
  - Incorporated city, village, town, hamlet
  - Reservation, national or state
  - Small park, cemetery, airport, etc.
  - Land grant
- Township or range line, United States land survey
- Township or range line, approximate location
- Section line, United States land survey
- Section line, approximate location
- Township line, not United States land survey
- Section line, not United States land survey
- Section corner, found and indicated
- Boundary monument: land grant and other
- United States mineral or location monument

- Index contour
- Intermediate contour
- Supplementary contour
- Depression contours
- Fill
- Cut
- Levee
- Levee with road
- Mine dump
- Wash
- Tailings
- Tailings pond
- Strip mine
- Distorted surface
- Sand area
- Gravel beach

- Perennial streams
- Intermittent streams
- Elevated aqueduct
- Aqueduct tunnel
- Water well and spring
- Disappearing stream
- Small rapids
- Small falls
- Large rapids
- Large falls
- Intermittent lake
- Dry lake
- Foreshore flat
- Rock or coral reef
- Sounding, depth curve
- Piling or dolphin
- Exposed wreck
- Sunken wreck
- Rock, bare or awash; dangerous to navigation

- Marsh (swamp)
- Submerged marsh
- Wooded marsh
- Mangrove
- Woods or brushwood
- Orchard
- Vineyard
- Scrub
- Inundation area
- Urban area

APPENDIX C SYMBOLS FOR GEOLOGIC MAPS

Contacts

Definite

Approximately located

Concealed by mapped unit

Bedding

Horizontal beds

Strike and dip of beds
(strike north; dip 20° east)

Strike of vertical beds

Strike and dip of overturned beds
(strike north; dip 70° east)

Faults

Fault (showing relative vertical motion)

Fault (showing dip)

Inferred fault

Fault concealed by mapped unit

Thrust or reverse fault
(barbs on side of upper plate)

Folds

Anticline
(trace of axial surface)

Syncline
(trace of axial surface)

Overturned Anticline
(showing trace of axial surface and dip of limbs)

Overturned Syncline
(showing trace of axial surface and dip of limbs)

Anticline (showing crestline and plunge)

Syncline (showing crestline and plunge)

Dome

Joint

Strike and dip of joint

Foliation

Strike and dip of foliation

Bearing and plunge of lineation

Glacial striation

APPENDIX D. KEY FOR FOSSIL IDENTIFICATION*

I. ASYMMETRIC SHELLS OR SKELETONS

A. one-piece shells .... Many Gastropoda (a class of the Phylum Mollusca)

II. RADIALLY SYMMETRICAL SHELLS OR SKELETONS

A. solitary animals

1. skeletons one-piece; horn or cup-shaped .... solitary coral (Phylum Coelenterata)

2. skeletons a mosaic of many pieces, often spiny .... Phylum Echinodermata

a) with a plated stem

i) few plates in skeleton (about 13) .... Class Blastoidea

ii) many plates in skeleton .... Class Crinoidea

b) without a stem

i) star-shaped, 5 arms .... starfish (Class Stelleroidea)

ii) bun-or melon-shaped .... echinoids (Class Echinoidea)

B. colonial animals; tubes readily visible, each showing radial symmetry .... colonial corals (Phylum Coelenterata)

III. BILATERALLY SYMMETRICAL SHELLS OR SKELETONS

A. fossil material solid, not porous or cellular

1. solitary animals

a) one-piece shells

i) symmetrically coiled shells undivided by internal partitions .... some Gastropoda (a class of the phylum Mollusca)

ii) straight or symmetrically coiled shells divided internally by transverse partitions, the edges of which show as grooved lines (called *sutures*) around the fossil .... Cephalopoda (a class of the Phylum Mollusca)

x) sutures straight or broadly curved .... nautiloid cephalopods

y) sutures very wrinkled .... ammonoid cephalopods

b) bivalved shells

i) equivalved .... Pelecypoda (a class of the Phylum Mollusca)

ii) inequivalved .... Phylum Brachiopoda

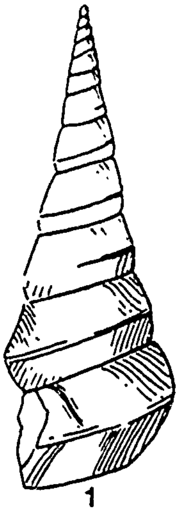
c) skeleton of many pieces .... Phylum Arthropoda (trilobites only common large fossils)

2. colonial animals; symmetry not obvious; colonies twig-or branchlike, or laminated, encrusting, or fan-shaped; individual tubes very tiny .... Phylum Bryozoa

B. fossil material originally cellular. Complete skeletons of many pieces is only rarely found .... Phylum Chordata

* (From Fuller and Utgard, eds., Laboratory Manual for Introductory Geology, copyright 1978, Department of Geology and Mineralogy, The Ohio State University. Reprinted with permission.)

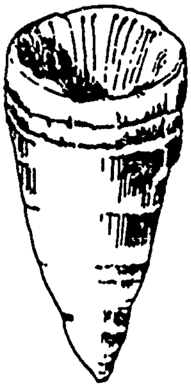
Fossil Plate I



1

Symmetry ____________

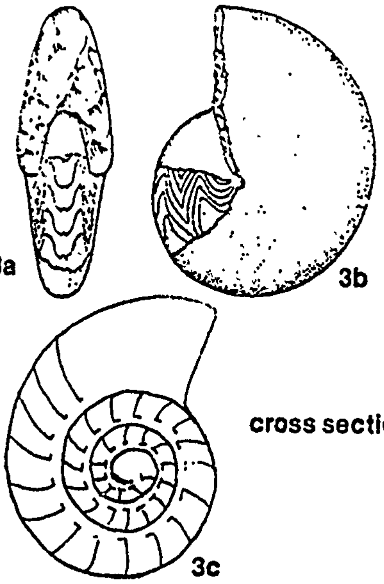
Class ________________



2

Symmetry ____________

Common name ________



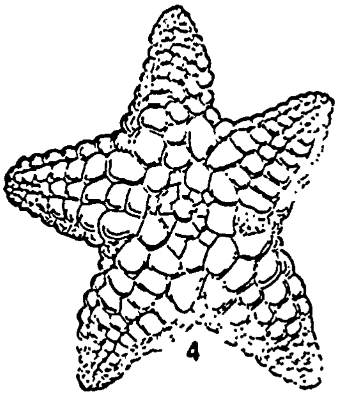
3a 3b

cross section

3c

Symmetry ____________

Class ________________



4

Symmetry ____________

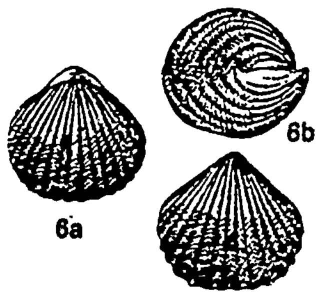
Common name ________

5

Solitary or colonial?

____

Common name ____________



6a 6b 6c

Symmetry ____________

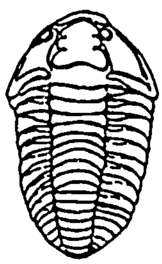
Phylum ______________

7a 7b

Symmetry ______________________

Equi- or inequivalved __________

Class __________________________

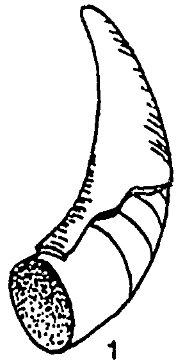


8

Symmetry ____________

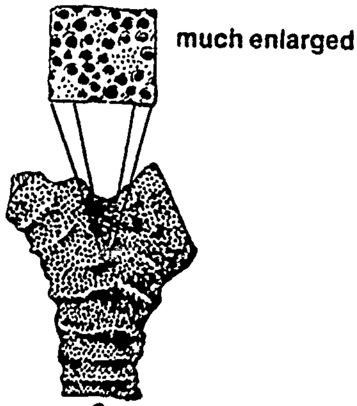
Common name __________

Fossil Plate II



1

Class ____________



2

Symmetry ____________

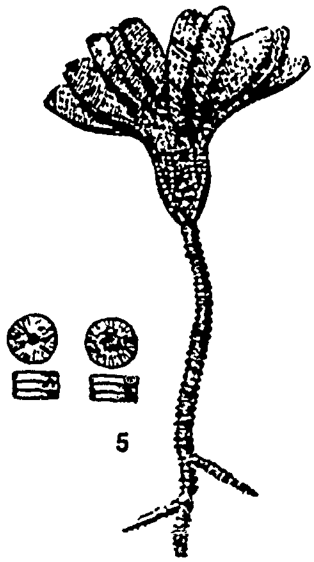
Solitary or colonial? ____________

Phylum ____________

3

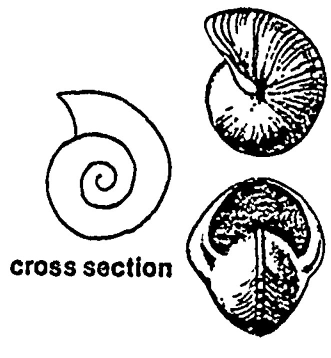
Class ____________

4

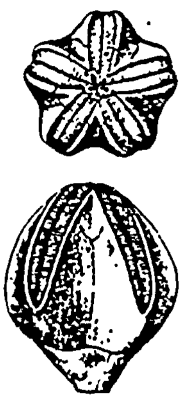


5

Class ____________



6



7

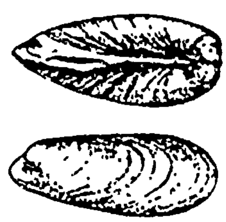
Class ____________

8

Symmetry ____________

Class ____________

Group ____________



9

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NOTES AND DIAGRAMS

... and some rin up hill and down dale,
knapping the chunky stanes to pieces wi' hammers
like so many road-makers run daft--
they say t'is to see how the warld was made!
Sir Walter Scott

NOTES AND DIAGRAMS

"Go my sons, Burn your books, Buy yourselves stout shoes
Get away to the mountains, the deserts and the ends of the earth
In this way and no other will you gain TRUE Knowledge of things
And of their properties! - Peter Severinus, 1571.

ROAD LOG AND STOP DESCRIPTIONS — FIRST DAY

Columbus, OH to Princeton, WV

Major Stops: 1. Teays Drainage at Salt Creek; 2. Pennsylvanian and Mississippian Systems in road cuts; 3. Gallia County strip mines; 4. Point Pleasant Flood Control; 5. Amos Power Plant; 6. Cyclothems near Cabin Creek; 7. Spheroidal weathering in sandstones.

From Ohio State University take I-71 south, I-270 east, and US 23 south. From Columbus to beyond Chillicothe we cross till plains of the Central Lowland Province (Fig. 1·1 and Guide to the Geology Along U.S. Route 23). Topography is subdued; a few kames and eskers are visible. From Columbus to Chillicothe we traverse Devonian Shale bedrock beneath till of the ground moraine. The Wisconsinan end moraine at Chillicothe is subdued because of erosion and the large bedrock hills of the area. The Scioto Valley is floored with alluvium and Wisconsinan outwash. Beyond Chillicothe we also follow outwash terraces; however, some of these are of Illinoian age. The Illinoian ground moraine extends about 10 miles south of the Wisconsinan boundary, but where we cross this area little of the moraine is visible because of outwash.

What clues in the area of the Hartman Farms south of Columbus suggest that the glacial drift is sorted? What are the possibilities for economic deposits in this area and for groundwater supplies for metropolitan Columbus?

Take US 35 east toward Jackson, OH from Chillicothe. At Chillicothe rocks of Mississippian age begin; they form an escarpment at the edge of the Cumberland or Appalachian Plateau. The Mississippian rocks consist of conglomerate, sandstone, siltstone, and shale, which are more resistant to erosion than the Devonian shales. The outcrop belt of these rocks is about 18 miles wide.

Stop 1. Teays Drainage: Roadside park at Salt Creek, 2 miles beyond the Miami Gravel Co. on US 35. Description of Teays drainage (Fig. 1·2), Illinoian end moraine, outwash, and lake deposits. (Glacial Map of Ohio, 15' topo maps). The New River, which begins near Blowing Rock, N.C. in the Blue Ridge Mountains, follows the course of part of the preglacial Teays River.

* * * * *

Continue southeast on US 35 for 11 miles to a deep road cut on the northeast side.

Stop 2. Paleozoic Strata of the Plateau: Road cut showing both Pennsylvanian and Mississippian systems. What and where is the boundary between these systems? Rocks are conglomerate, sandstone, and shale. Are there any fossils? What sedimentary features can you see? How do you think the large blocks of sandstone arrived at the base of the section? Beware! (Stratigraphic section of Ohio, Table 2).

* * * * *

We continue toward Jackson on Pennsylvanian strata and will remain on these nearly flat-lying rocks almost to the end of the day's journey. These sandstones, shales and coal beds have been extensively eroded by streams and the resultant rough and hilly surface is in a stage of early maturity with maximum relief.

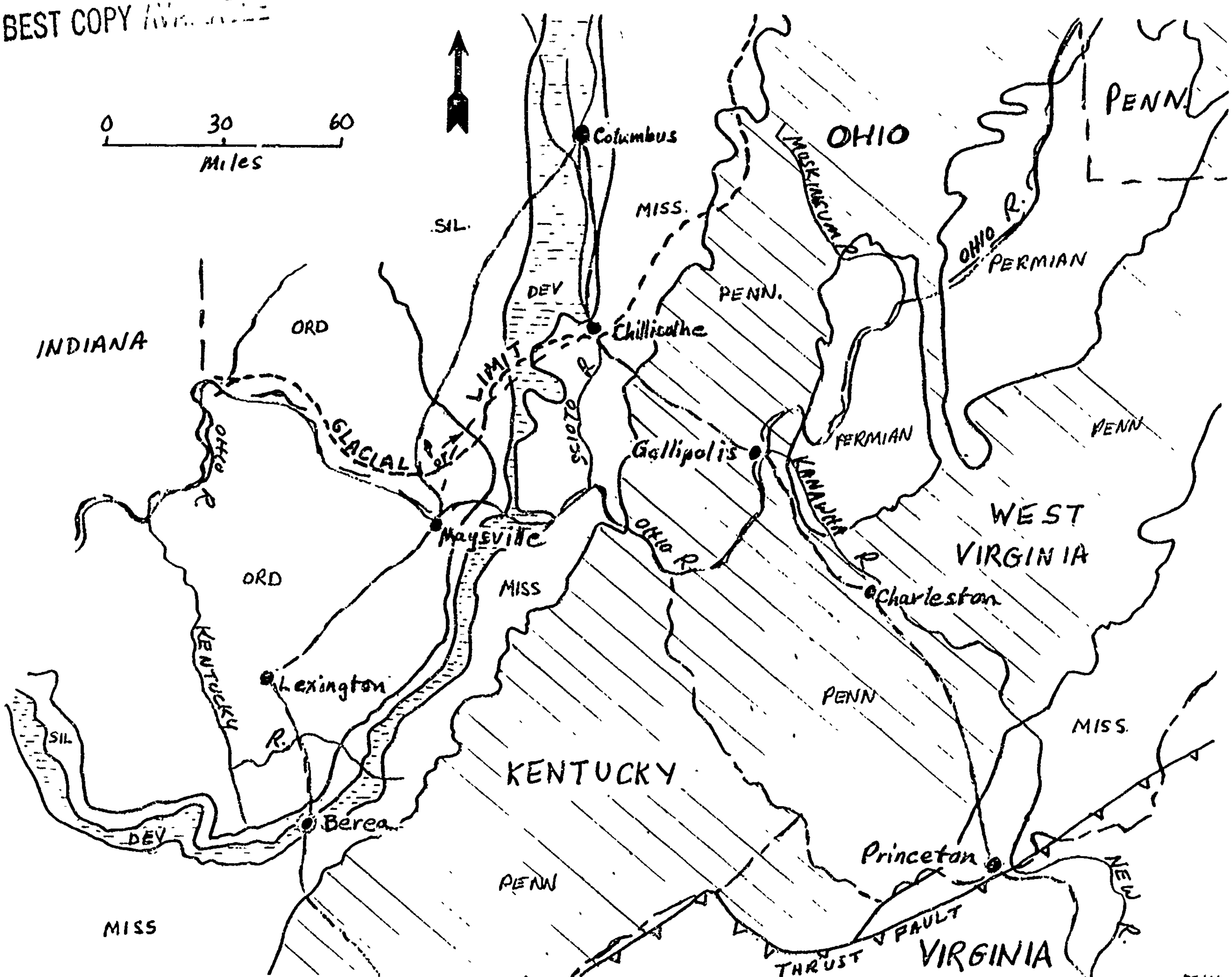


Figure 1.1 Itinerary for the first and fifth days.

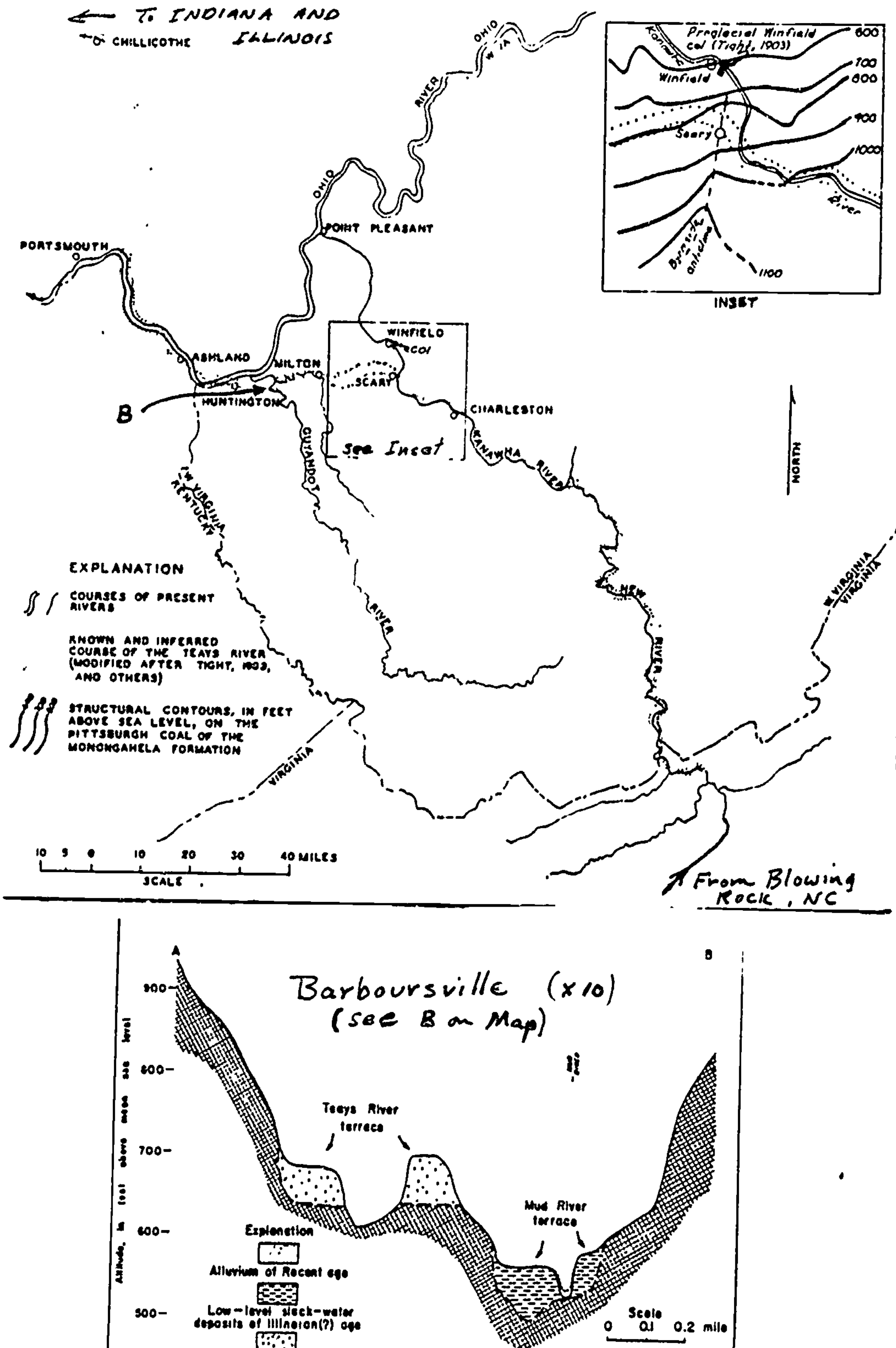


Figure 1.2 Teays River system (Modified from Rhodehamel and Carlston(1963).

BEST COPY AVAILABLE

Three miles down the road we enter Jackson. The water tower is painted to look like an ——————? Why? What was the geologic reason for the growth of this area into a town? There are several old furnaces in Cooper Hollow Wildlife Area (14 miles down the road from Jackson) that once produced iron in this area. Note the landslides near the interchange for the Appalachian Highway. What was the reason for building this highway? Continue on US 35 toward Rio Grande.

As we traverse Gallia County and other areas of Appalachia it is appropriate to recall the words of William Least Heat Moon (1983). "Of the thirteen thousand miles of highway I'd driven in the last months, Ohio 218 through Gallia County set a standard to measure bad roads by with pavement so rough I looked forward to sections where the blacktop was gone completely. Along the shoulders lay stripped cars, presumably from drivers who had given up."

Turn left on OH 325 just after you see the sign for Rio Grande (Fig. 1·3). Take this road past the sewage treatment plant for this town (plus 800 college students) and turn right on OH 554 toward Porter. Continue through Porter for several miles and turn right toward the area of the next stop.

Stop 3. Gallia County Coal Mines and Power Plants: This "stop" includes several stops (Fig. 1·3) to see siltation from unreclaimed strip mines, the strip mines themselves, the Kyger Creek Power Plant (1.0 million kilowatts), and the Gavin Power Plant (2.6 million kilowatts).

Abandoned Surface Mines: Surface mining has disturbed more than 17 percent of the Addison Quadrangle in Gallia County. Mining was done between 1948 and 1965 using the modified-contour technique with hill-top removal and some augering. Reclamation consisted of truncation of the spoil-bank tops to a width of 4.6 meters (15 ft). Trees were planted in nontoxic areas. Survival was minimal and most spoil banks have little vegetation today.

Bedrock in the area is primarily gently dipping, medium-grained Pomeroy Sandstone and associated shale and thin Redstone (No. 8a) coal (Table 1) of the Upper Pennsylvanian Conemaugh Group.. Pre-mining relief was about 90 meters (300 feet). A lack of limestones in the area prevents natural neutralization of acid drainage.

Soils (Muskingum-Upshur and Muskingum-Rarden-Wellston) are part of the sandstone and shale residual soil region. They are shallow to moderately deep, acid-rich, and developed on strongly sloping to steep topography (10 to 20°). These characteristics make the area best suited for forestry.

The continental climate produces an annual precipitation of 965 millimeters (39 in.), which is distributed throughout the year.

Spoil banks consist of disturbed soil and rock (McKenzie and Studlick, 1979). Without vegetative cover, they erode rapidly, as evidenced by numerous gullies and thick sediment accumulations. Grain size ranges from clay to boulders 3 meters (10 ft) in diameter. Soil-size material comprises 60 percent to 80 percent of the spoil material. Sieve analyses (44 samples of spoil and sediment) of the fraction less than 2 millimeters indicated an average grain-size distribution of 92 percent sand, 5 percent silt, and 2 percent clay.

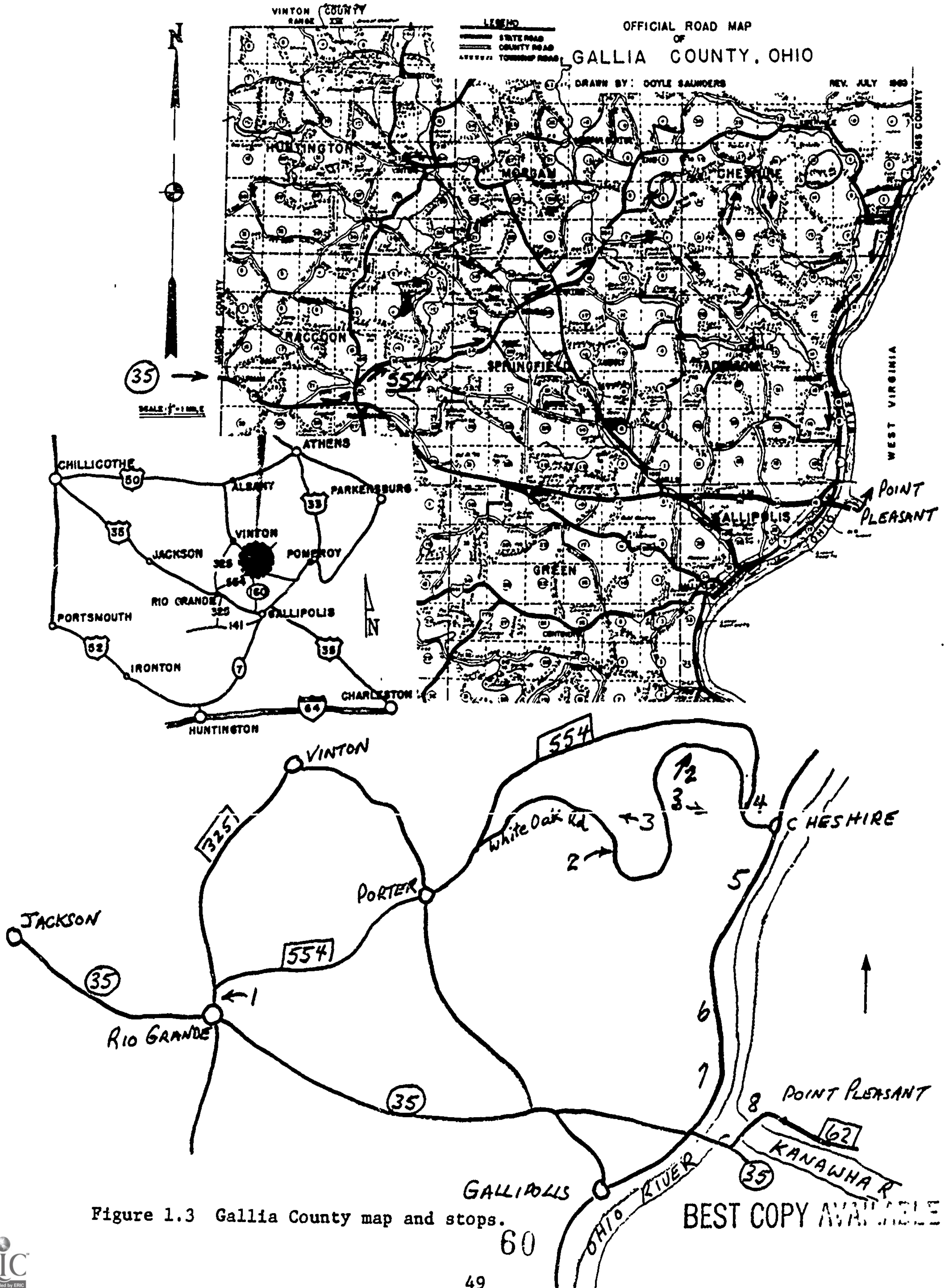


Figure 1.3 Gallia County map and stops.

A composite sample was analyzed for nutrients by standard and greenhouse tests. The material is not suited for plant growth. High surface temperatures due to the spoil's dark color may also hinder growth. Spoil pH, determined for more than 200 samples, ranged from 2.5 to 4.0 in 85 percent of the samples. The limited vegetation now seen on spoil banks is much different than the climax vegetation for this area (Braun, 1969).

Mineralogically, the spoil is similar to the parent rock (overburden), consisting of quartz, feldspar, coal, shale fragments, and clay (primarily illite and kaolinite).

Erosion rates have been measured by several techniques (McKenzie and Studlick, 1978; 1979; McKenzie and Utgard, 1978) and range from 16,000-40,000 metric tons per square kilometer per year (75-175 t/a/yr). Acid mine drainage is a problem in this region due to the oxidation of pyrite (FeS_2).

Power Plants: We will see the Gavin Power Plant (2.6 million kilowatts) which is located up the Ohio River from Kyger Creek, and is one of the main reasons for the "boom" in the area. Some of the coal for the Gavin Plant is deep-mined near Salem Center from the Clarion (No. 4a) Coal and shipped by conveyor belt 10 miles to the power plant. Up to 8 million tons per year is mined from this seam which averages 57" in thickness, 300 to 400 feet below the surface. The coal is mined using the long wall mining technique which has resulted in considerable subsidence of the surface in the area of mining. The Southern Ohio Coal Co. holds the rights for 55,600 acres in western and southwestern Meigs County. The Gavin plant recovers over 99% of the fly ash (where does it go?) and yet the 1,100 foot stacks disperse about 12.5 tons per day.

Do you have any suggestions for the management of the Gallia County strip mine area? Strip mining is not the first industry to change S.E. Ohio. The 19th century iron industry resulted in the removal of vegetation to produce charcoal (Bryant and Drummond 1972). (Stratigraphic section of Ohio, 7 1/2' topo maps, Summer Institute reports).

* * * * *

Leave the power plant area and follow US 7 south to US 35 (Figure 1.3). Note the Gallia Rural Water Plant on the flood plain. Cross the Ohio River (noting barges in the river), and then cross the Kanawha River to Point Pleasant, WV. Turn left off the bridge to Tu-Endie-Wei Park, the 4th stop.

Stop 4. Point Pleasant, WV, Flood Protection: Flood protection for 250 acres of Point Pleasant includes concrete walls, earth levees, pump stations and a diversion channel. It was completed in 1951 at a cost of about $3 million. Flood-damage stage was equalled or exceeded 28 times from 1937 to 1964. During the 1937 flood, the stage reached the top of the porch roof of the log cabin in the park; in all, 2,700 persons were refugees. This flood stage equalled the 1913 flood. **Can you determine how the flood gates work? Why are some houses across from the park not within the flood walls?** It has been suggested that some inhabitants of Point Pleasant enjoyed the floods--the Red Cross came to town, new clothing was obtained, and they sometimes got new wall paper! (Park brochure, flood control information for Point Pleasant). The battle of Point Pleasant was the first major military victory (Oct. 10, 1774) by an exclusively American army. It played a role in the American Revolution (Fleming, 1975).

Continue east through town and follow WV 62 south on the northeast side of the Kanawha River (pronounced by locals as "Kanah"). Note the rugged topography, abundant cedar trees (Eastern Red) and an occasional coal mine. At Leon we see another Public Water System similiar to that in Gallia County. Many rural water systems were developed during the 60's & 70's to improve life in rural and suburban areas; plastic pipe played an important part in this development. Near Leon we encounter the Pennsylvanian-Permian unconformity. Paleocurrents for the Dunkard Group (Permian?) in this area indicate a source area for the sediment to the SE in the Appalachians. Deposition of the Dunkard was in a NE-SW trending basin; the southwestern part of the basin where we are was a fluvial plain during formation of much of this unit. To the north was a deltaic environment in this basin, where the streams were sluggish and swamps and lakes were common. Resulting deposits there were coals, limestones and thin sandstones and clays. Here the sandstones are thick; there were few swamps as the area was well drained. Figure 1·4 shows the paleogeography of the area during Pennsylvanian time, before formation of the Dunkard Group.

At Arbuckle, 4 miles down the road, you will note that the road has buckled! More landslide problems. **How do the ground conditions affect the houses in the area?**

Buffalo is 6 miles up the road; 8 miles beyond that is Eleanor. **Are there any observable differences in these two communities? Why?** One reason for the difference may be two miles beyond Eleanor at ACF.

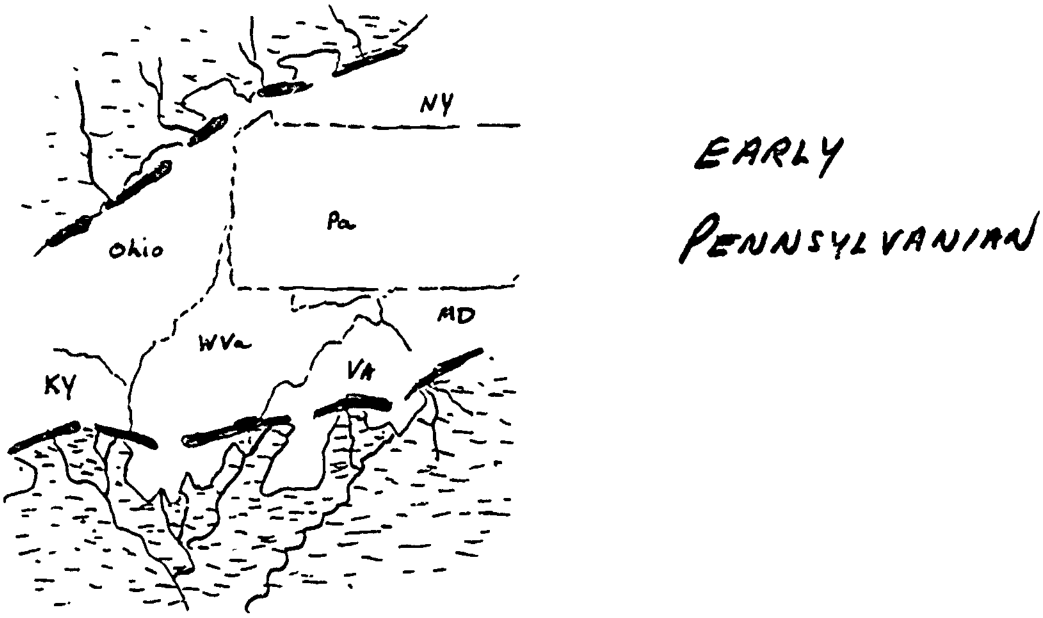
Turn right at "To 35" and cross the bridge over the Kanawha River which is 0.8 miles beyond the Winfield Locks. Continue south on US 35 for about 6 miles for Stop #5.

Stop 5. **A BIG coal-fired electric power plant!** The John E. Amos Power Plant, run by AEP, has a capacity of 2.9 million kilowatts and burns 0.8% sulfur coal mainly from mines in the area. See Figure 1·5 for diagrams of the plant, the precipitaters and the cooling towers. The cooling towers are about 500 feet high, the stacks -- 900 feet (Power Plant Brochures).

* * * * *

3.5 miles down the road, take a **CWS (Car Window Stop)** to view the **Monsanto Chemical complex** along the Kanawha. Between here and the WV Turnpike there is much evidence of industry in the area. The industry is mainly chemical, developed here because of the brines obtained from wells and the coal resources. Salt brine springs occur near Charleston at Burning Springs Creek where the Indians and first settlers prepared salt. The early chemical industry relied on brine and gas from the "Salt Sands" which are sandstones in the Pottsville group (Table 1) (Lower Pennsylvanian); local consumption of brine also includes that from the Silurian rock salt beds of Tyler and Pleasant Counties. Oil and gas, Conemaugh clays used to produce brick and tile, and sandstone used for highway aggregate are other economic products of the area. (Geologic map and report of Charleston, AAPG road map).

At the Monsanto Plant turn right onto I-64. We are now in an abandoned valley of the Teays River (Figure 1·2). We will continue on I-64 crossing the Kanawha again and passing through Nitro, Institute, and Dunbar before crossing the Kanawha for the 4th and 5th times today. Nitro is a town created during WWI to produce smokeless powder. In a short time 3,400 buildings were constructed and the



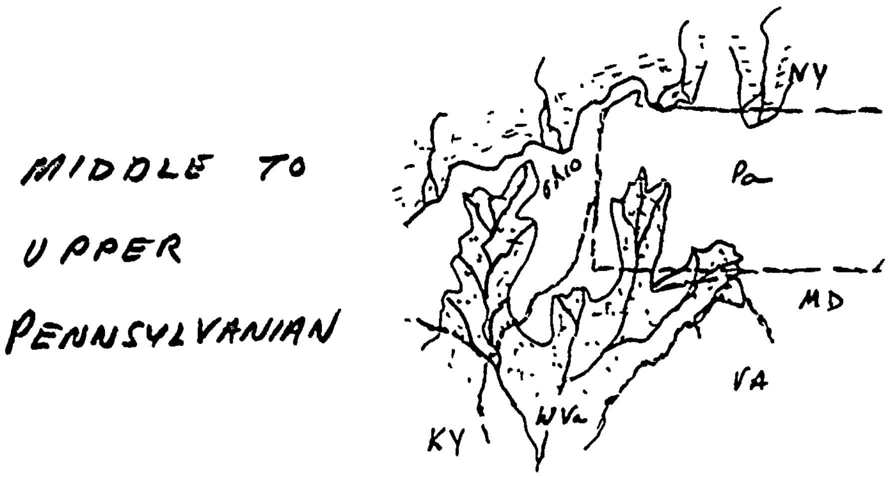
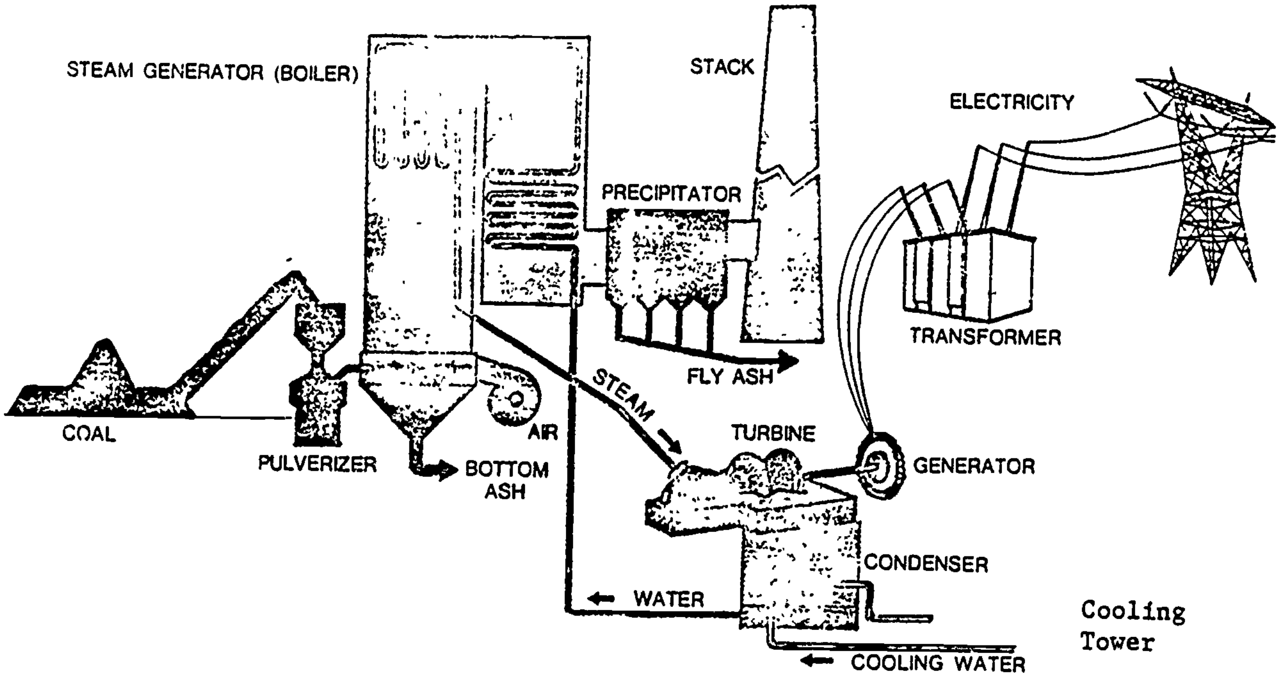
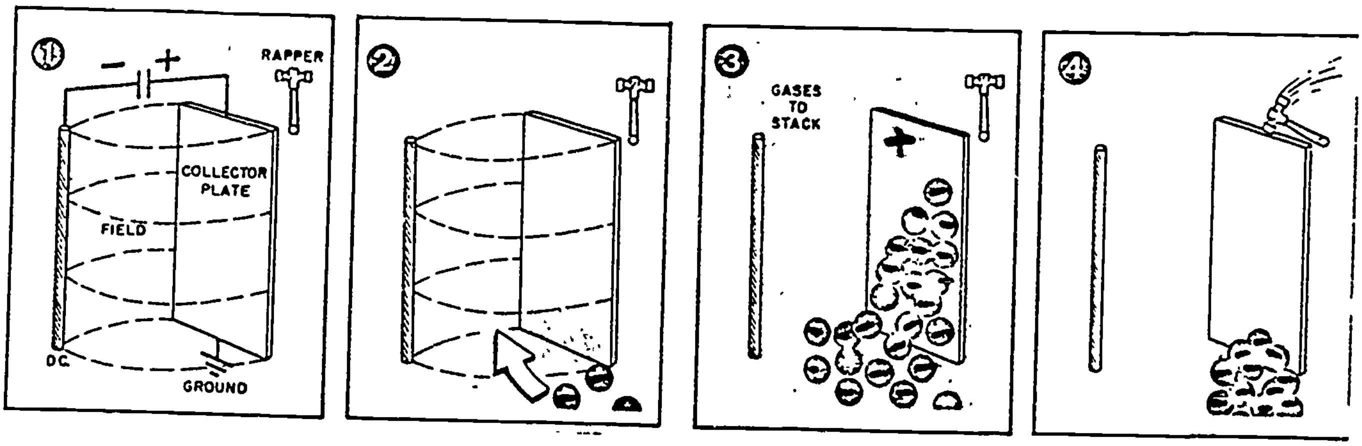


Figure 1.4 Paleogeography of the Appalachian Basin during the Pennsylvanian (modified from Donaldson, 1972).



Cooling Tower

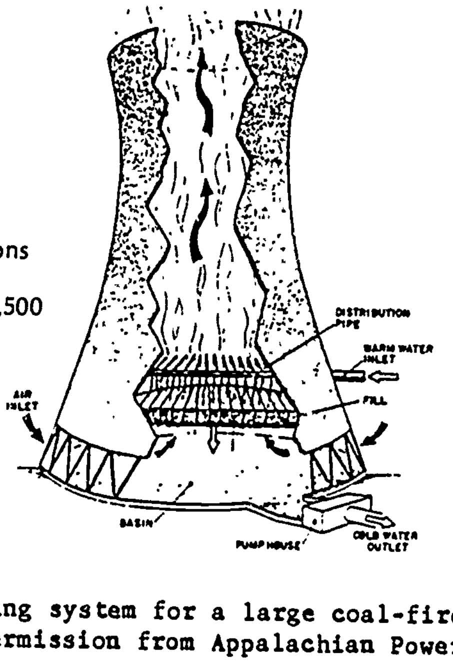


Precipitator

These statistics show the size and capacity of the towers:

Cooling Towers for Units 1 and 2
- Height — 433 feet
- Base diameter — 310 feet
- Circulation rate — 248,000 gallons of water per minute
- Maximum evaporation loss — 5,500 gallons per minute each

Cooling Tower



Cooling Tower for Unit 3
- Height — 492 feet
- Base diameter — 395 feet
- Circulation rate — 600,000 gallons of water per minute
- Maximum evaporation loss — 10,000 gallons per minute

Figure 1.5 Operating system for a large coal-fired power plant (modified with permission from Appalachian Power Company brochures.)

population reached 35,000. After the war the town declined; it now makes chemicals and rayon. Note industries such as FMC, Union Carbide, U.S. Military. A sign on the Union Carbide Plant in the island where I-64 crosses the river reads "Union Carbide helps to build a greater WV." In December, 1984, a Union Carbide plant in Bhopal, India had a poisonous gas (methyl isocyanate) leak, killing more than 2,500 people. That caused concern among the inhabitants of Institute. **Why?** Union Carbide had image problems in Alloy, W.V. in 1970. That plant was known as "The world's smokiest factory" (Anonymous, 1974). It is much cleaner now.

Continue on I-64 and I-77, following the signs toward Beckley, through Charleston, the state capital. Opposite Charleston there is a tall apartment building (Imperial Towers). Knowing that the Pennsylvanian system contains rocks that are suject to sliding, **what rock type do you think underlies these stable, tall buildings?**

We will cross the Kanawha River again just South of Charleston and proceed on I-77 and the West Virginia Turnpike. In the Charleston area we are near the center of a shallow flat basin that is part of the Appalachian Plateau. Before the end of the day we will cross back onto Mississippian rocks. We will make several stops along the Turnpike (I-77), courtesy of the Turnpike Commission. Please do not get so enthusiastic about the rocks that you forget the traffic! Some stops will only be CWS.

Stop 6. **Cyclic deposits in Pennsylvanian:** At the first toll plaza (mile 81) pull off to the right to observe the section from the vehicle. An ideal cyclotherm is shown in Figure 1·6. How did these cyclic deposits originate?

* * * * *

About 18 miles beyond this stop note the mines at Paint Creek and the tramway to the mines (CWS). **How steep are the mountain slopes?**

Nearby Beckley is on a high plateau surrounded by fertile valleys. An agricultural and mining center, it is the "Smokeless Coal Capital of the World" and produced the standard bunker fuel during WWI. An old underground coal mine here is open to tourists.

Stop 7. **Penecontemporaneous deformation in shales:** In the area between miles 27-23 we also see spheroidal weathering at several places. It is best seen between miles 24 and 23..

* * * * *

At Mile 26 we reach an elevation of 3245'. **How many feet have we risen since leaving Campus?** In about two miles we cross the valley of the Bluestone River. Note entrenched meanders and concordant surfaces. **What stage of regional development is this?**

Continue toward Princeton. At mile 21 note weathering, to form rounded columns, in shale. 18 miles beyond the Bluestone River note cut-and-fill features and small fault (CWS). Enter Princeton. End of first day. Fourteen miles west of Princeton is Bluefield - the "Air-conditioned City" - named for the blue chicory on the hills. The Pocahontas Coal Field is nearby.

Departure time 8:00 a.m. tomorrow, after breakfast. Review geologic mapping and the Brunton compass for tomorrow. Study the correlation chart (Fig. 1·7).

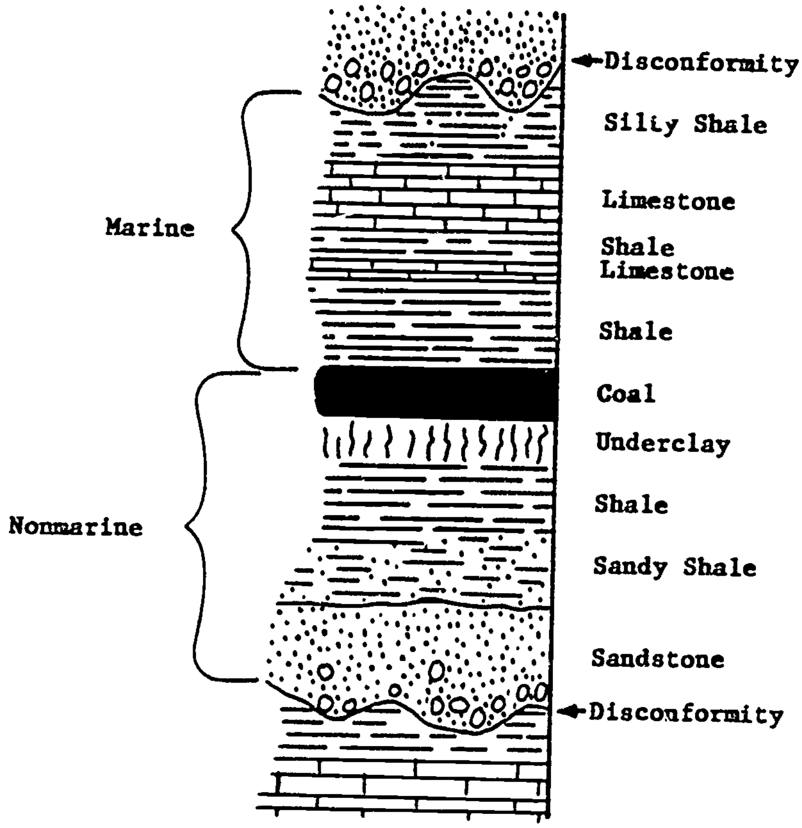


Fig. 1.6 A cyclothem, typical of Pennsylvanian deposits in the eastern interior of North America. Rocks from the lower disconformity to the top of the coal bed are nonmarine, whereas those from the top of the coal to the higher disconformity contain marine fossils. The underclay just below the coal is thought to be the soil on which the coal forest grew. Not all units are present in every cyclothem (modified from Bates, Sweet and Utgard, 1973).

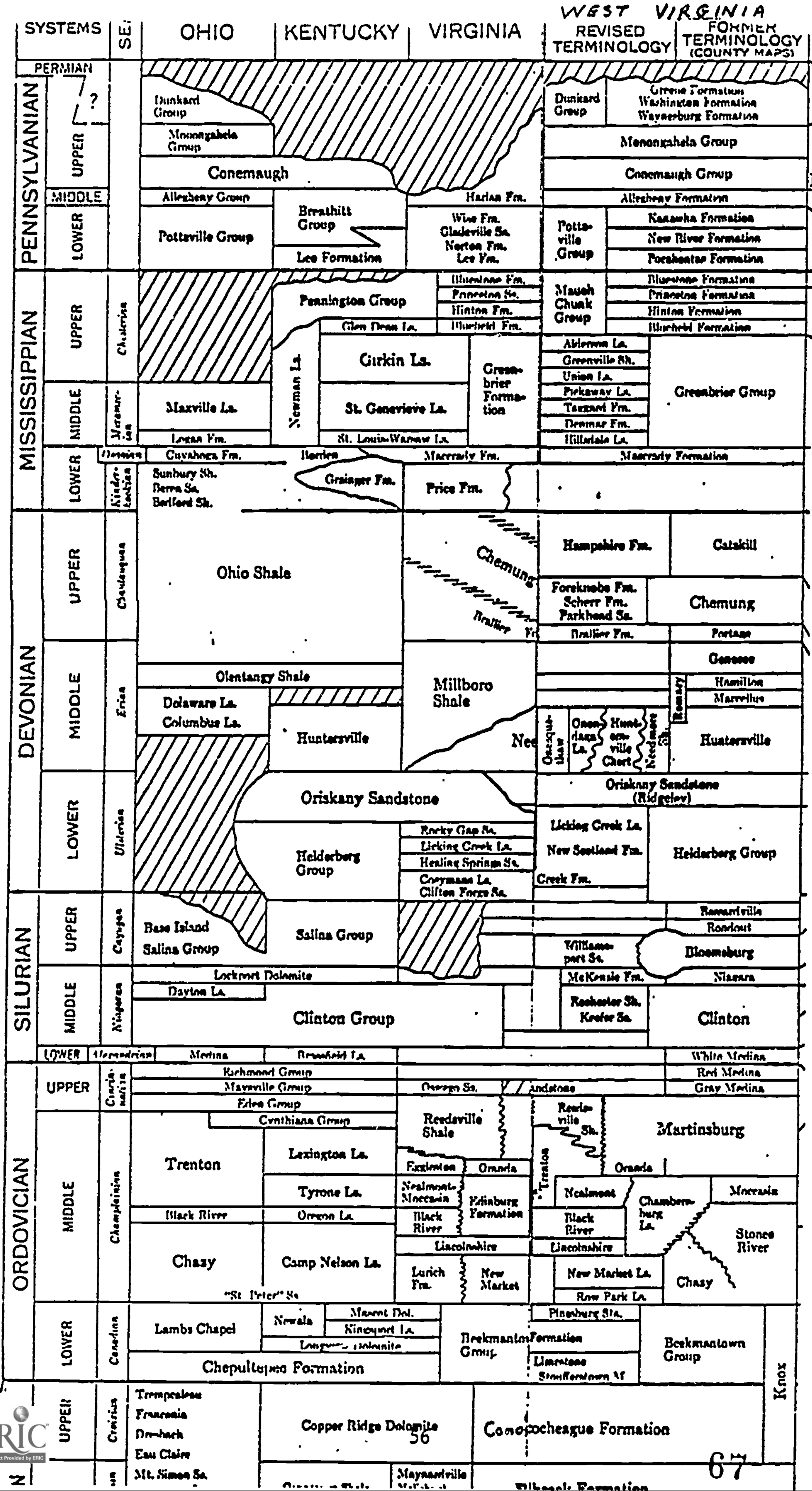
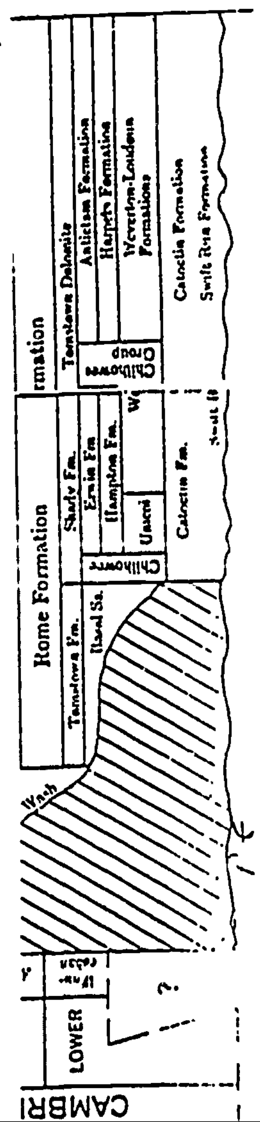


Figure 1.7.

Correlation chart for Ohio, Kentucky, West Virginia and Virginia. (From WV Geol Survey, 1968).



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6.2 Maps for FIRST DAY

Road maps of eastern U.S. and Ohio (AAA)
Glacial map of Ohio (USGS I-316)
Bedrock map of Ohio (OGS)
Guide to geology along Route 23 (OGS)
AAPG highway geology map of mid-Atlantic region
Chillicothe, Scioto, Waverly (15' maps)
Physiographic diagram of United States
Geologic map of West Virginia.
Geologic map of Charleston area

6.3 Daily Summary - First Day

SUMMARY OF HIGHLIGHTS

MY DEFINITIONS OF NEW TERMS

CONCEPTS, TERMS AND IDEAS THAT NEED FURTHER EXPLANATION

7.0 ROAD LOG AND STOP DESCRIPTIONS -- SECOND DAY

Princeton, WV to Mt. Airy, NC

Major stops: 1. Road cut near Oakvale; 2. Glen Lyn section; 3. Narrows overlook; Rich Creek section; 5. Narrows area; 6. Pearisburg; 7. Roadside cave; 8. Cloyds Mtn.; 9. Draper Mtn.; 10. Hillsville Quarry; 11. Blue Ridge escarpment.

As we begin the second day you should remember to make a few observations on environmental features such as vegetation, architecture, industries, and natural resources. Many reports are available on the mineral resources (Cooper 1944, and Woodward, 1932), the vegetation (Braun, 1967 and Kuchler, 1964) and the cultural setting of Appalachia (Caudill, 1972).

This morning will be spent interpreting and mapping the geology in a portion of the Valley and Ridge Province from Glen Lyn to Pearisburg.

Information gathered will be used to solve the "Narrows Problem" this evening. In the afternoon we will cross the remainder of the Valley and Ridge with more interesting structures, the Blue Ridge and part of the upland section of the Piedmont Province.

Depart Princeton on US460 east for Rich Creek. As we travel along the south-eastern edge of the Cumberland Plateau, East River Mtn., the northwesternmost ridge of the Valley and Ridge Province, will occasionally be visible on the right. Figures 2.1 and 2.2 will assist you in deciphering the geology today.

Stop 1. **Road cut near Oakvale:** Exit from U.S. 460 at Oakvale and examine the roadcut across from the school. **What is the attitude of the strata at this stop?** Strike is ____________. Dip is ______________. **What are the rock types?** Continue on US460 to Stop 2.

Stop 2. **Glen Lyn Section:** Exit left from US460 at the State Line and park beside the road. Walk north along the section observing the stratigraphy and structure. Note strikes and dips and make a sketch of the section. We are in the Mississippian __________ Formation (Fig. 2.1); locate this stop on Figure 2.2. We will begin working on a geologic mapping problem at this stop. Note rock types and structures at each stop from here through Stop 6. Refer to Figures 2.1, 2.2 and 2.3 for help. Use the topographic maps provided to record position and geologic information. With the information collected at Stops 2 through 6 we will construct a geologic map and cross section of this folded and faulted belt. Consult the Appendix and Figures 8, 9, and 10 for map symbols. Proceed on US460 across New River bridge; turn left on VA906 to Narrows "Overlook" and Stop 3.

Stop 3. **Narrows Overlook:** Observe the topography of the Narrows. **What is the name for this geomorphic feature and how did it form?** The headwaters of the New River are at Blowing Rock, North Carolina. **Where does the river terminate?**

* * * * *

Continue on VA906 toward Rich Creek and Stop 4 where Rich Creek passes under US460.

Stop 4. **Rich Creek Section:** Walk north along US460 and examine the section where exposed. Observe rock types and structure. **How does the structure relate to that at Glen Lyn and Oakvale?** Note this on the map (Figure 2.2). Proceed <u>east</u> on US460. Turn left opposite the roadside rest; go <u>west</u> on US460 to Stop 5.

Stop 5. **Narrows Area:** We will make several stops in this area to decipher the geology. Be sure to record your position and geologic information for each stop.

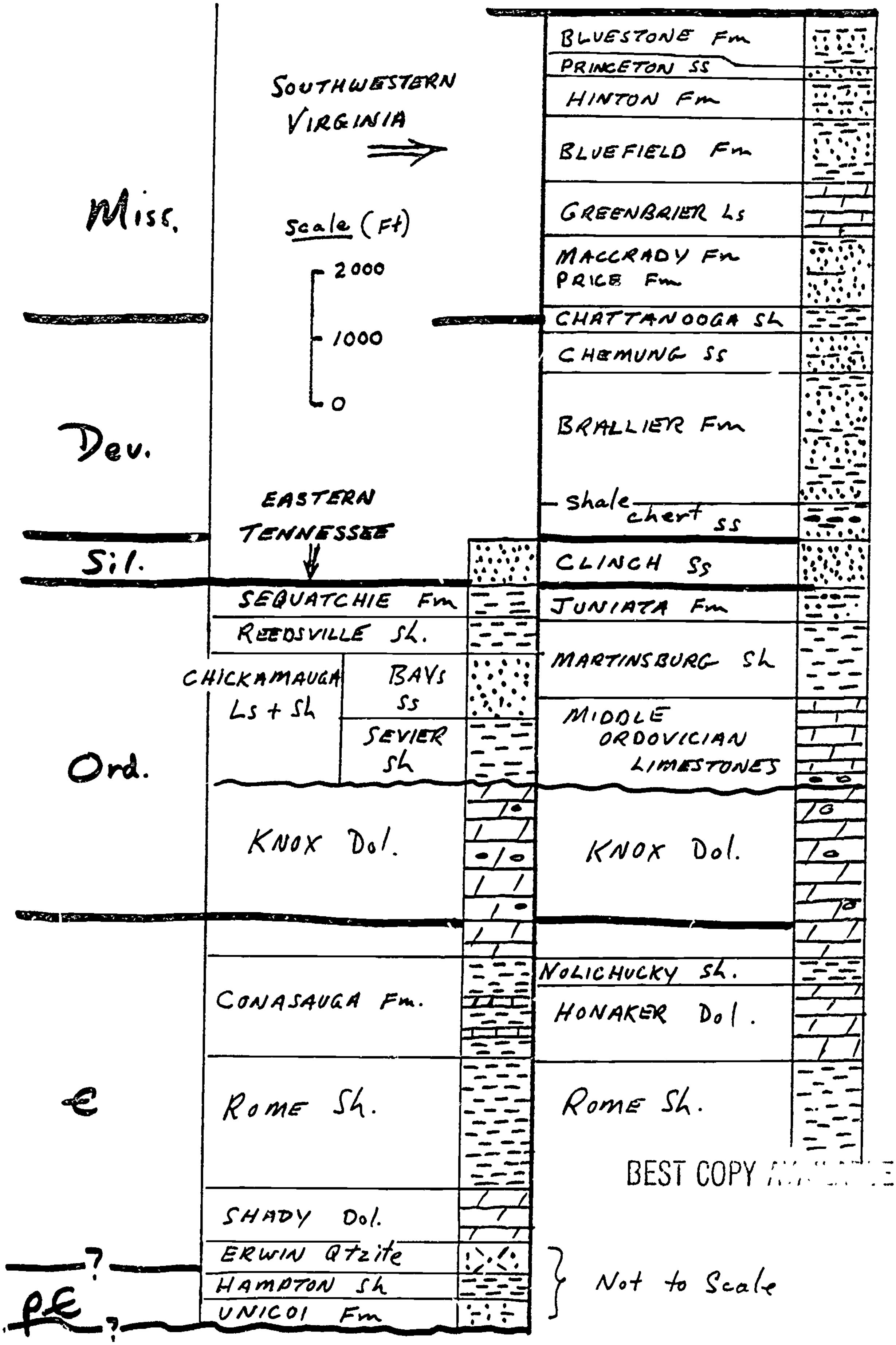


Figure 2.1 Geologic columns for Eastern Tennessee and Southwestern Virginia.

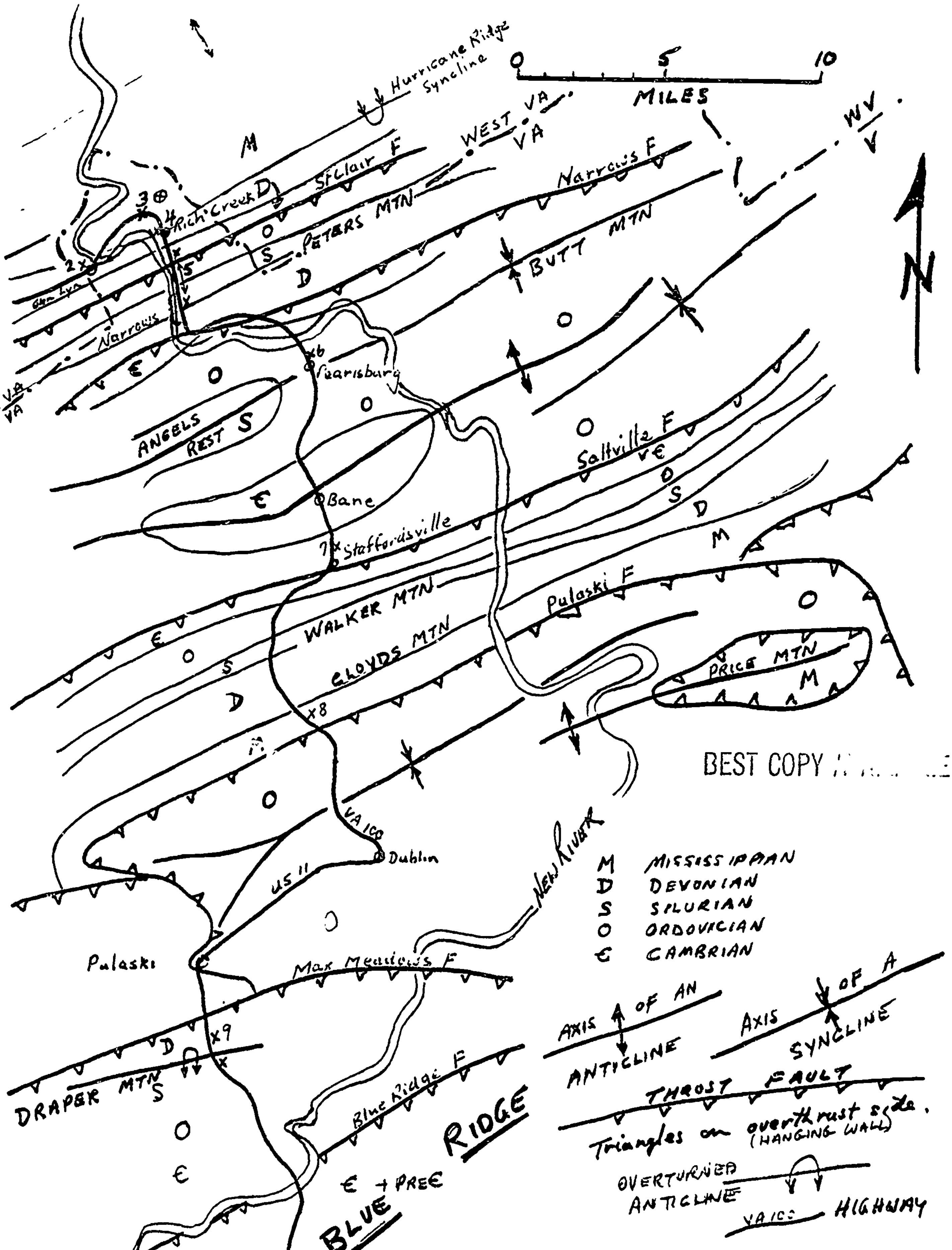
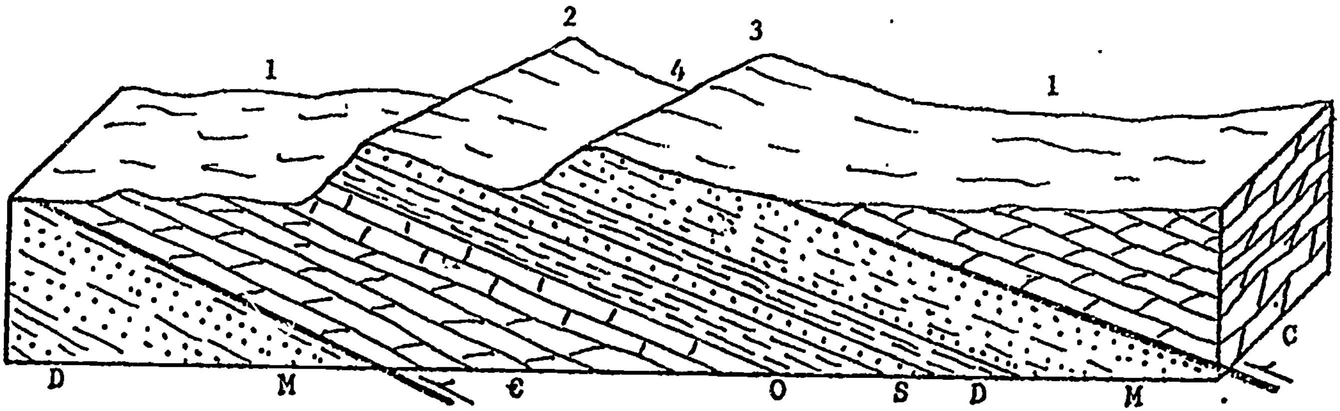


Figure 2.2 Geologic sketch map of Valley and Ridge Province from Glen Lyn to Sylvatus.



1. Cambro-Ordovician limestones and dolomites make broad fertile valleys.

2. The Silurian Clinch sandstone makes a prominent ridge, with a steep escarpment on one side and a long dip slope on the other.

3. Mississippian sandstones also make a pronounced ridge, with similar slopes.

4. Devonian shales make a "poor valley" between the ridges.

Figure 2.3 Relation between lithology and topography in the Valley and Ridge.

Stop 5a - Greenbrier Formation at Rich Creek. Continue E on US460.

Stop 5b - The Narrows. Observe rapids in the river and the rock type. Cross to highroad (US460 West) and make two stops.

Stop 5c - Observe attitude and rock type.

Stop 5d - Observe attitude and rock type.

* * * * *

Continue toward Pearisburg. Note the "galloping highway." The next stop (6) is beside Hardee's restaurant in Pearisburg.

Stop 6. **Pearisburg: What is the rock type and the attitude of the beds?** Explain the structure and the rock type at Angels Rest. Observe the regolith and the weathering pattern of the bedrock behind the restaurant.

* * * * *

Continue south on VA100 across the river and through Bane. The Bane dome or anticline (Fig. 2.2) contains Cambrian rocks (Honaker dolomite). The structure here has been worked out using conodont data (Perry et al., 1979).

Continue for about 1 mile, stopping before crossing the bridge to Staffordsville.

Stop 7. **Roadside Cave:** Observe opening to cave, its relation to the rock structure, and any speleothems. **What is the rock type and age? What mineral might be expected in the residual regolith above the cave?**

* * * * *

Continue south on VA100, crossing the Saltville thrust. Proceed through a full section of Upper Cambrian (Copper Ridge Dolomite at fault), Ordovician, and Silurian (Clinch Sandstone). At Walker Creek on Walker Mountain, the Clinch is exposed in the water gap.

Continue into the Devonian. Sandstone also makes up the crest of Cloyds Mountain. On the south side of Cloyds Mtn. we are in Lower Mississippian (Figure 2.2).

Stop 8. **Cloyds Mountain:** Semianthracite (Merrimac coal) in the Mississippian Price Formation is exposed in the left side of the road. Plant fossils may be found here. **What is the strike and dip of these rocks?**

* * * * *

At the base of Cloyds Mountain we continue up the Mississippian section and cross the MacCrady Formation (shales and sandstones) before crossing the Pulaski Thrust Fault near the bridge over Back Creek. After crossing the thrust we travel briefly over Cambrian carbonates near the fault and then the Ordovician carbonates that comprise a part of the Great Valley. Turn west onto US11 at Dublin, noting the sinkhole near the junction with VA100. Continue west in the Great Valley through Pulaski and more carbonates.

Stop 9. **Draper Mountain:** On Draper Mtn. several thousand feet of Paleozoic beds are exposed. These rocks are overturned, that is, upside down; so that, as we go <u>up</u> the highway from Pulaski to the summit, we go <u>down</u> the stratigraphic section, from Mississippian to Silurian. At Draper Wayside Park we will inspect the Clinch Formation. **Can you see sedimentary structures that indicate overturned strata?** Sketch them.

* * * * *

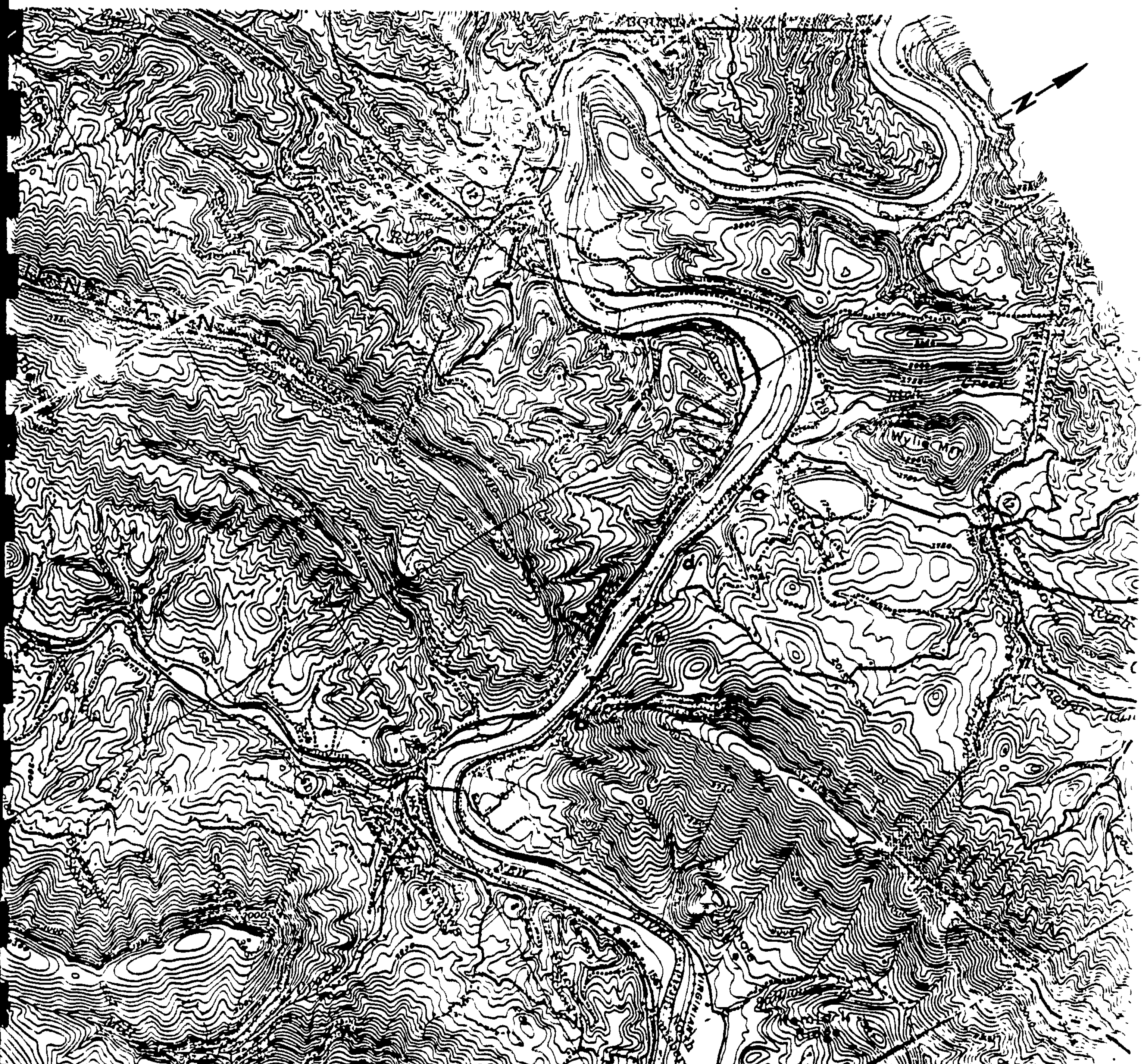


Figure 2.4 Topographic map of Narrows area.

On the way down Draper Mtn. we cross the Martinsburg and Juniata Fms. (Ord). In Draper Valley we are on Ordovician limestones. Do you notice any karst features? Cross I-81 on VA100. Cross the New River again. Notice Ordovician carbonates to the east along the river. Three miles from the New River is Stop 10.

Stop 10. **Hillsville Quarry:** The quarry will most likely be closed; however, we can observe the rock types from the gate. Notice the depth of weathering exposed in the quarry. We are now in Cambrian and Precambrian rocks of the Blue Ridge (Figure 2.2). According to geologic maps of this region (Rankin et al., 1972 and Espenshade et al., 1975), rocks in this area include the Cambrian Erwin and Hampton (ss, qtzite, and shale), Unicoi (congl. ss, shale, siltstone, qtzite, and basalt flows near the middle), and Precambrian biotite muscovite gneiss with mica schist (Maps I-709A, and I-709-B).

* * * * *

Continue south on VA100 through Sylvatus (1.7 miles) to Hillsville. Take US52 toward Mt. Airy.

In the Blue Ridge Upland the elevations are about 2500 feet and the climate is considerably cooler than in the low-lying Piedmont province to the east. The eastern belt of the Blue Ridge consists of Precambrian gneisses. After going through Fancy Gap we will pass under the Blue Ridge Parkway and begin descending the Blue Ridge Escarpment, which rises 1500 feet above the Piedmont and is said by some to be a fault scarp. Others believe that it is an erosional feature that reflects long-continued retreat of the Appalachian-Blue Ridge Highlands. Southwest of here this boundary is the Brevard Fault zone (Figures 2.5 and 2.6).

Stop 11. **Blue Ridge Escarpment:** Midway down the escarpment, park on the right side near a motel to view the Piedmont. Both the town of Mt. Airy and Pilot Mtn., a monadnock of massive quartzite of Paleozoic (?) age, may be visible. Examine rocks on the left side of the road. **What are they?** Beware of traffic here!

Continue down the escarpment. On the Piedmont we cross an area with mature dissection and moderate relief.

End of day at motel on US-52 Bypass. Departure for the Mt. Airy granite quarry will be at 8:00 AM tomorrow.

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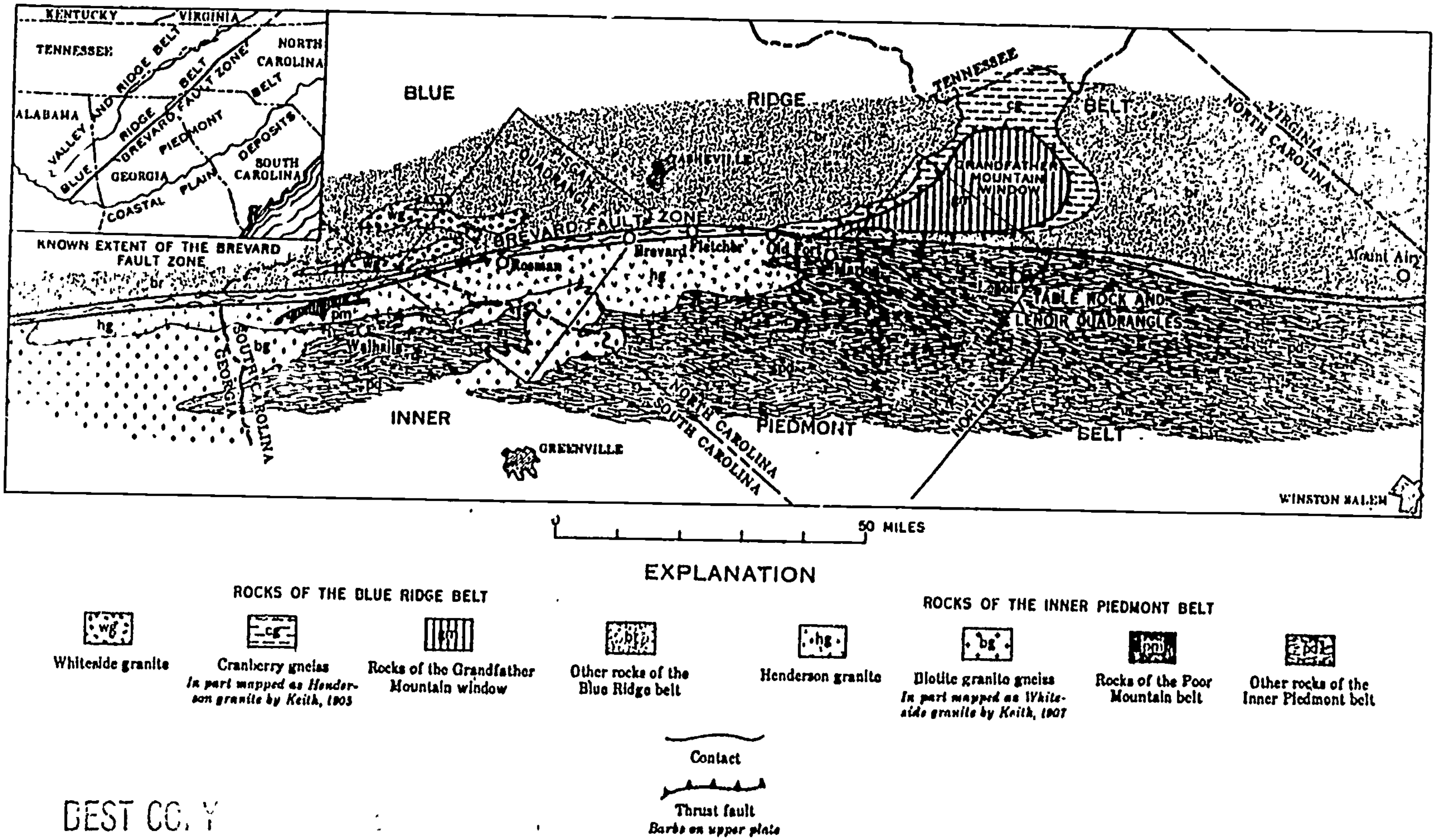

Figure 2.5 Brevard zone in North and South Carolina (Reed et al, 1961).

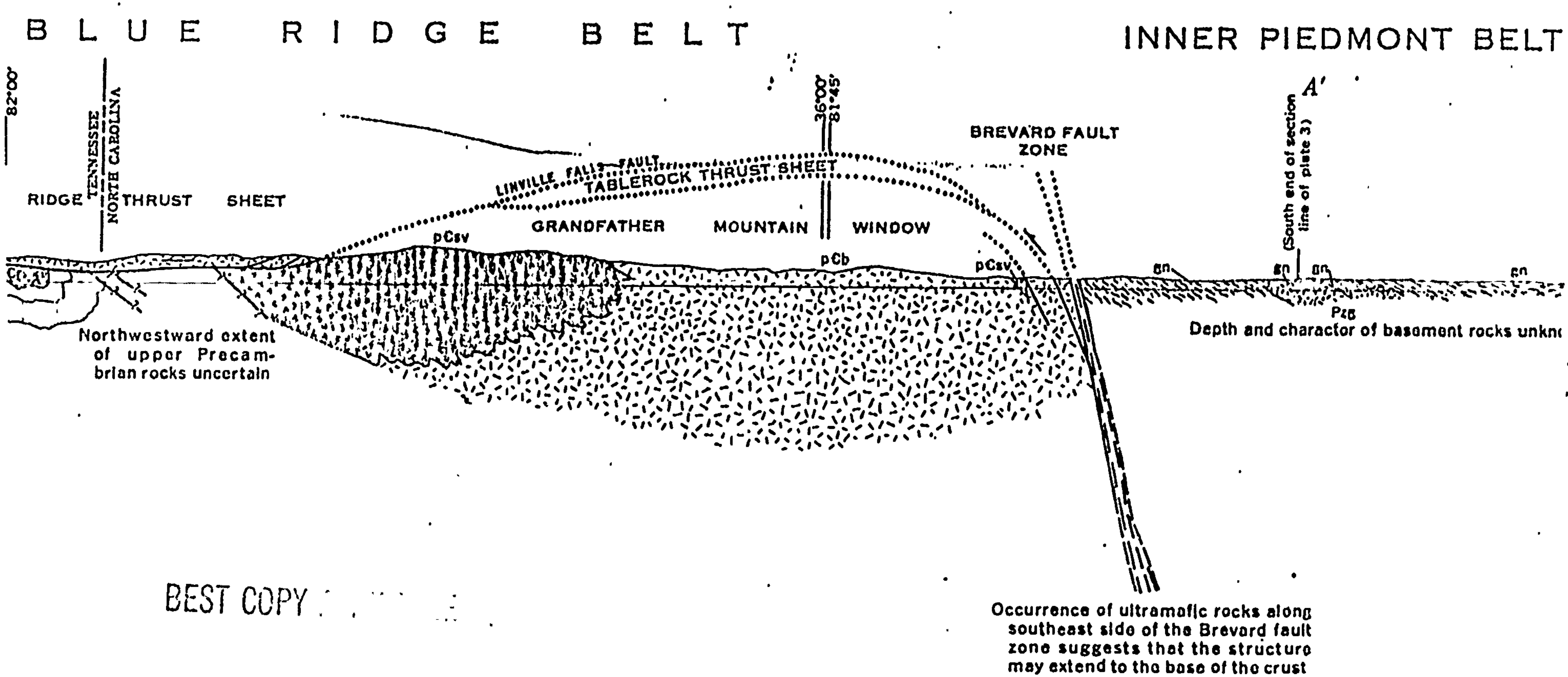

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Figure 2.6 Cross-section of the Grandfather Mountain Window (Bryant and Reed, 1970).

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7.2 Maps for Second Day

Geological Map for Mercer, Monroe, Raleigh and Summers Counties West Virginia Geological Survey (1:62,500).

Geologic Map of Virginia, Virginia Division of Mineral Resources.

Pearisburg VA quadrangle (7.5', 1965).

Winston-Salem Quadrangle (East and West)

Mount Airy and Surry County, NC

7.3 Daily Summary - Second Day

SUMMARY OF HIGHLIGHTS

MY DEFINITIONS OF NEW TERMS

CONCEPTS, TERMS AND IDEAS THAT NEED FURTHER EXPLANATION

8.0 ROAD LOG AND STOP DESCRIPTIONS — THIRD DAY

Mt. Airy, NC to Bristol, TN

Major Stops: 1. Mt. Airy Granite Quarry; 2. Saprolite near Lowgap, NC; 3. Gossan Lead District; 4. Eocambrian glacigenic deposits of the Mt. Rogers area; 5. Mt. Rogers Volcanic Group - Middle Part; 6. Lower Part; 7. Whitetop Mountain; 8. Tillite at Big Hill.

From US52 Bypass, take NC89 (Pine Street) into Mt. Airy, cross Main Street, where it becomes NC103. The quarry is about 1 mile from the center of town.

Mt. Airy lies in Surry County, in the western Piedmont of North Carolina. Most of the county is underlain by gneiss and schist (Fig. 3•1). Granite outcrops are scarce, and most are deeply weathered. A notable exception is a large dome-like outcrop, about 1 by 1.5 miles in dimension, along the crest of a hill 1 mile northeast of Mt. Airy.

Stop 1. North Carolina Granite Corporation: The open-face quarry at Mt. Airy is the world's largest. Dimension stone has been produced here since 1889. Products now include cut stone (for memorials and curbing), grit and crushed stone, and paving blocks and flagstone. There is practically no loss in the operation as they have a product "small enough to feed canaries and large enough for huge buildings". The quarry ships about 3,000 carloads a year, approximately half of this by truck. There are abut 250 employees in the quarry, office and cutting plants. Machinery in the cutting plants include gang, wire, and rotary saws, and grinding, polishing, and sandblasting equipment.

About 40 acres of bare rock existed in 1872 when the farm on which the quarry now sits was purchased. This exposure and the thin overburden around the quarry was suitable for an open-face quarry rather than a pit quarry which is more difficult to work.

Dynamite is not used to quarry blocks as this would damage the granite. This massive rock will develop sheeting parallel to the surface, and this tendency is used in producing the sheets of granite or "lifts" that begin the quarrying processes.

The layers of granite are separated from the main mass by inducing horizontal sheeting planes 4 to 8 feet below the surface. In this process, a 2.5 inch hole is drilled in the center of the sheet to be lifted; small amounts of black powder are successively detonated at the bottom until a horizontal crack extends outward from the hole.

Successively larger charges are used to propagate the split or propagation occurs with the natural daily heating and cooling in summer, or cooling in winter. Daily charges are used for about a month; completion of a lift may require all summer. Additional 2-5-inch holes are used near the edge of the split. The edges are found by sounding--tapping the granite surface with a hammer.

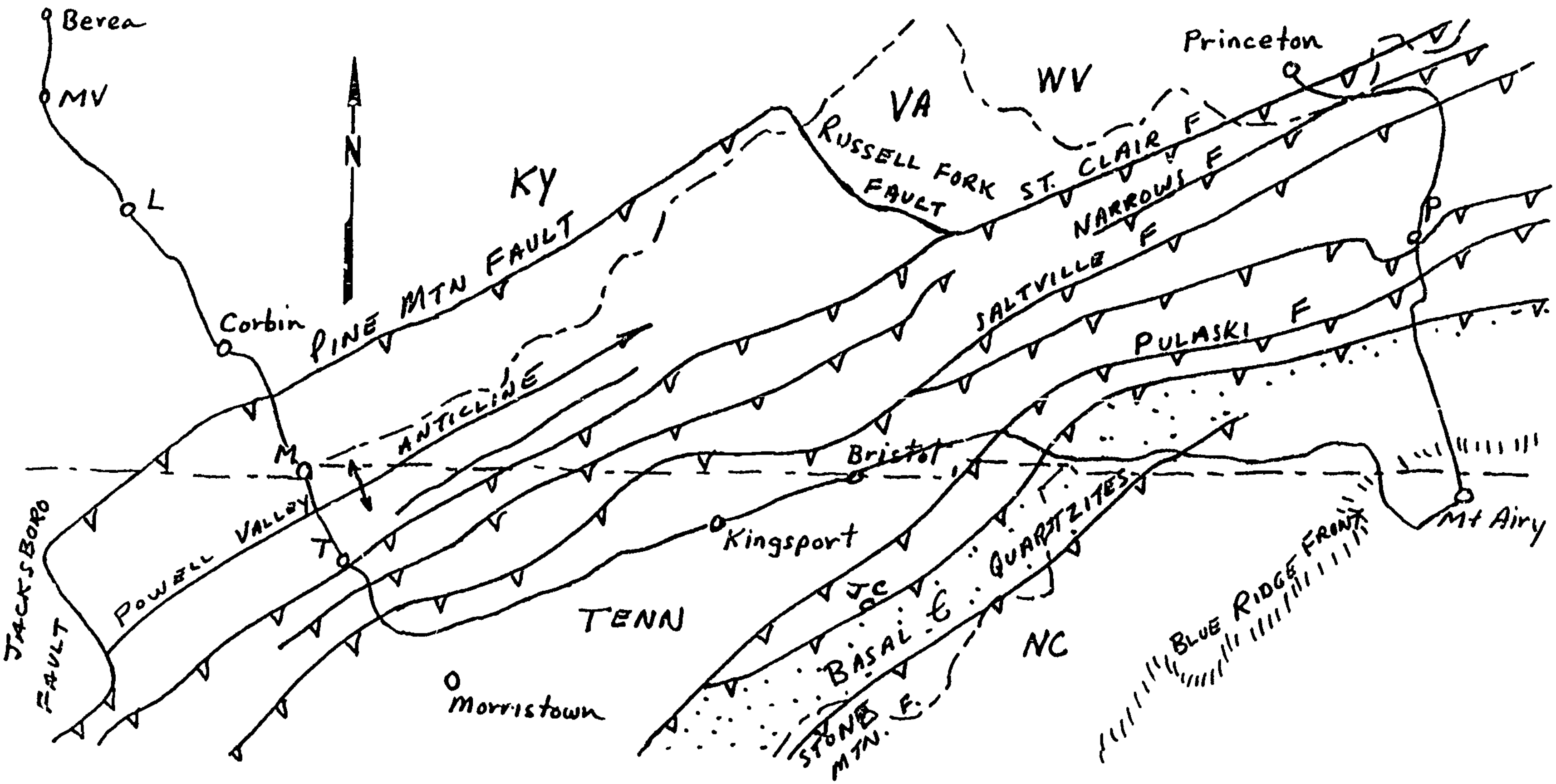

Figure 3.1 Major faults in the Valley and Ridge; itinerary for the second, third and fourth days.

Blocks of granite are quarried from the lift by drilling 4-in. deep holes 4" apart and inserting wedges with a 10-pound sledge hammer. This causes a vertical fracture. The granite is then cut, surfaced and finished in one of the more modern granite mills in the country.

The stone is light gray medium-grained uniform stone that is known in the trade as "white granite." Actually it is not a true granite, but a granodiorite, as indicated by the large proportion of plagioclase feldspar:

Plagioclase........................	55.0%
Quartz.............................	20.0
Microcline (orthoclase)............	19.5
Biotite............................	2.5
Accessory minerals.................	3.0
	100.0%

The granite was probably emplaced as a magma at a depth of 2.3 to 12 miles below the earth's surface, at temperatures of 650 to 710°C. It is believed to be of Mid to Late Paleozoic age and to have formed during the Appalachian Orogeny.

Chemical Analysis

Silica (SiO_2)	67.33	Toughness	11
Alumina (Al_2O_3)	18.51		
Iron Sesquioxide (Fe_2O_3)	1.78	Crushing Strength	31,560 p.s.i.
Magnesium Oxide (MgO)	0.41	Modules of Rupture	2,045 p.s.i.
Calcium Oxide (CaO)	2.63	Weight per cubic foot	165 lbs
Sodium Oxide (Na_2O)	3.60	Bulk Specific Gravity	2.64
Potassium Oxide	3.96	Absorption	0.2357%
Manganese Oxide (MnO_2)	0.12	Expansion	$4.38 \times 10^{-6}/^0F$
Titania (TiO_2)	0.38		
Phosphorous Pentoxide (P_2O_2)	0.05		
Sulphur Trioxide (SO_3)	0.01		

* * * * *

Depart Mt. Airy on NC89 west toward the Blue Ridge.

Stop 2. Near Lowgap, NC: Saprolite. Chemical Weathering in this humid area has proceeded to a depth of ± 100 m. leaving a residual layer of soft, earthy, clay-rich thoroughly decomposed rock called saprolite. Some of the structures and resistant minerals of the original metamorphic bedrock have been preserved.

* * * * *

Proceed on NC89 to VA89 and to Galax, VA.

Stop 3. Iron Ridge area north of Galax, near Fries, VA: This area is part of the Gossan Lead District including Carroll and Grayson Counties. It contains several diverse series of sedimentary, igneous and metamorphic rocks which have a complicated structure ard contain valuable minerals. The following have been produced in the District: barite, copper, garnet, iron, kyanite, lead, limestone,

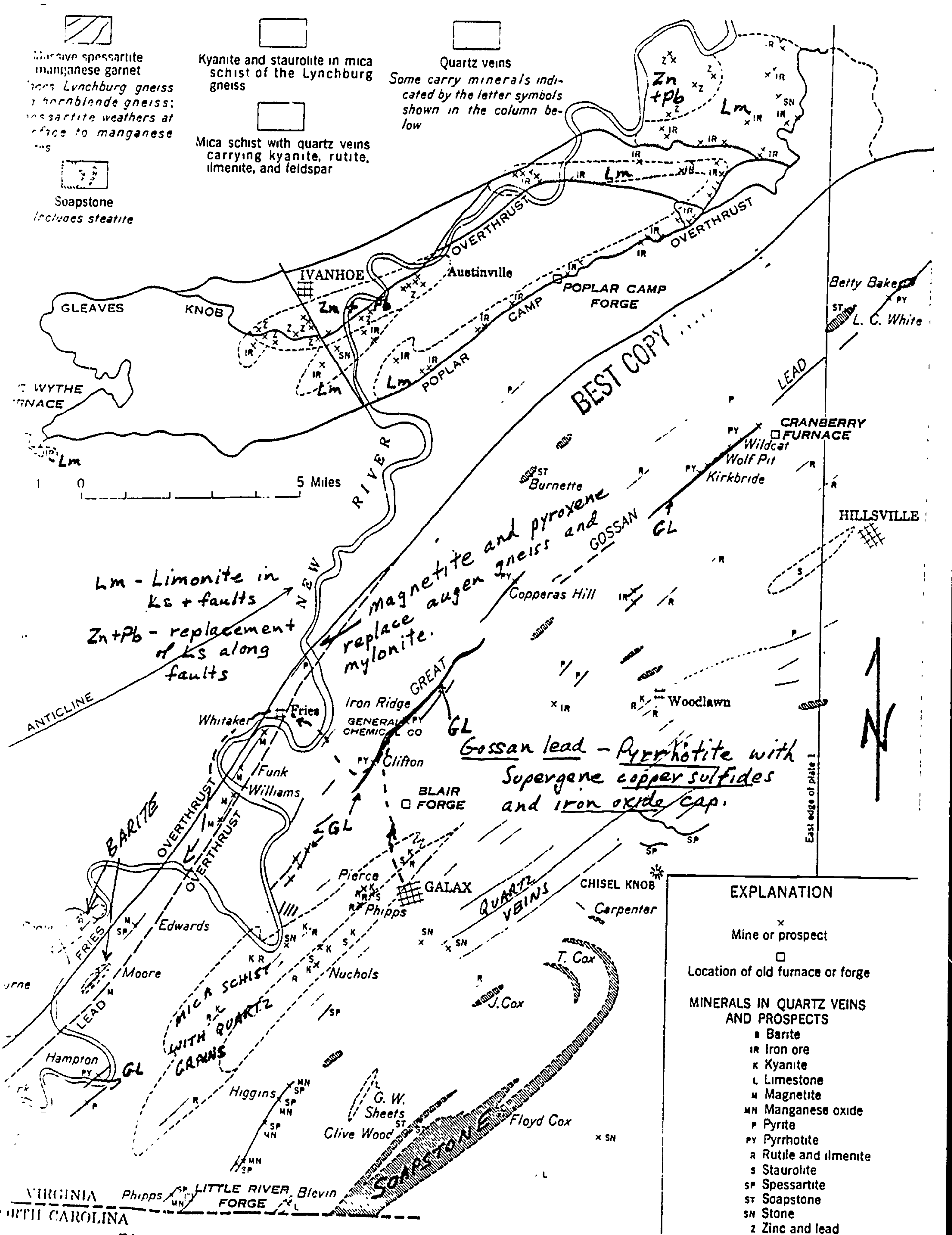

Figure 3.2 Geology of the Gossan Lead District, VA (Stose and Stose,1957)

manganese, pyrrhotite, quartz, rutile and ilmenite, soapstone, and zinc. In the 1930s much of the mineral wealth was derived from mining pyrrhotite (FeS) at Iron Ridge, and zinc and lead around Austinville (Fig. 3•2) New Jersey Zinc Co. operated mines at Austinville and Ivanhoe and a processing plant at Austinville until 1981. They mined ore containing approximately 3.5%Zn and 0.6%Pb which they extracted, in addition to selling agricultural limestone, a by-product of the milling operation.

The Gossan Lead zone consists of several ore bodies arranged en echelon in a 20-mile zone that trends southwestward from 5 miles north of Hillsville (Figure 3•2). In general the ore veins are parallel to the strike of the foliation of the country rock (Lynchburg gneiss). The dip of the veins and the foliation is to the southeast. Sulphides in the veins are mainly pyrite (FeS_2), pyrrhotite (FeS), and chalcopyrite ($CuFeS_2$) with lesser amounts of sphalerite (ZnS) and galena (PbS). The veins have a gossan of limonite; note numerous old prospects and pits. The gossan (hydrated iron oxide deposit on mineral veins) is 200 feet wide in places and has a depth of 20 to 60 feet. It is floored with a 1 to 6 foot thick zone of secondary copper ores with the unaltered sulphides below.

The ore is thought to have formed from hydrothermal solutions entering the country rock along foliation planes and traveling long distances from their source, possibly granites to the east in the Piedmont. The emplacement of ores occurred after the major deformation and thrusting in the area, which is late Paleozoic since rocks of Mississippian age elsewhere are involved in the thrusting. Although the rocks in the area are Precambrian and Cambrian age, the mineralization is Late Paleozoic (Allegheny Orogeny) or later.

Figure 3•2 indicates the extent of mineralization of the lead-zinc area in the Austinville-Ivanhoe District. There are no active lead and zinc mines in the area at present. The ores in this "district" are related to the breccia zones where galena and sphalerite occur. There are some barren breccia zones where associated minerals in the area include: pyrite, dolomite, barite ($BaSO_4$), quartz and fluorite (CaF_2). The host rock is the Shady Dolomite or its equivalent and there are some cross faults that show mineralization.

* * * * *

From the Galax-Fries area we will proceed to the west over the shortest and best route (probably Hwy 58) to the Mt. Rogers National Recreation Area of Jefferson National Forest, where we will look at Precambrian volcanics and glacial deposits among other things of geologic interest.

Stop 4. Eocambrian Glacigenic deposits of the Mount Rogers area: We will make three stops (4a, 4b, 4c) along the road from Trout Dale to Konnarock. The information for these stops comes by courtesy of Professor Malcuit of Denison University; it is derived largely from the 1967 GSA trip to the area (Rankin, 1967).

Several lithofacies of Late Precambrian glacial deposits are exposed along the road (VA603) between Trout Dale and Konnarock, Virginia (Trout Dale and Whitetop Mountain Quadrangles). The lithofacies include (1) the Boulder Clay Lithofacies (lithified glacial till), (2) the Cross-bedded Sandstone/Conglomerate Lithofacies (lithified glacial outwash material), (3) the Laminated Sandstone/Siltstone/Shale with oversized Clasts Lithofacies (lithified "varved" sediments with dropstones presumably dropped from icebergs as they melted -- these laminated sediments are also called "rhythmites"). In addition, there are good examples of graded beds (interpreted as turbidite deposits) and some submarine slump structures.

These glacial deposits are interpreted to be the equivalent of the upper glacial horizon of Late Precambrian "global" glaciation as described by Frakes (1979).

The numbered stops refer to numbers on the Trout Dale and Whitetop Mountain Quadrangle maps (Figs. 3•3 and 3•4).

4a. Starting just west of Trout Dale there are a number of outcrops of the laminated units with dropstones. In some cases the structures are better displayed on the blocks that have been blasted off and pushed over the bank on the opposite side of the road.

4b. The Crossbedded Sandstone/Conglomerate Lithofacies if beautifully displayed at a place where Fox Creek comes very close to the road. A waterfall (cascade) is formed by these rocks. Close by, on the opposite side of the road, are some boulders of the Boulder Clay Lithofacies.

4c. On the west side of the stream divide, there is a newly opened rock cut showing graded beds, laminated rocks, submarine slump and soft sediment deformation structures. Here again, the structures are better displayed and much more accessible on the south side of the roadside parking place.

* * * * *

After Stop 4c proceed on VA603 to VA600. Going south on VA600, Mt. Rogers (Fig. 3•5), the highest point in Virginia (5729 feet) will be to the left and Whitetop Mtn. (5520 feet) is to your right. The rocks along here are in the Mt. Rogers volcanic series of Precambrian age which we will take a look at. If the weather and time permit we may be able to drive on the highest auto road in Virginia to near the summit of Whitetop Mtn. and see something of the Blue Ridge province from this vantage point.

Stop 5. **Mt. Rogers Volcanic Group - Middle Part:** About 2.3 miles south of the CCC camp on Whitetop Mtn. Drive are rhyolites of the Mt. Rogers Volcanic Group (Fig. 3•61 and 3•62), all slightly metamorphosed. This group (10,000 feet thick) is divided into three parts: Lower Part is interbedded sedimentary rocks, basalt and rhyolite (graywacke of this part may be seen at Stop #6); Middle Part is made up of three rhyolite units recognized by phenocrysts in each, and the Upper Part consists mainly of arkose, rhythmite, laminated pebbly mudstone and tillite, characterized by a red color. The regional geology of this area is given in Figure 3•5 showing the tectonic slices and windows. For more detail on the Grandfather Mountain window see Figures 2•4 and 2•6 of the Second Day.

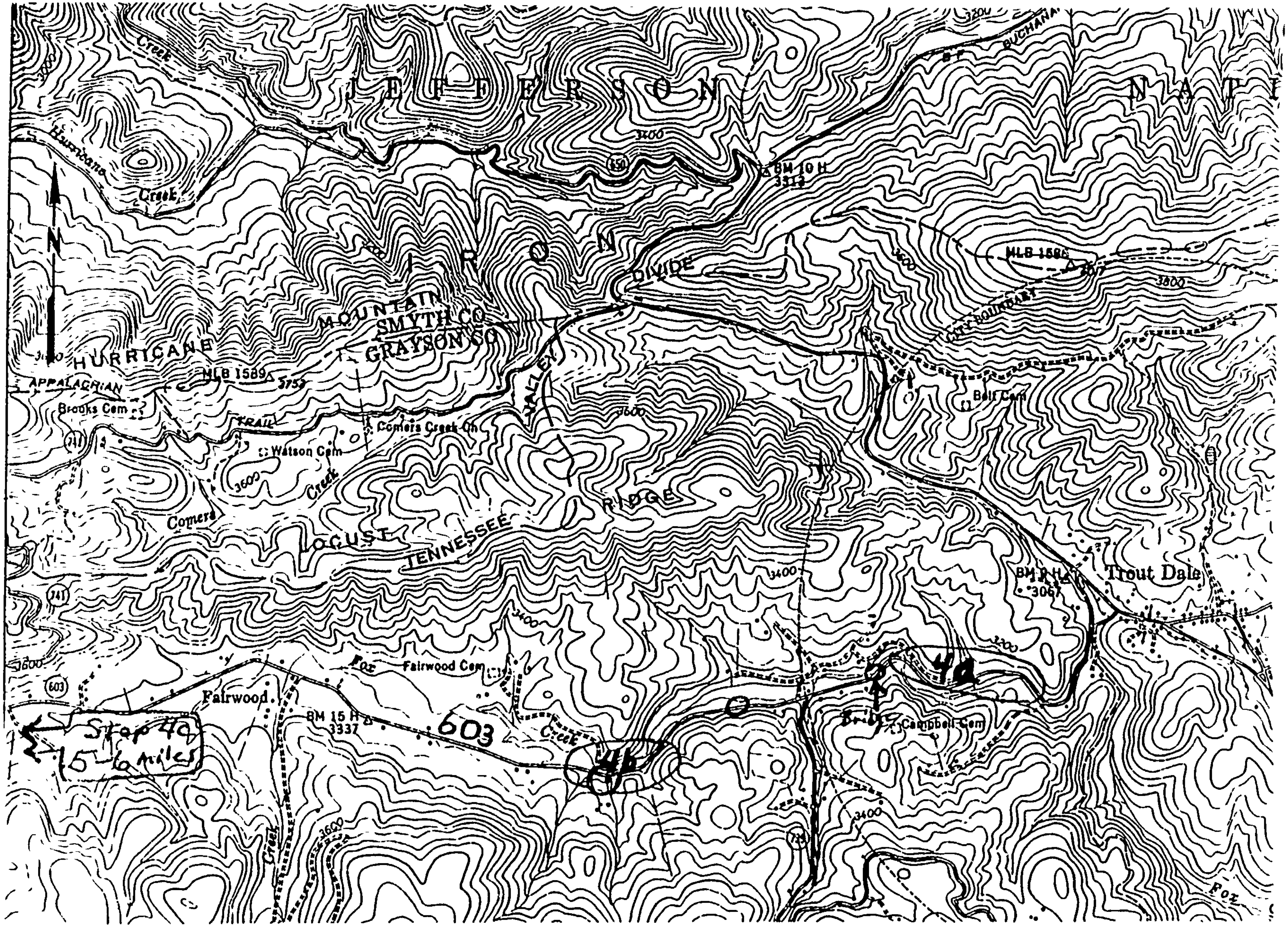

Figure 3.3 Stops between Trout Dale and Konnarock. (4a and 4b).

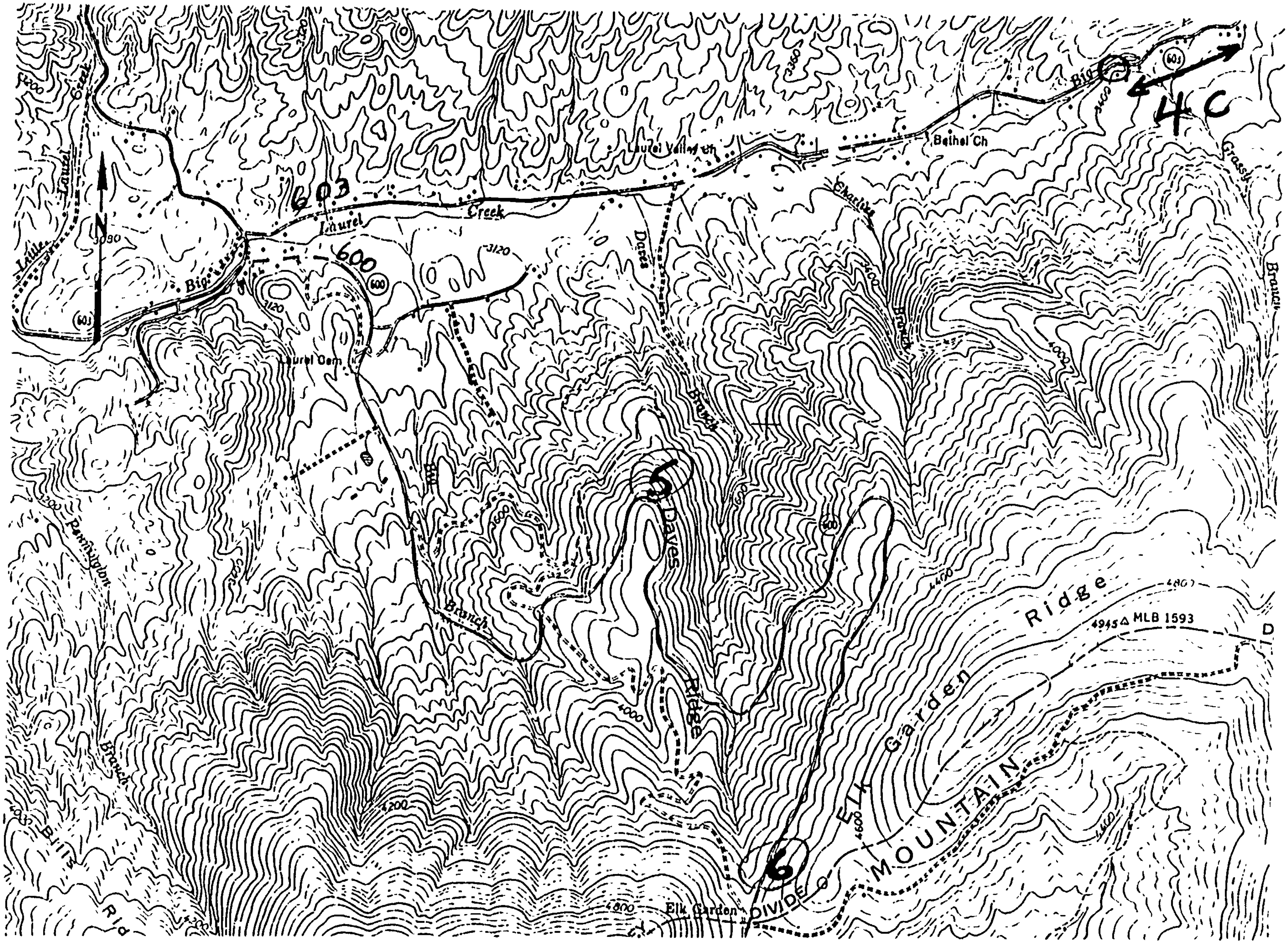

Figure 3.4. Stops between Trout Dale and Konnarock (4c).

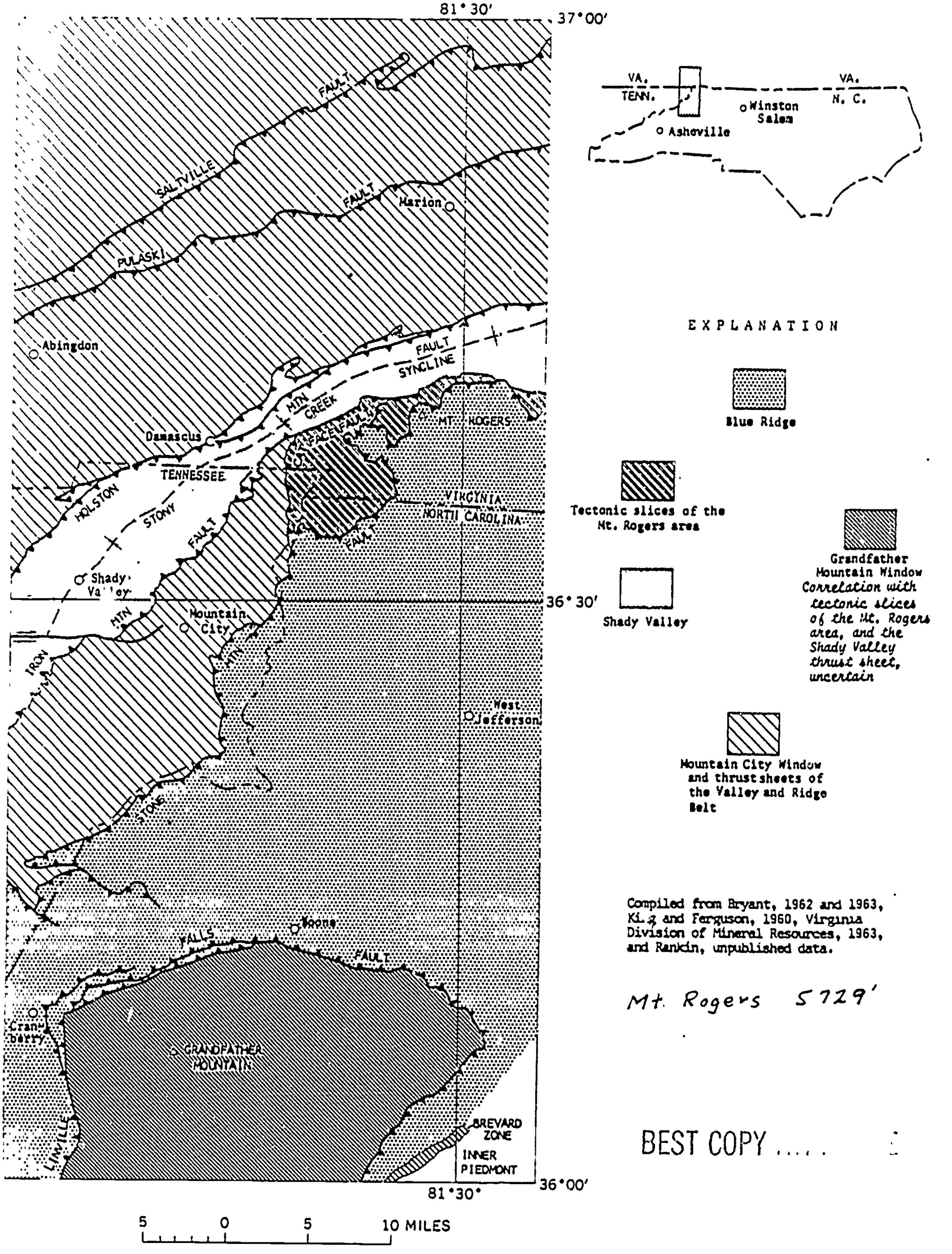

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Figure 3.5 Geology of the Mt. Rogers area (Rankin, 1967).

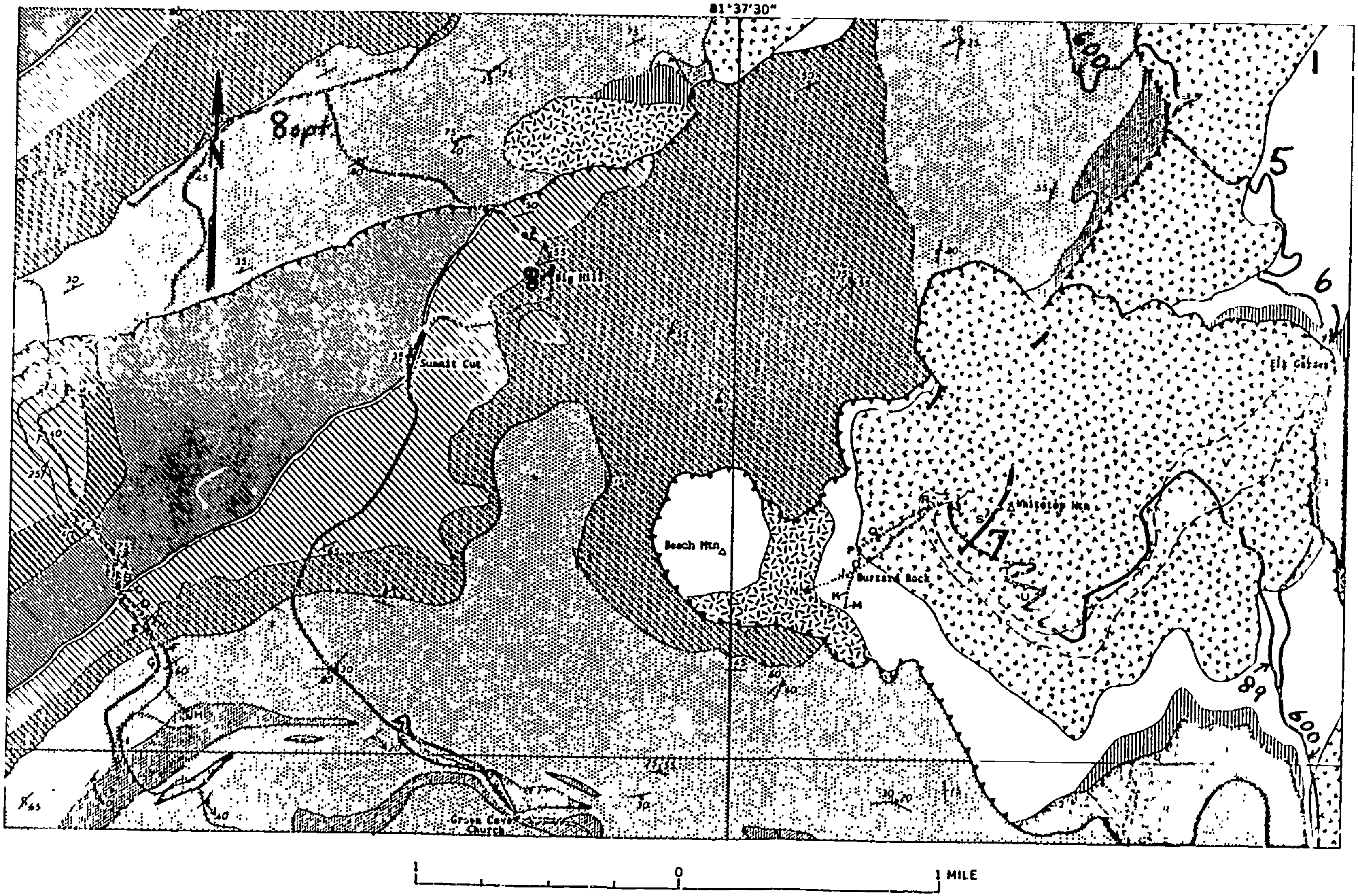

Figure 3.61 Geology of Whitetop Mountain area (Rankin, 1967).

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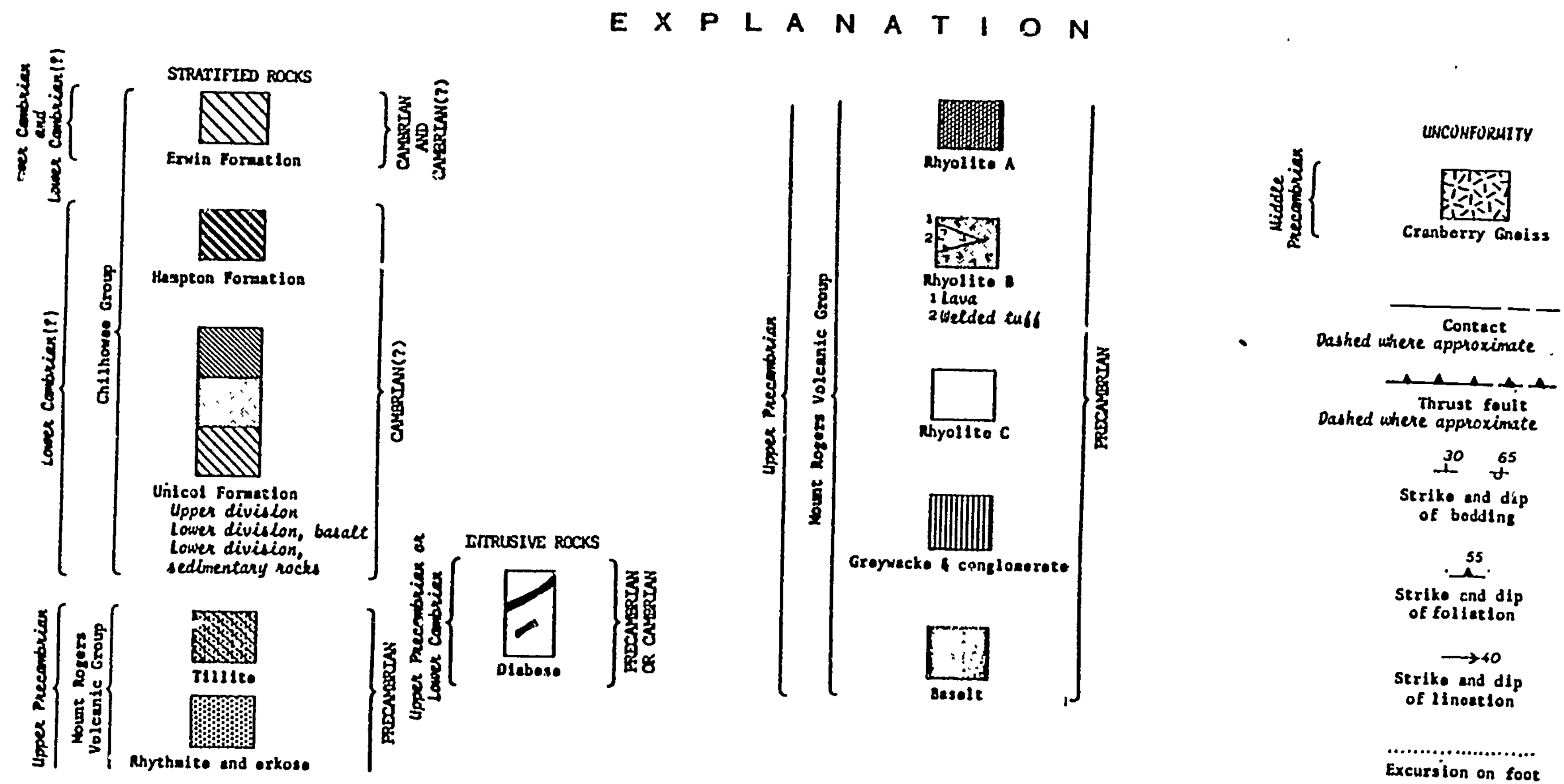

Figure 3.62 Explanation for 3.61 (Rankin, 1967).

The lower and older rhyolite, unit C, of the **Middle Part** (Figure 3·61), contains 5% to 20% phenocrysts of perthite and plagioclase and some flowbanding suggesting a lava origin. Unit B is usually nonporpnyritic with some chaotic flowbanding, indicating the bulk of this unit is made up of lava flows. Unit A contains 30% phenocrysts of quartz and perthite. Stop #5 will be in either C or B.

* * * * *

Proceed up the mountain about 1 mile to within a quarter mile of the divide and the Appalachian Trail.

Stop 6. **Lower Part (optional):** This stop may show graywacke of the Lower Part of the Mt. Rogers Volcanic Group. In addition there may be a gray or greenish gray muddy-matrix conglomerate with stretched pebbles and boulders.

* * * * *

About 1 mile from here take a right turn up Whitetop Mtn. Drive. Rhyolites of unit B, some lavas and some welded tuffs, make up this mountain.

Stop 7. **Whitetop Mtn. - View of Blue Ridge province; rhyolites on Mtn.:** Rhyolite B (Middle Part of the Mt. Rogers Volcanic Group) makes up most of the mountain. Both lava and welded tuff are present.

* * * * *

Retrace path down mountain to VA600. Turn right here until you reach US58. Follow US58 west toward Damascus. We will be crossing rhyolites, basalts, rhythmites and tillites of Upper Precambrian age, and sedimentary rocks of Lower Cambrian age. At the next stop, 5 miles West on US58, we will observe the latter two rock types.

Stop 8. **Tillite at Big Hill (Stop #2 of 1967 GSA trip):** Tillite of the Upper Part of the Mt. Rogers Volcanic Group is exposed at the sharp curve here and down the hill to the north where you will see the overlying conglomerate of the Unicoi Fm., Lower Cambrian. The tillite is massive, poorly-sorted, and muddy, with a red-matrix. Because of the age and the association with the rhythmites with clasts up to 1 meter across, some authors have suggested that these rocks are of glacial origin (tillite), and not just conglomerates. **What are your thoughts on their origin?**

The Unicoi is a rusty-weathering quartz-pebble congomerate and arkose. Conglomerate beds are usually 1 to 3 feet thick. **Which way do the beds dip? Where is the contact with the underlying shale and arkose of the Mt. Rogers Group?** Color should provide a clue!

Follow US58 west to Damascus and note the change in topography in this area (Fig. 3·5). **Why the change?**

Ten miles from Damascus we pick up I81 again and proceed to Bristol, TN where we will stay at King College or a motel.

Departure time tomorrow: 8:00 a.m., after breakfast in the college cafeteria.

8.1 References for Third Day

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8.2 Maps for Third Day

8.3 Daily Summary - Third Day

SUMMARY OF HIGHLIGHTS

MY DEFINITIONS OF NEW TERMS

CONCEPTS, TERMS AND IDEAS THAT NEED FURTHER EXPLANATION

9.0 ROAD LOG AND STOP DESCRIPTIONS — FOURTH DAY

Major Stops: 1. Soils; 2. National Quarry at Cherokee Lake; 3. Thorn Hill Section; 4. Copper Creek Fault; 5. Tazewell Sinkholes; 6. Cumberland Gap Tunnel; 7. Cumberland Gap; 8. Middlesboro Landslide; 9. Fossils, near Barbourville.

From King College in Bristol, TN follow State Street west to US11W. Proceed on US11W to Kingsport (about 25 miles) over Upper Cambrian and Ordovician carbonates (See Fig. 3•1, Third Day for itinerary). A distinctive topography has developed on this limestone and dolostone. What physiographic region are we in between Bristol and Kingsport?

The first stop is any suitable roadcut in or near Kingsport.

Stop 1. Soils in Roadcut at Kingsport: This soil has developed by weathering of coarsely crystalline limestone to form a residual regolith. **What is the residual material from weathering of a limestone (mainly $CaCO_3$)? How thick is the regolith?**

* * * * *

Continue westward. About 21 miles from Kingsport we might see a sinking creek. **What rock type would this feature suggest?** Between Stops #1 and #2 we may also stop, if appropriate road cuts are seen about 34 miles from Stop #1, to view folded siltstones and shales exhibiting a vertical attitude.

About 27 miles from Kingsport we take US11W Bypass around Rogersville (4•1). Note the topography over the next 13 miles to Stop #2.

Stop 2. National Quarry at Quarryville Roadside Rest, Cherokee Lake: We may be able to drive from the Roadside Rest to the lake shore; however, lake deposits of clay may make the trail very slippery. The rock exposed in the lake is the Holston Formation. This crystalline limestone is known as the Holston Marble and has been used in many buildings in the nation's capital. The limestone is 97.5% $CaCO_3$; it has also been used for lime, grit and cement. Look for hand specimens of cut stone in the exposed lake bottom and quarry floor. **What is the reason for the red color of the limestone? Would you expect any problems if you were planning a man-made lake in carbonate terrane? Why?**

* * * * *

Continue west on US11W for about 7 miles. Rest stop at Mooresville gas station. Then follow US11W for 3 miles beyond Bean Station. Take US25E north toward Tazewell. As we approach Clinch Mtn. we pass through Poor Valley Ridge (Rome Fm., see Fig. 2•1), and then cross the Saltville Fault where the Cambrian Rome Fm. lies on Mississippian limestone (Figure 4•2).

Between the Saltville fault and Tazewell we cross **three belts of Paleozoic strata** bounded by major thrust faults (Figure 4•2). The first of these belts, in which Clinch Mountain lies, contains an unbroken succession of strata from Mississippian limestone down to the Rome formation. This is well known among geologists as the Thorn Hill section. We will make several **CWS** on the way through the section.

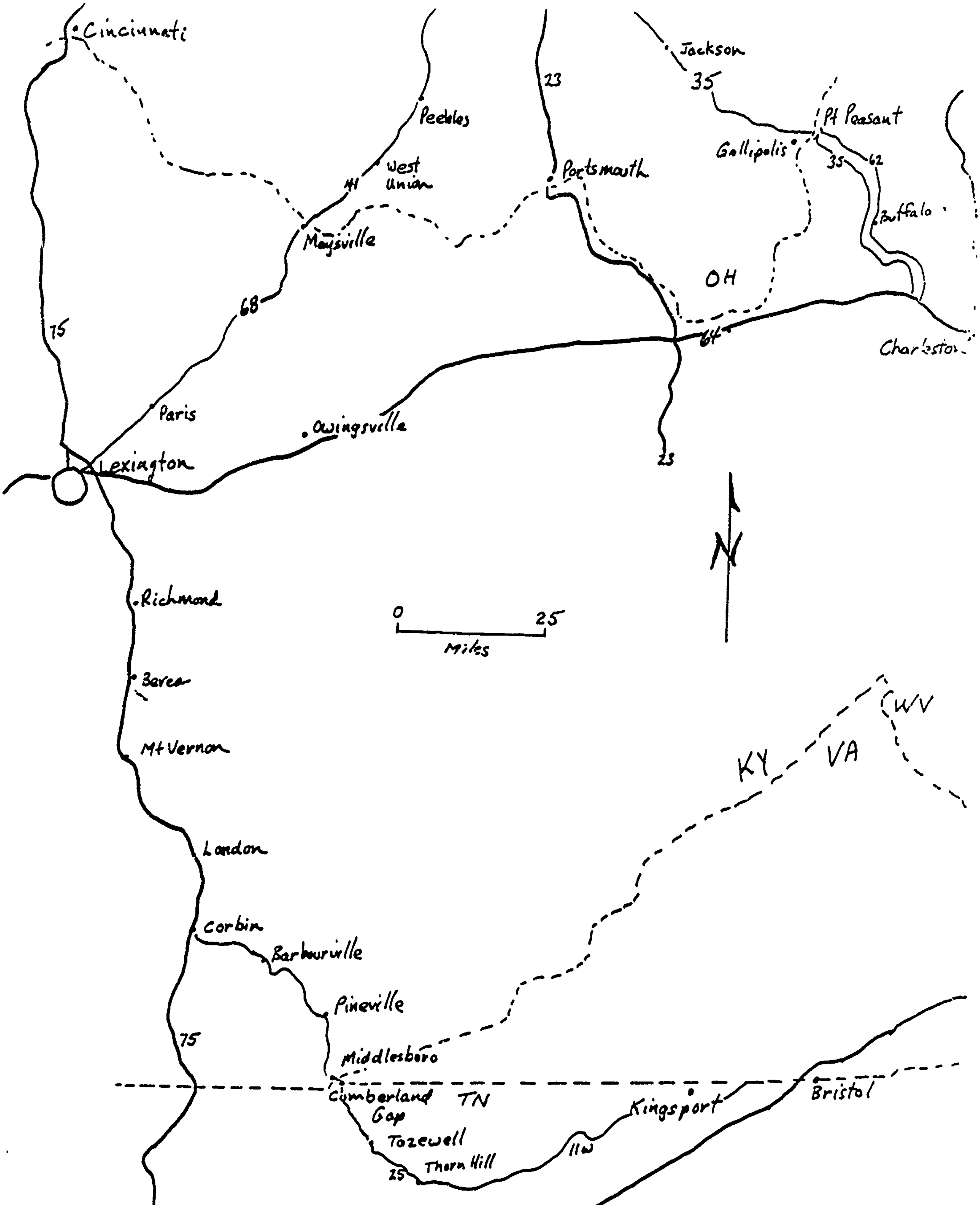

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Figure 4.1 Road map, days 4 and 5.

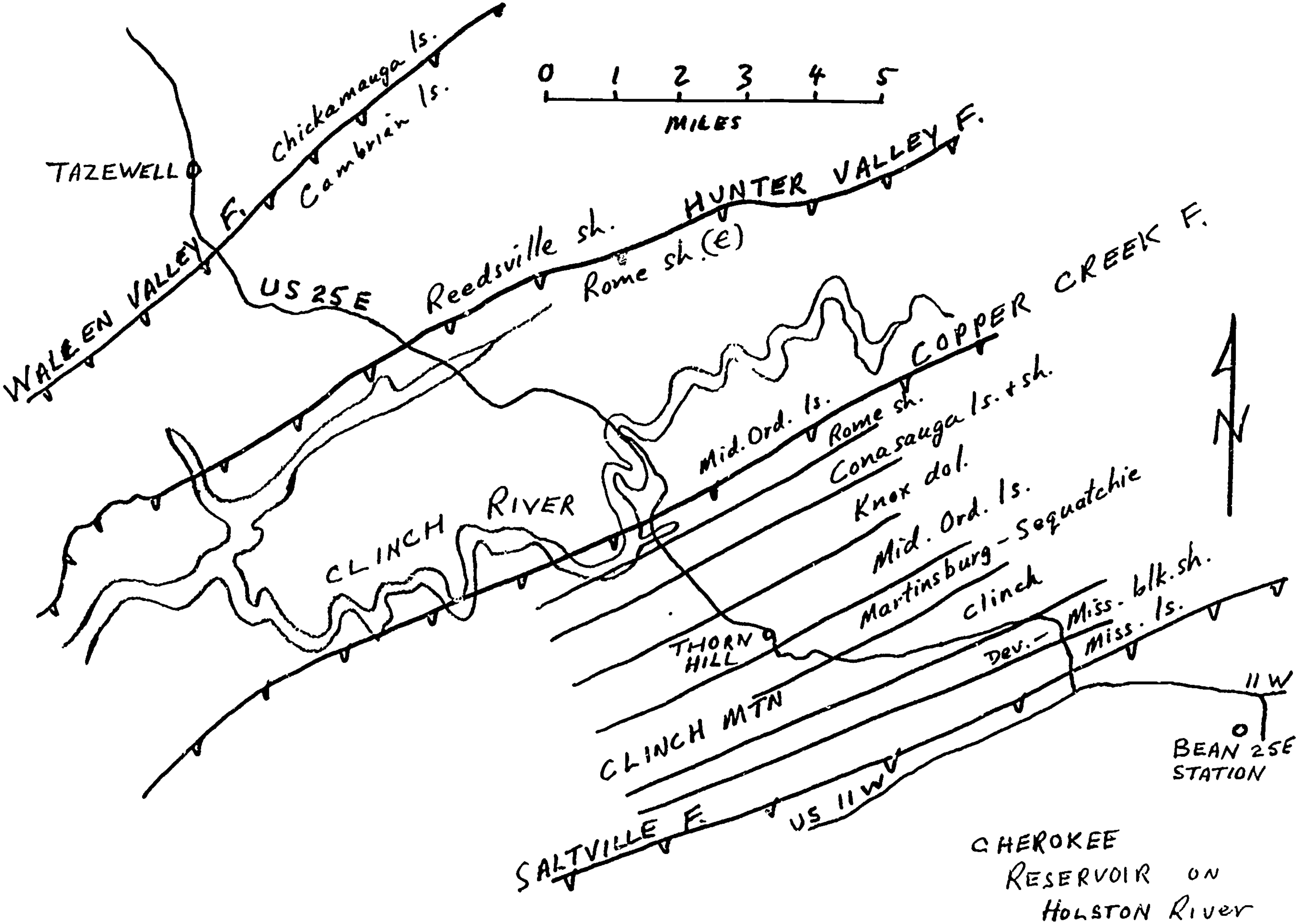

Figure 4.2 Thrust faults in the Valley and Ridge between Cherokee Reservoir and Tazewell .

Stop 3a. Devonian-Mississippian Black Shale: About 3 miles from US11W, look for evidence of the rock type here. As we proceed up the mountain we go down section through older and older rocks.

* * * * *

Continue part way up the mountain. Observe the rock outcrops and boulders.

Stop 3b. Clinch sandstone: In roadcut and as colluvium. Note crossbedding.

* * * * *

Proceed to the roadside rest on the south side of the road.

Stop 3c. Overlook: View of the Valley and Ridge Province. Also note the rock type and fossils in the barriers at the overlook. Which way is the bedrock here dipping?

* * * * *

Continue to the top of the section, stopping on the right side of the road.

Stop 3d. Martinsburg Formation See Fig. 2•1 for age and rock type. What is the strike and dip here? How does it compare with the attitude of rocks at the overlook? Place the ages of the formations on Figure 4•2 and draw in the system boundaries.

* * * * *

Continue down the section and down the mountain noting the small scale folding in the grey beds of the Martinsburg.

Stop 3e. Limestone at Base of Mountain:

* * * * *

Continue north on US25E across Norris Reservoir on the Clinch River. Stop #4 is 0.15 miles beyond the reservoir bridge.

Stop 4. Copper Creek Fault: Examine the fault to determine nature and dip. Consult the geologic map and Figure 4•2 to obtain the regional picture here and compare it with the traverse made through the Narrows on the Second Day. Note the differences in structural style in the south and the central Appalachians (Fig. 4•3).

* * * * *

Continue north. About 2.2 miles from the Copper Creek Fault we cross the Hunter Valley Fault. This is another thrust fault with Rome Shale (____________ age) overlying Reedsville Shale (______________ age).

Why has the Rome Shale been involved in these thrust faults? How far to the northeast does the Clinch Formation extend from Clinch Mountain?

Continue to Tazewell for lunch and a discussion of the topography.

Stop 5. Sinkholes in Downtown Tazewell: Compare the geologic map with the observed topography and topographic map. Do you think that there might be problems in urbanizing this region?

* * * * *

Follow US25E northwest toward Cumberland Gap.

In this stretch we cross a major structure, the Powell Valley anticline. We are approximately on its axis as we cross the Powell River. Strata dip NW and SE away from the River. What might account for the river being in the axis of the anticline. Bedrock is Knox dolomite and Middle Ordovician limestones. Note Karst topography. Cumberland Mountain, ahead, marks the edge of the Cumberland Plateau. It is formed by resistant Pennsylvanian strata

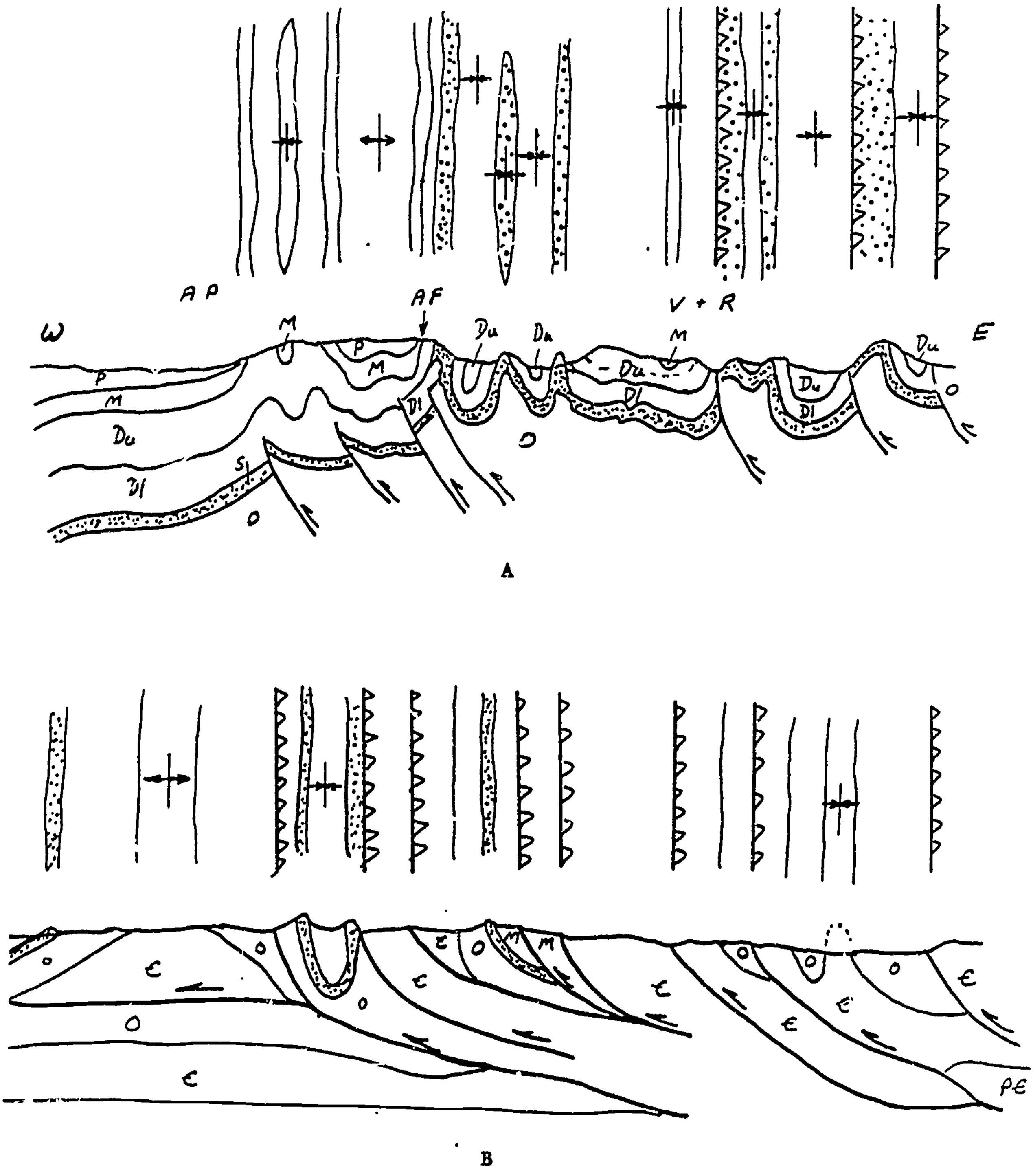

Figure 4.3 Appalachian structure, central (A) and south (B). (Modified from Renfro and Feray, 1970).

At Cumberland Gap we will pass from the Powell Valley anticline into a wide flat syncline called the Middlesboro syncline, in which Pennsylvanian rocks are at the surface. All of this area, including the anticline and the syncline, is underlain by a flat thrust fault, on which the rocks have been pushed bodily many miles to the northwest. The fault, called the Pine Mountain thrust, comes to the surface some distance ahead to the northwest (Figure 4•4). The thrust block is bounded at each end by "tear faults": the Russell Fork fault on the northeast and the Jacksboro fault on the southwest. In 1976 a 4.5 magnitude earthquake near Cumberland Gap had its focus 6 miles deep. **Could it have been on the flat fault?**

Stop 6. Cumberland Gap Tunnel: Turn left near the approach to the gap and descend into the town of Cumberland Gap. Park near the RR tracks and walk toward the tunnel. Observe the rock types and structure in the cut about 100 feet south of the tunnel entrance.

* * * * *

Return to US25E and follow it into the Visitor Center of Cumberland Gap National Park.

Stop 7. Cumberland Gap Visitor Center: There are several displays, books and a movie for those interested. If weather and time permit we will make a trip to the Pinnacle, on the northeast side of the gap (Fig. 4•5). See appendix for more information on the park.

* * * * *

Follow US25E north through Middlesboro. On the outskirts of the city is the next stop at a shopping center.

Stop 8. Middlesboro Landslide: Landslide area and explanation of geology of the Middlesboro region (see Figure 4•6). This landslide has been active since at least the early 70's. Note the technique taken to solve the problem. The geologic setting of Middlesboro may be explained as a crytoexplosive structure. Descriptions of similar features are given by Black (1964) and others.

* * * * *

Continue north. We cross the Pine Mountain thrust fault (Figure 4•7) just beyond Pineville. This is the northwestern edge of the Cumberland thrust fault. From here on we are on flat-lying Pennsylvanian ss, sh, and coal, like those crossed in West Virginia on the first day. About 23-24 miles from Middlesboro we will stop and collect fossils.

Stop 9. Fossils near Barbourville: Lower Pennsylvanian strata of Pottsville age (Fig. 2•1). Sketch the fossils found and identify them if possible. You might see Calamites, Stigmaria, Lepidodendron and Sigillaria.

* * * * *

Follow US25E to Corbin. Turn left in Corbin and follow US25W toward the interchange for I75, south of Corbin. Our Motel for the night should be here. This place is dry. Only claim to fame is the Original KFC restaurant!

Departure for the last leg of the trip is 8:00 a.m. (so what's new!).

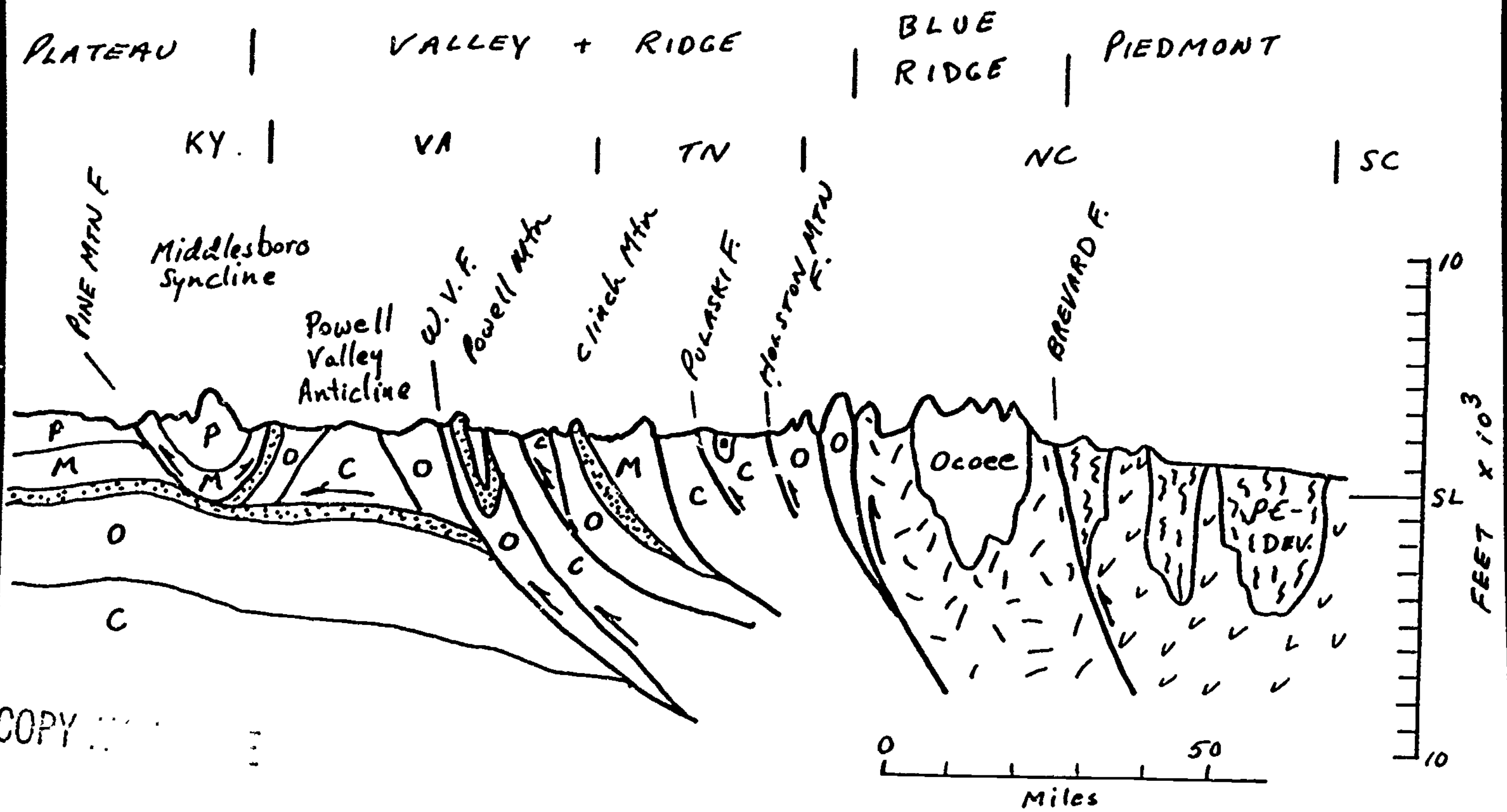

Figure 4.4 Powell Valley anticline and Appalachian cross section from Plateau to Piedmont (KY - SC). NW -SE section through Kingsport, TN. State Boundaries approximate. Vertical exaggeration: 20X. (Modified from Renfro and Feray, 1970).

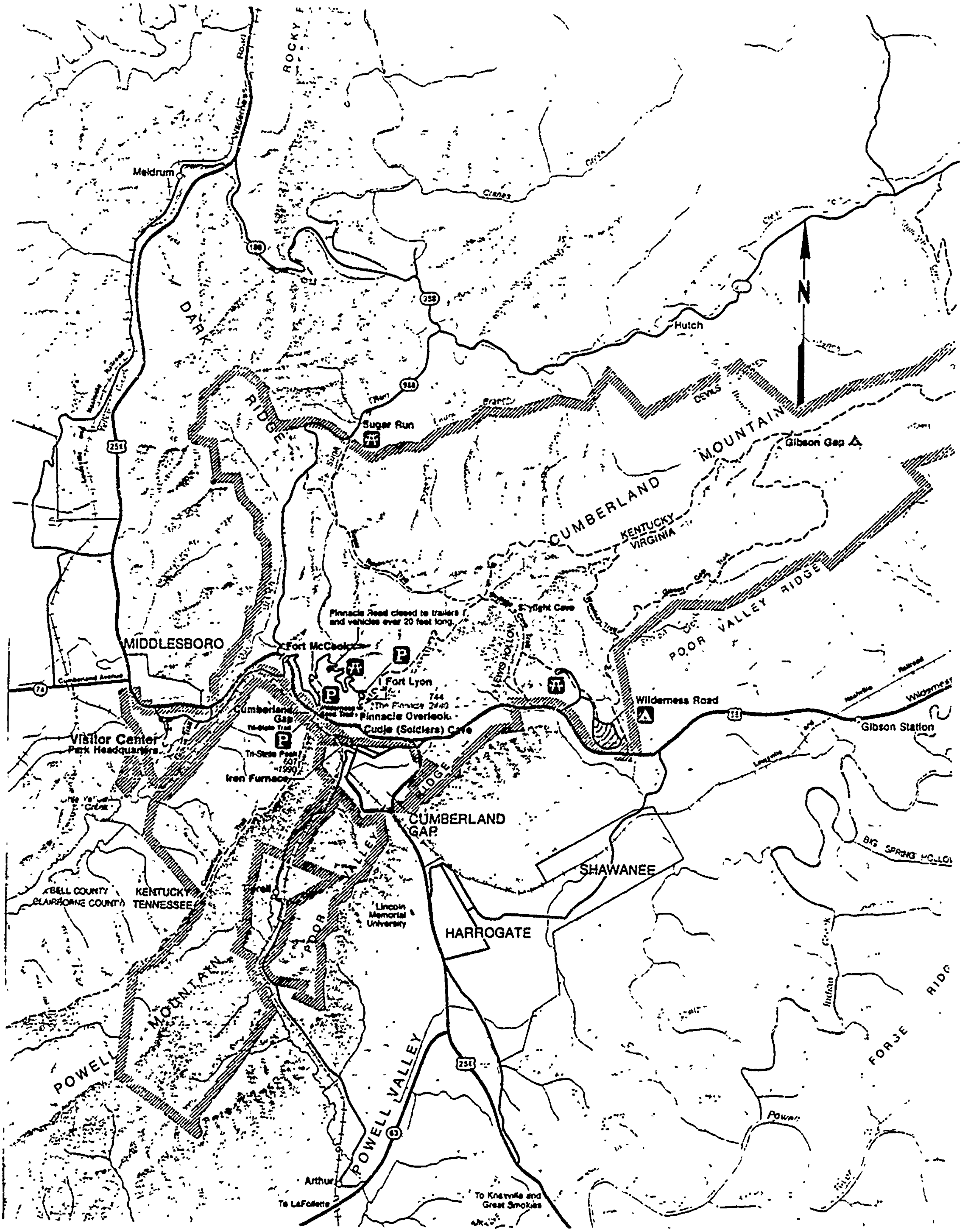

Figure 4.5 Map of Cumberland Gap (NPS).

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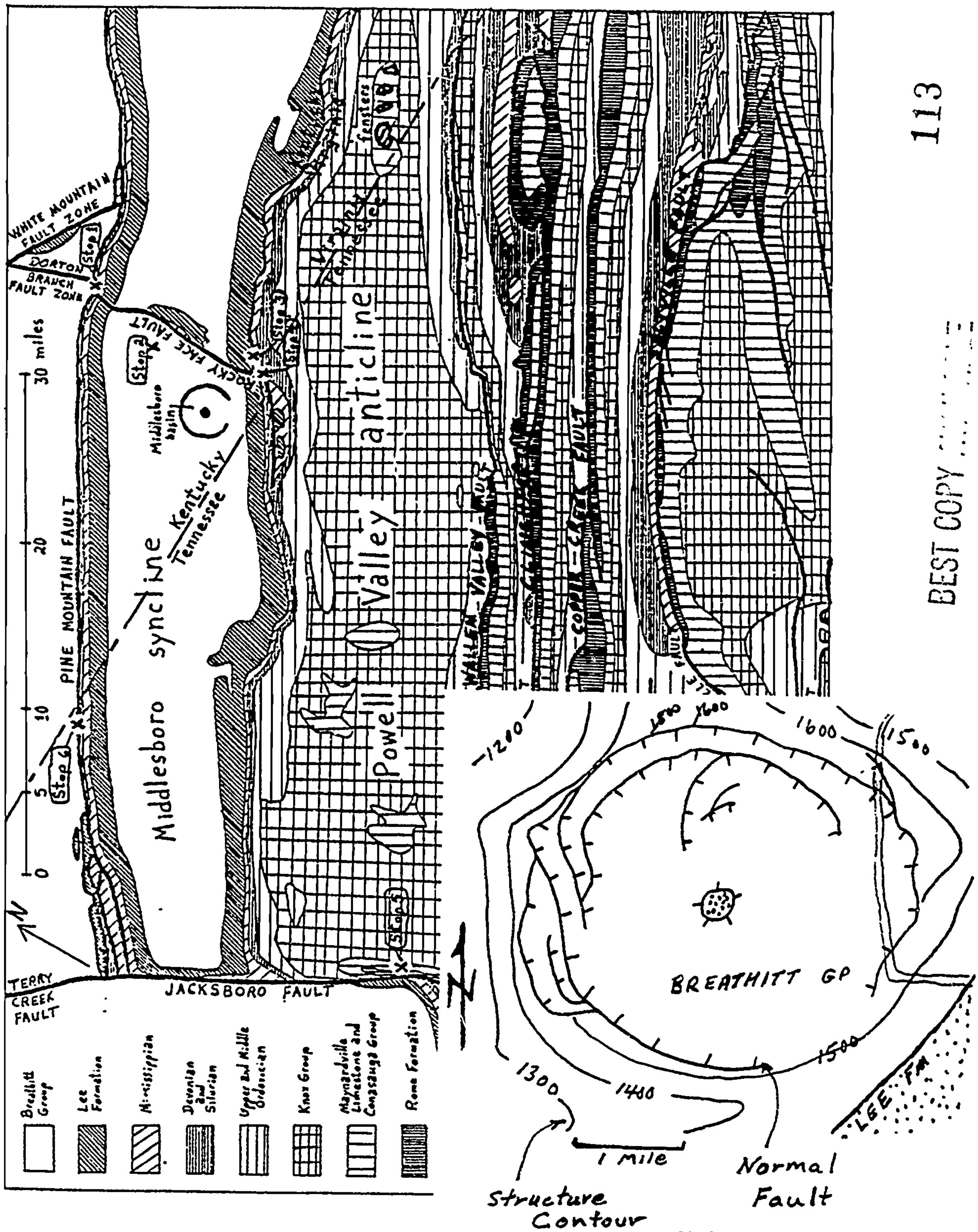

Middlesboro Basin.

Figure 4.6 Geology of the Middlesboro area (modified from Coskren, 1984, with permission.)

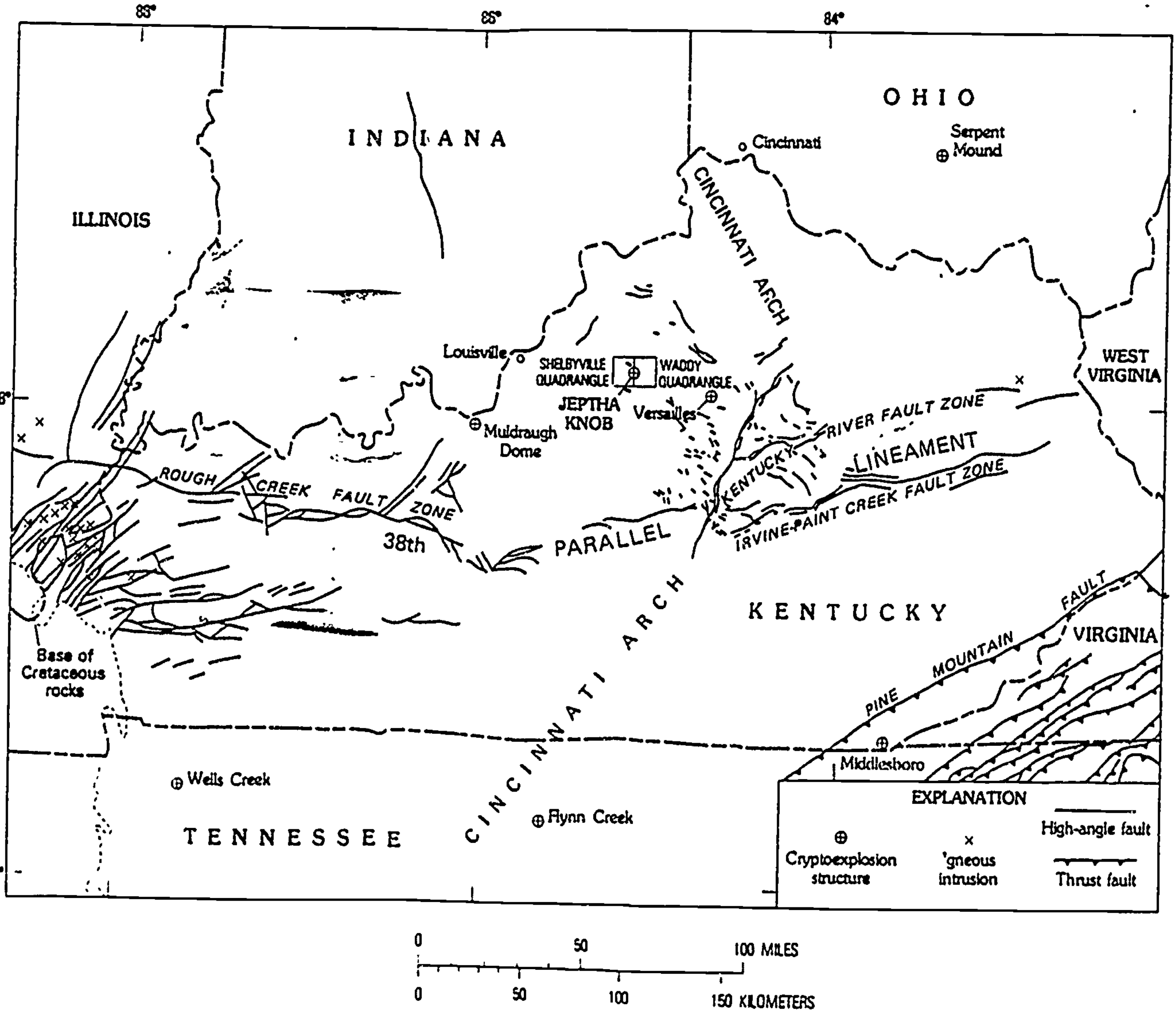

Figure 4.7 Structural features of Kentucky (Cressman, 1981).

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9.2 Maps for Fourth Day

AAPG Road Map
Corbin Geological Quadrangle (USGS Map GQ 231)
Middlesboro South Geological Quadrangle (USGS Map GQ-301)
Middlesboro North Geological Quadrangle (USGS Map GQ-300)
Pineville Geological Quadrangle (USGS Map 1129)
Tazewell, TN Geological Quadrangle (USGS Map GQ-465)
Topographic Map of Tazewell, TN
Howard Quarter, TN. Geological Quadrangle (USGS Map GQ-842)
Honaker, TN Geological Quadrangle (USGS Map GQ-1542)
Geologic Map of Tennessee

9.3 Daily Summary - Fourth Day

SUMMARY OF HIGHLIGHTS

MY DEFINITIONS OF NEW TERMS

CONCEPTS, TERMS AND IDEAS THAT NEED FURTHER EXPLANATION

10.0 ROAD LOG AND STOP DESCRIPTIONS — FIFTH DAY

Corbin, KY to Columbus, OH

Major Stops: 1. Deltaic deposits at Livingston Exit, KY; 2. Mississippian Limestone at Mt. Vernon Exit; 3. Kentucky River fault; 4. Barite vein; 5. Karst of the Inner Bluegrass, Lexington; 6. Ordovician fossils, Maysville, KY; 7. Bedrock stream, northeast of Aberdeen, OH.

Stop 1. Deltaic Deposits at Livingston Exit: Deposits here show several depositional environments, and include coal, iron nodules, cross-bedding, massive sandstone, and inter-bedded shale and sandstone. **How many major units can you detect from the viewing area on the first bench of the roadcut? How much relief is there in this area?**

Interpretations of the roadcut (by Ferm et al., 1971; and others) of these deposits have centered on their comparison with present-day alluvial plain-deltaic environments such as are being formed in the Mississippi Delta. Figures 5·1 and 5·2 give plan and cross-sectional views of Carboniferous rocks in Eastern Kentucky, and Table 5·1 relates the rock types to the depositional environments. Although the geology is complicated, with time and practice one can visualize the environments that existed 300 million years ago. Similar sequences of rocks can be seen in Eastern Ohio.

What depositional environments do you see? Sketch the stratigraphy seen in the roadcut.

Table 5.1 Lithologic description of facies and their interpreted depositional environments. (Modified from Ferm et al., 1971. Reprinted with permission, Geological Society of Kentucky.)

DEPOSITIONAL ENVIRONMENT	DESCRIPTION OF FACIES
1.0 Lower Alluvial Plain to Upper Delta Plain	
1.1 Meandering Channels	Massive thick sandstones with point-bar structures and wedge-to trough-type large scale cross-beds with erosional basal contacts. Plant and wood fragments. Grain size and bedding thickness decreases upward. Shale plugs.
1.2 Levee and crevasse-splay	Alternative thin-beds of mudstone and fine-grained sandstone to siltstone with ripple bedding, root-disrupted parallel laminations, and plant fragments.
1.3 Swamp	Coal. Carbonaceous clay in well-drained swamps; peat in poorly drained swamps. Pyrite.

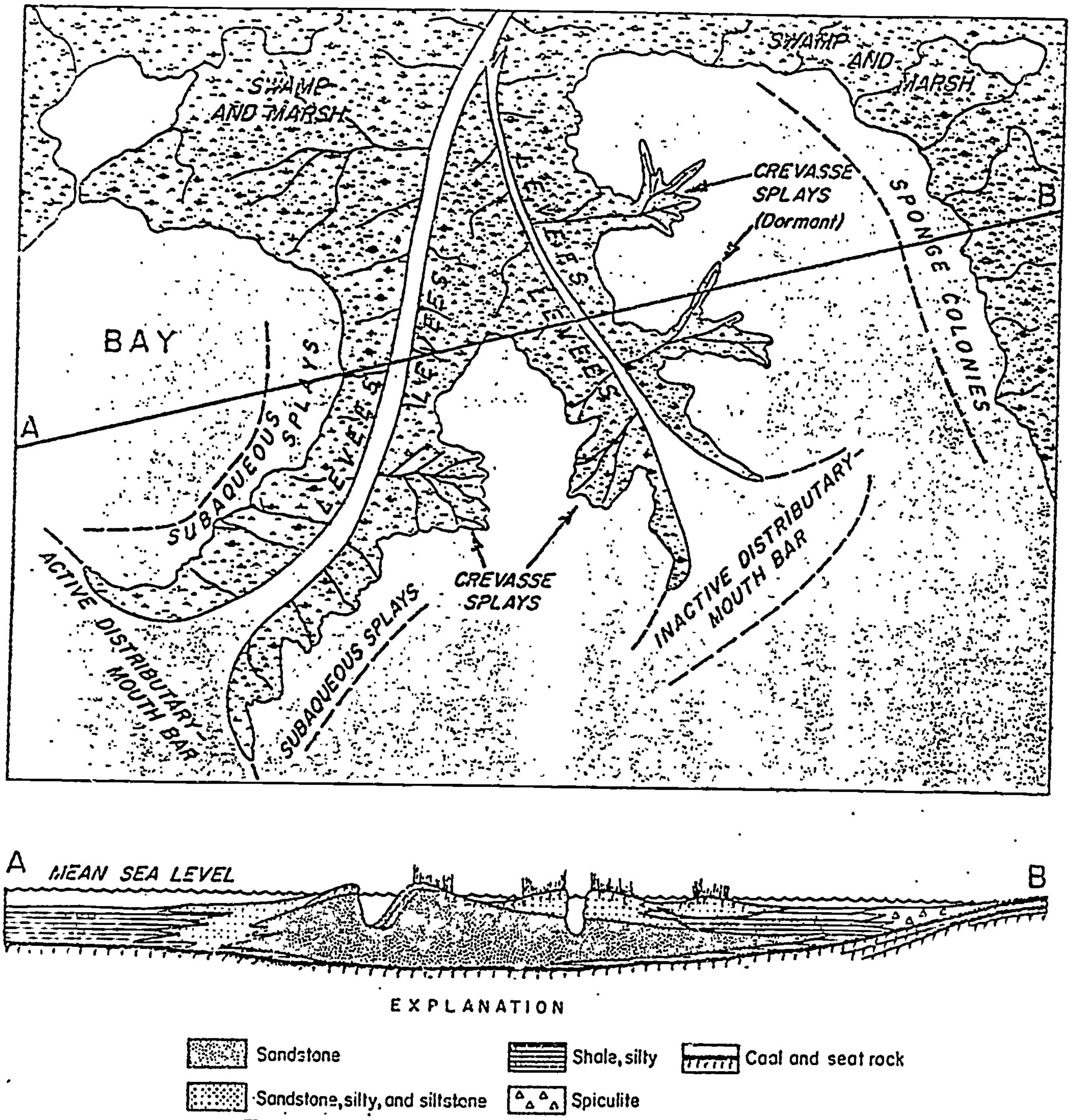

Figure 5.1 Upper delta plain model. (Modified from Ferm et al., 1971. Reprinted with permission, Geological Society of Kentucky.)

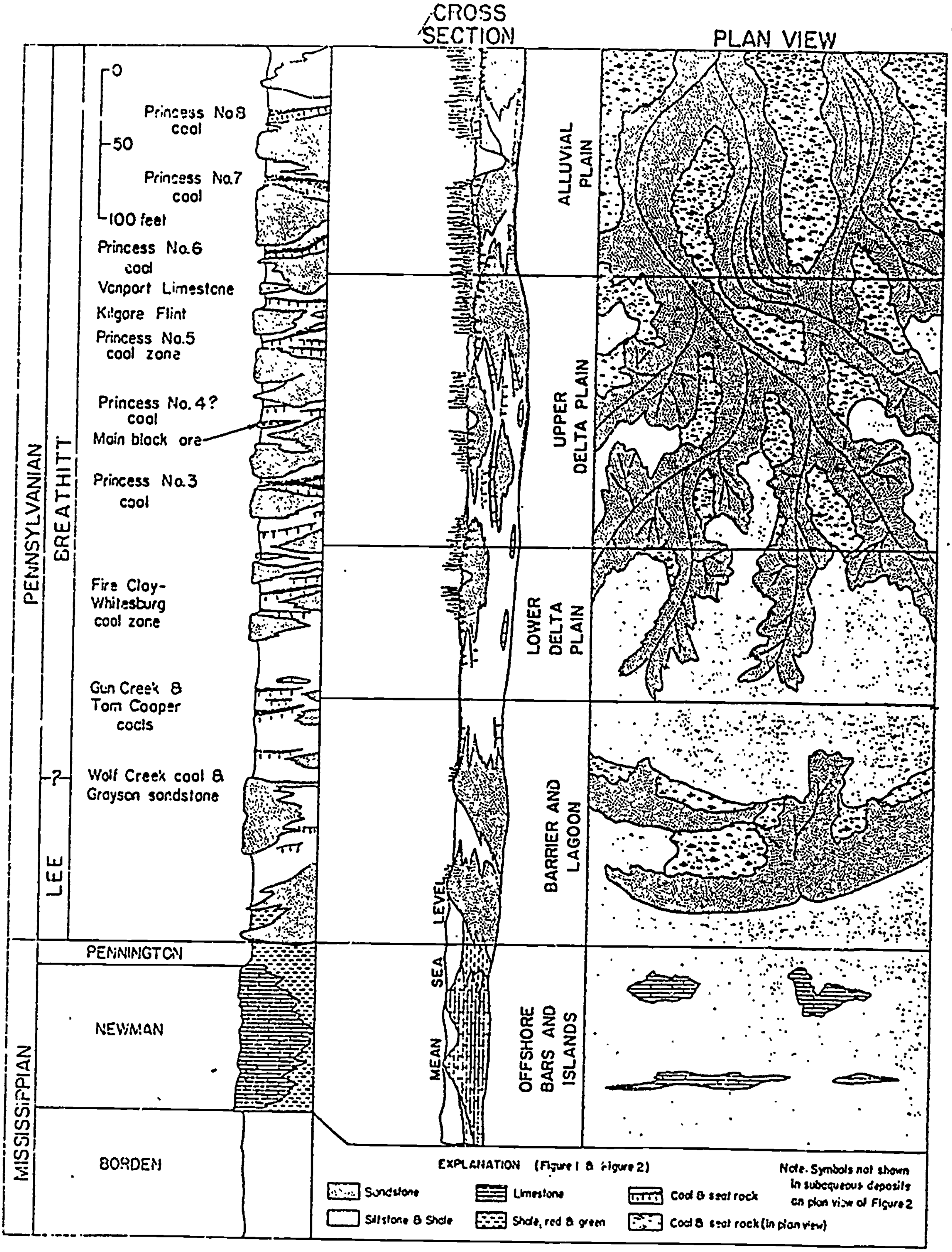

Figure 5.2 Paleoenvironmental interpretation of Carboniferous rocks. (From Ferm et al., 1971. Reprinted with permission, Geological Society of Kentucky.)

Table 5.1. Continued.

DEPOSITIONAL ENVIRONMENT	DESCRIPTION OF FACIES
1.4 Lake	**Limestone** alternating with dark-gray calcareous shale. Spirorbis, (worm tubes usually on other fossils), fish parts, and ostracodes are most common fossils.
2.0 Lower Delta Plain	
2.1 Distributary channels	Massive **sandstone** with dune and ripple structures; basal scour. Abandoned channel deposits of siltstone and dark-gray shale with abundant plant fragments. Siderite and ironstone concretions.
2.2 Levee and crevasse-splay	Alternating thin-beds of **siltstone** and **mudstone** with plant fragments, disrupted parallel laminations, and ripple bedding. Iron oxide concretions.
2.3 Swamp	Coal, pyrite, claystone-siltstone partings.
2.4 Lake interdistributary bay, and interdelta bay	**Shale**, ironstone concretions, plant fragments. Limestones with ostracodes, Spirorbis and fish scales.
2.5 Beach	Thin **siltstone** and fine-grained **sandstone** beds.
3.0 Delta-front distributary-mouth bars	**Alternating** thin beds of **siltstone**, fine-grained **sandstone** and shale (mudstone) with gradational basal contact. Slightly arched beddings reflecting bar shape. Ripple, dune, and parallel bedding with burrow-mottled structures, especially at distal fringe.
4.0 Prodelta	Laminated silty **shale** and massive sandstone.
5.0 Bay	**Mudstone** and **shale**, dark-gray to reddish-gray. **Limestones**, with brackish fossils.

Stop 2. Mississippian Limestone at Mt. Vernon Exit: Check the rock type and observe the weathering features in this roadcut. Beware of rockfalls. What is the name of this formation? A few miles down the road we leave the Pennsylvanian behind as we go down section.

* * * * *

Continue north on I75 in Mississippian rocks. At Berea we are on the New Albany Shale and Boyle Dolomite. We are now beyond the hill region -- the Cumberland Plateau -- of southeastern Kentucky. (Mt. Vernon and Berea maps)

Within three miles of Berea we cross Silurian limestones and then enter Upper Ordovician rocks — a green calcareous shale. In this 3-mile trip we have crossed the very thin section of Devonian present here. From here to Lexington we go down section over progressively older Ordovician strata. These rocks are well exposed in the Kentucky River gorge. **What physiographic province are we in?**

Our route from Berea to Lexington crosses the famous "Bluegrass region" of Kentucky. This is also known as the Jessamine Dome. This area is typically a rolling upland, with fertile soil which is residual from solution of the underlying Ordovician limestones. The surface is dotted with sink-holes, and the term "karst topography" is appropriate. **Note the drainage pattern.** Three sections of the Bluegrass region are recognized (Figure 5•3).

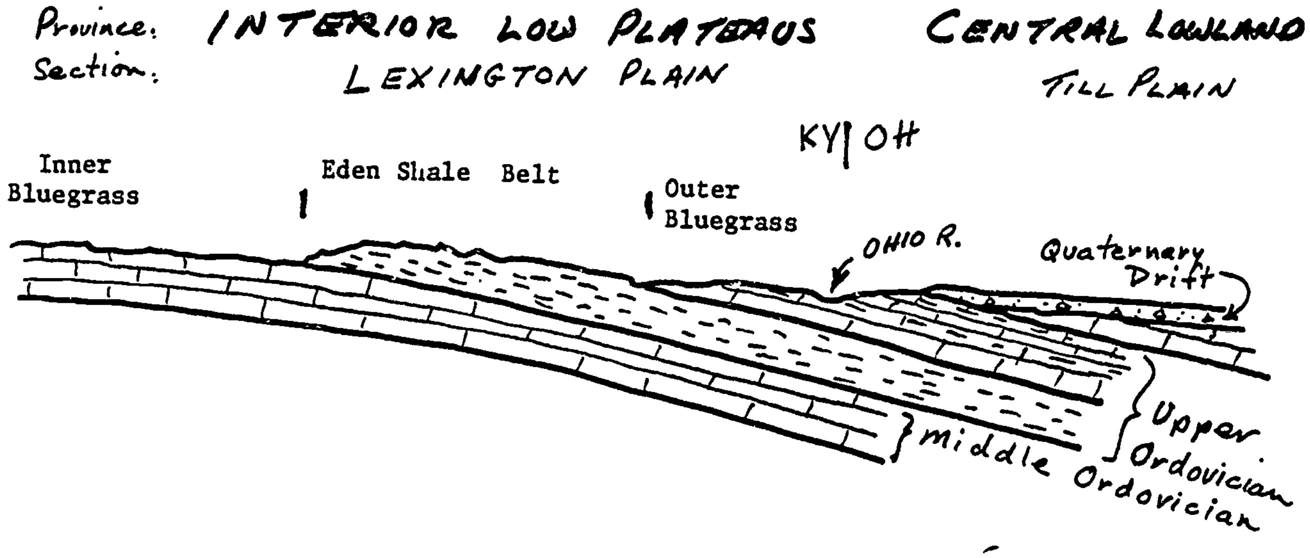

Figure 5•3. Three physiographic areas of the Bluegrass Region.

The Inner Bluegrass is the central division, in which Lexington is situated. It is underlain by Middle Ordovician limestones (See AAPG map and time unit chart). It is a gently rolling plain, broken by mature topography near large streams and in areas where the rocks are shaly. We enter it first at the Kentucky River. Note indicators of affluence, if any.

The Eden Shale Belt, surrounding the Inner Bluegrass area, is a rough hilly belt, underlain by the Upper Ordovician Eden formation. This unit, which overlies the limestones of the inner division, is dominantly shale. The topography produced by stream erosion on this shale is angular and mature. Valleys are narrow, and the divides separating them are narrow and winding.

The Outer Bluegrass. Rocks above the Eden shale contain more limestone than the Eden, and so the Outer Bluegrass belt is much like the Inner Bluegrass. The topography is somewhat rougher, because the rocks contain more shale than Middle Ordovician limestones, but it is not as rough as the Eden shale belt.

From I-75 take the Clays Ferry Exit (US 25) south. After crossing I-75, turn north. Stop 3a is at the overlook beside the house with the stone wall.

Stop 3. **Kentucky River Fault: see Figures 4•7 and 5•4.**

(a) Overview of Kentucky River gorge.

(b) Drive down the hill and park on roadside near stairs to house on the hill. Walk along the section of Upper Ordovician rocks and locate the fault. **Make a sketch of the fault zone.**(Ford, KY Quadrangle)

* * * * *

Follow US25 across the Kentucky River. Note the caves on the west side of the gorge as you head north out of the gorge. Note also that the meandering river has straight segments showing some fault control. Uplift has resulted in entrenchment of the river. About 6 miles from the river approach the I-75 overpass. Turn down the side road on the east side of the overpass to Stop 4.

Stop 4. **Barite Vein:** Exposed in this small roadcut is a vein of several minerals. **What are the minerals? What is the country rock?**

* * * * *

Return to US25, and turn left and drive NE toward Athens. Note the farms of the Inner Bluegrass and the relationship of rock and soil to the economic characteristics of the area. Rejoin I-75 and continue north to Lexington. Include Stop 5 if time permits. Otherwise bypass Lexington and take US68 to Maysville.

Stop 5. **Karst of the Inner Bluegrass, Lexington:** Proceed to downtown Lexington to view sinking stream and other karst features. Consider the potential for groundwater contamination from chemical spills along the highways in this area.

* * * * *

Follow I-75 north. Note mileage at I-75/US68 junction = ____________.

Take US68 north noting characteristics of the heart of the Bluegrass region. Eight miles from I-75/US68 junction enter **Bourbon County which is famous for** ____________.

Paris is the heart of the county. What is the major agricultural product of the area? We have been crossing from the Inner to the Outer Bluegrass region and rising up section again. At mile 21 (from I-75/US68) note the topography and economic conditions. **Explain both.** A magnitude 5 earthquake occurred in the area of Mile 37 in August 1980. At Mile 62 we reach Stop 6.

Stop 6. **Ordovician Fossils, Maysville, KY:** The rocks in the Cincinnati-Maysville region are among the world's most fossilerous, and have attracted much geological/paleontological attention for more than 125 years. The resulting nomenclature is complicated and much progress has been made in recent years in defining recognizable rock units, testing them by mapping a series of quadrangles along the

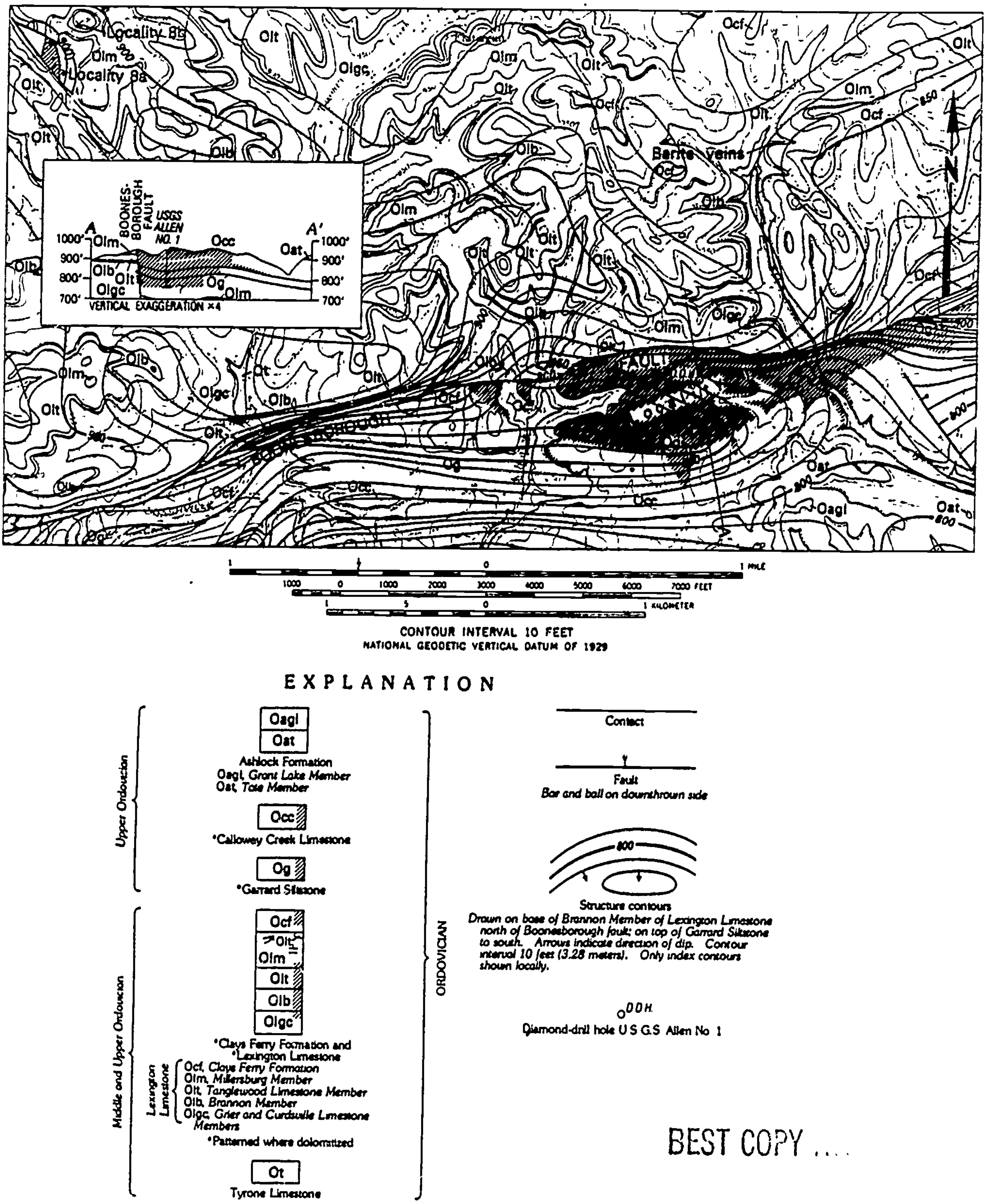

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Figure 5.4 Kentucky River Fault System (Boonesborough Fault portion) (Black, MacQuown and DeHaas, 1981).

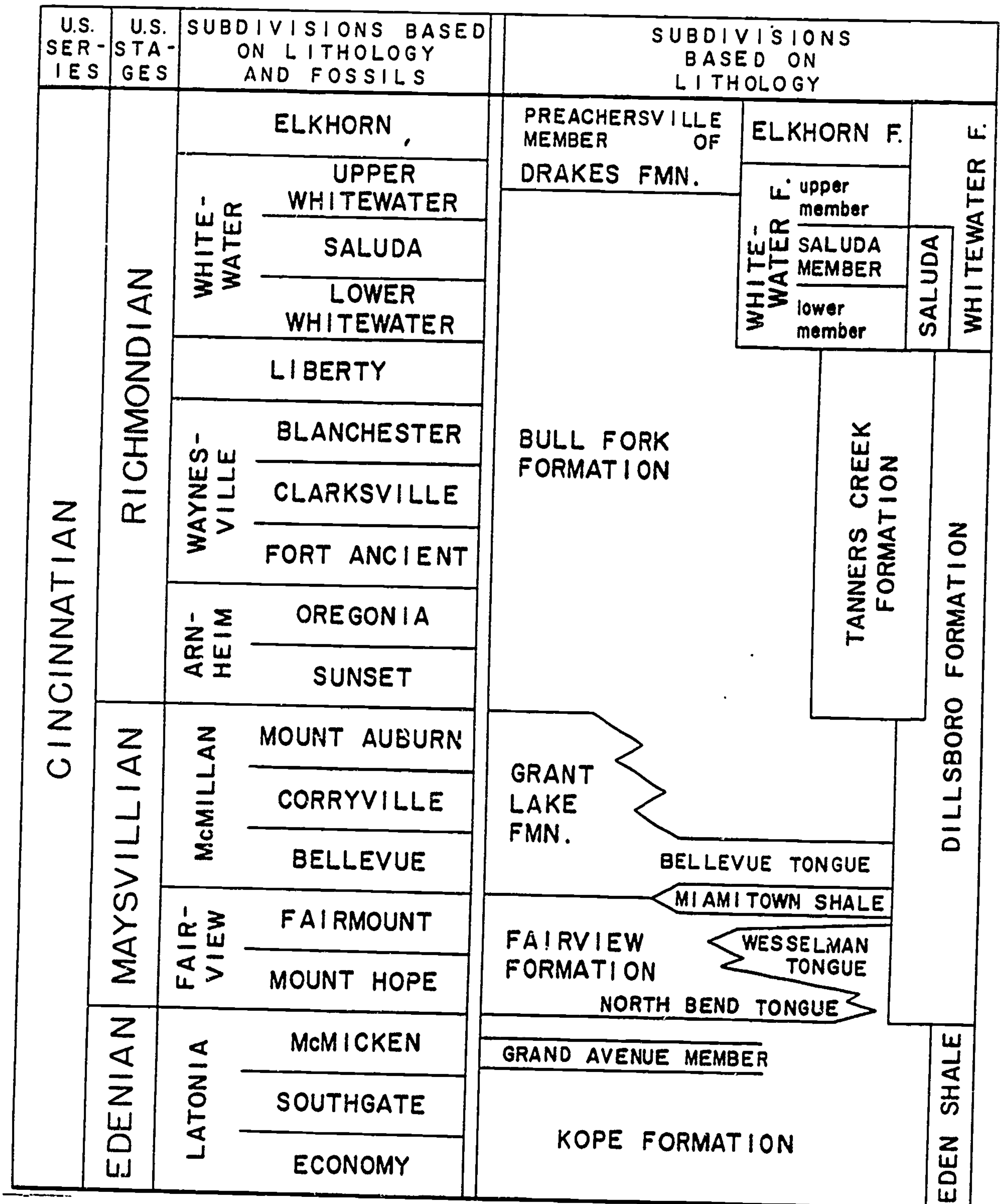

Figure 5.5 Stratigraphy in the Maysville area. The relationship of stratigraphic names that have been applied to rocks in the Indiana, Kentucky and Ohio area is shown on the right side of the diagram. These names do not necessarily represent different rock units or their lateral relationships. Data derived from: Caster, Dalve, and Pope (1955/61) and Anstey and Fowler (1969), Brown and Lineback (1966), Ford (1967,1974), Gray (1972), Hatfield (1968), Hay et al. (1981), Martin (1975), Peck (1966), and Ross et al. (1982). (Reprinted from Davis, 1981, with permission.)

Ohio River, and working out the fossil sequence by means of conodonts and other fossils. Table 5•2 - shows the stratigraphic relationships of the formations in this area (Sweet, 1979). At stop 6 we will be in rocks of Edenian age-the Kope Formation. Fossils found in this formation here include: Sowerbyella rugosa, Strophomena, Onniella, Rafinesquina fracta, Zygospira modesta, the trilobites Cryptolithus tesselatus and Flexicalymene meeki, graptolites (Climacograptus typicalus), mollusks, echinoderms and many bryozoans. See Davis (1981) for help in identification. We may also collect from the Fairview Formation. For more details on the Upper Ordovician stratigraphy see Figure 5•5. Make a list of fossils that we find here. In what rocks do they occur?

Table 5•2 Stratigraphy at Marysville

Group	Formation
RICHMOND	Preachersville m. of Drakes fm.; sh. & slst.) Bull Fork fm.; gray sh. with thin foss. lss.) not seen
MAYSVILLE	Grant Lake fm.; thin-bdd. rubbly ls., sh. partings ± 100' Fairview fm.; thin- to med-bdd. foss. ls., sh. partings up to 10" thick; flow rolls, ripple marks 70-110' Strophomena planoconvexa zone, ± 3' thick, near base
EDEN	Kope fm.; gray silty calc. sh., thin lenticular compact foss. lss. 200-230' exposed in sections near the Pepsi-Cola Warehouse.

* * * * *

From the Maysville section, continue north on US68 and cross the Ohio River. Intersection of US-68 with Ohio 41; Note mileage __________. We will continue north on Highway 41. Note landslides and signs warning of them about two miles down the road.

Stop 7. Bedrock Stream northeast of Aberdeen, OH: This channelized stream has a bed of bedrock. Most streams have a bed of alluvium. Is this stream in a "graded" state (in equilibrium, flowing on "adjustable" materials) according to the definition of Mackin (see Bloom, 1978).

* * * * *

Near, West Union we cross into Silurian. At Jacksonville, road cuts expose Silurian carbonates with the appearance of sandstone. Possible Stop.

If time permits we will make a stop at the Serpent Mound "Cryptoexplosion Structure" (Figure 5•6) to study the deformation associated with this structure which has been interpreted as meteorite impact (Dietz, 1946, 1960)-an astrobleme, and as a volcanic explosion (Bucher, 1936)-a geobleme. The 4-mile-wide circular structure has a central uplift zone surrounded by a downdropped outer ring graben (Reidel and Koucky, 1981). Mississippian Sunbury Shale is the youngest disturbed unit. It is overlain by Illinoian drift.

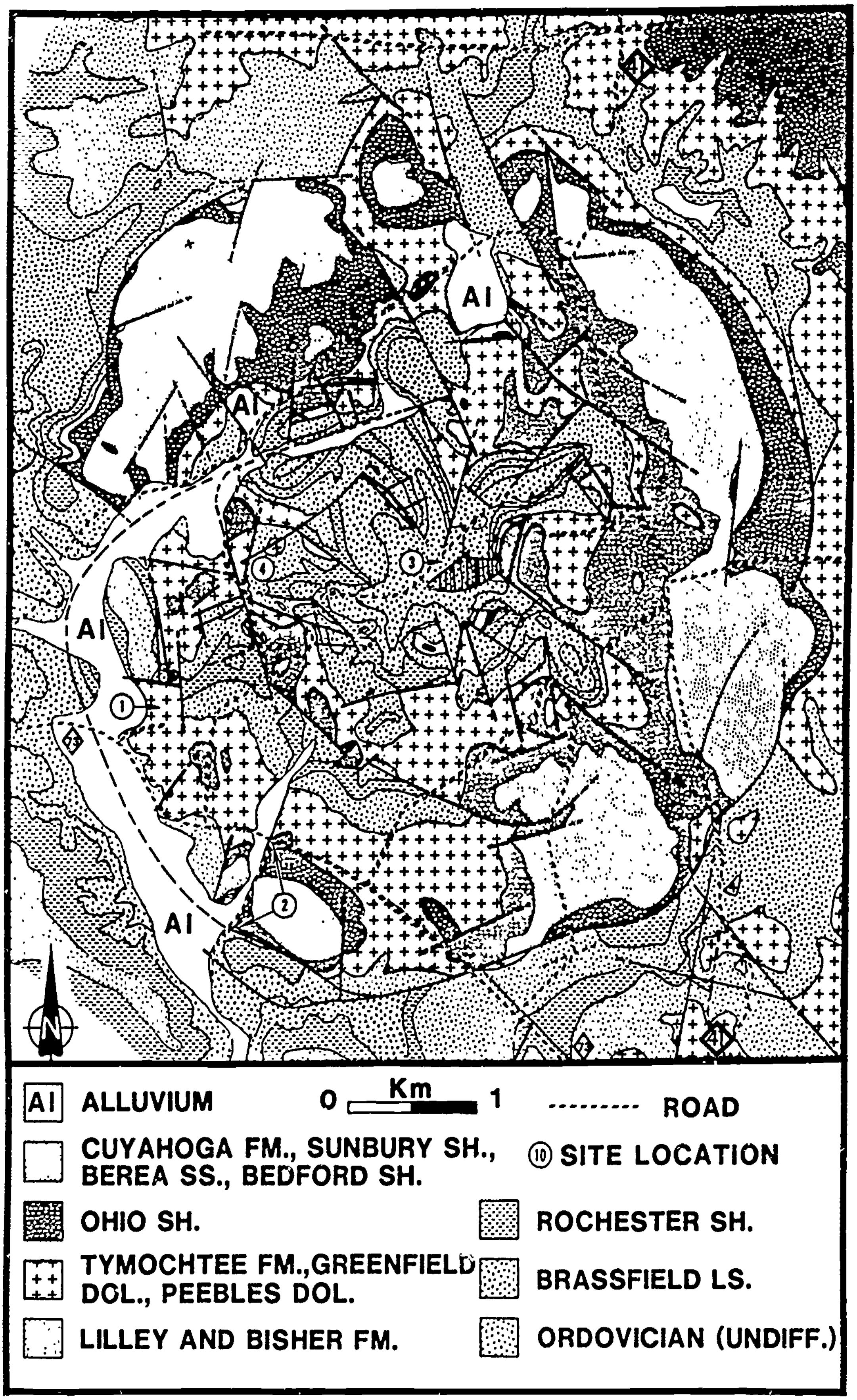

Figure 5.6. Geology of Serpent Mound, Ohio.(Modified from Reidel and Koucky, 1981. Used with permission.)

At Peebles, the Mississippian Plateau is on the eastern skyline. Continue on Highway 41 toward Chillicothe. Just before the "Fort Hill" turnoff, note the rock in road cuts. This is the Ohio Shale of Devonian age. High hills in the area are capped by Mississippian sandstones. A gravel pit, about 18 miles from 41/73 intersection, is probably Illinoian material and marks the glacial boundary. Note junkyard north of road.

After passing through the outskirts of Chillicothe we will take US23 north to Columbus. We will be crossing a till plain most of the way. Note glacial outwash deposits particularly near I-270.

Return to OSU -- End of FIFTH DAY. **Remember to remove all personal gear, samples and solid waste from the vehicle before leaving.**

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10.2 Maps for Fifth Day

AAPG road map for Mid-Atlantic Region
Mt. Vernon (U.S.G.S. Map GQ-902)
Berea (U.S.G.S. Map GQ-649)
Ford (U.S.G.S. Map GQ-764)
Lexington East (U.S.G.S. Map GQ-683)
Coletown (U.S.G.S. Map GQ-644)
Richmond South (U.S.G.S. GQ Map 479)
Richmond North (U.S.G.S. GQ Map 583)
Maysville West Quadrangle (U.S.G.S. Map GQ-1005)
Bedrock of Ohio
Glacial Map of Ohio

10.3 Daily Summary - Fifth Day

SUMMARY OF HIGHLIGHTS

MY DEFINITIONS OF NEW TERMS

CONCEPTS, TERMS AND IDEAS THAT NEED FURTHER EXPLANATION

GEOLOGIC MAP OF WEST VIRGINIA

WEST VIRGINIA GEOLOGICAL AND ECONOMIC SURVEY

Robert B. Erwin, State Geologist

1969

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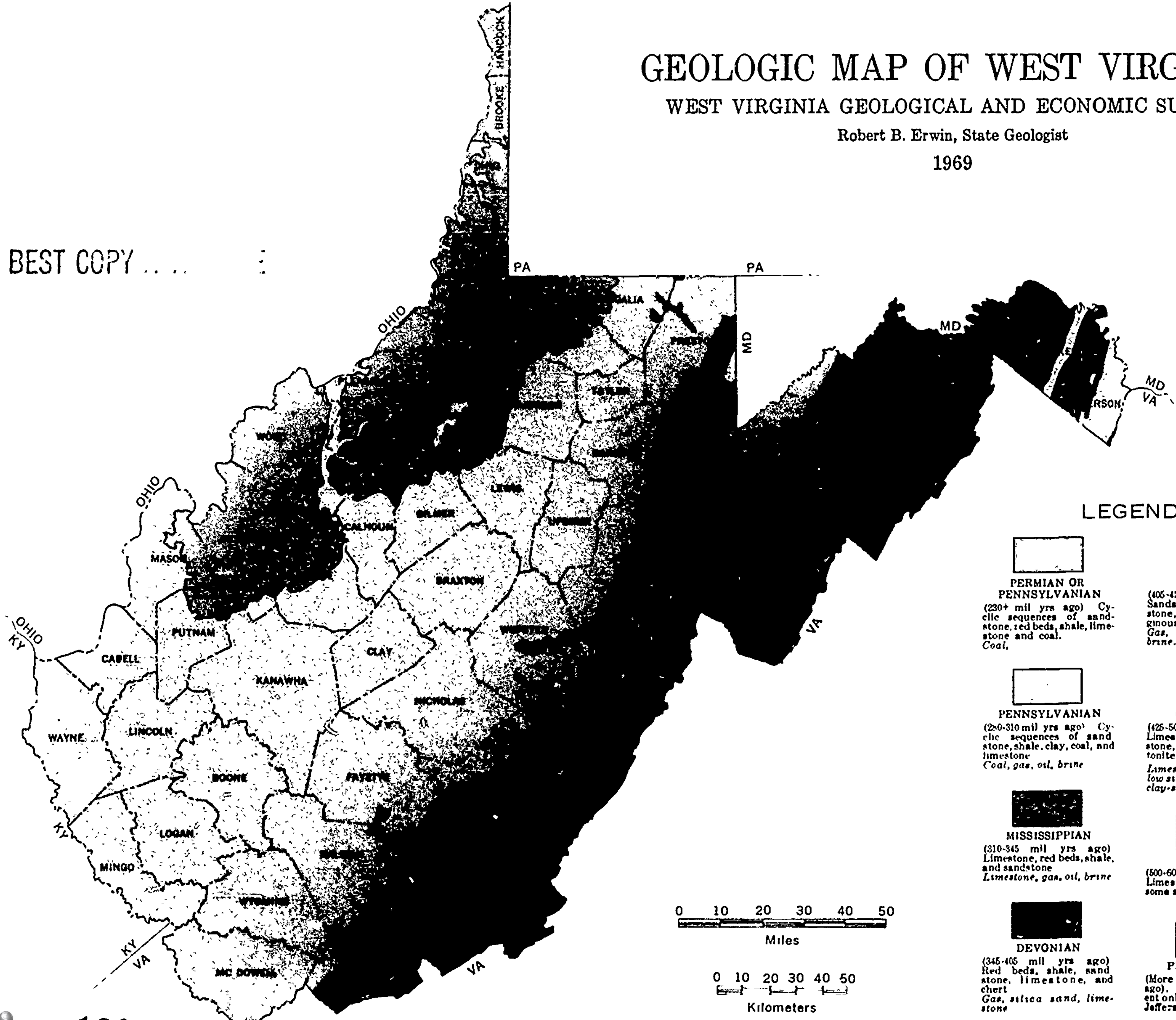


LEGEND

PERMIAN OR PENNSYLVANIAN
(230+ mil yrs ago) Cyclic sequences of sandstone, red beds, shale, limestone and coal.
Coal,

PENNSYLVANIAN
(250-310 mil yrs ago) Cyclic sequences of sandstone, shale, clay, coal, and limestone
Coal, gas, oil, brine

MISSISSIPPIAN
(310-345 mil yrs ago) Limestone, red beds, shale, and sandstone
Limestone, gas, oil, brine

DEVONIAN
(345-405 mil yrs ago) Red beds, shale, sand stone, limestone, and chert
Gas, silica sand, limestone

SILURIAN
(405-425 mil yrs. ago). Sandstone, shale, limestone, rock salt, and ferruginous beds
Gas, limestone, artificial brine.

ORDOVICIAN
(425-500 mil. yrs ago). Limestone, dolomite, sandstone, shale, and metabentonite
Limestone (particularly low silica), building stone, clay-shale

CAMBRIAN
(500-600 mil yrs. ago). Limestone and dolomite, some sandstone and shale.

PRECAMBRIAN
(More than 600 mil. yrs. ago). Greenstone. Present only in extreme eastern Jefferson County.

COMMONWEALTH OF VIRGINIA

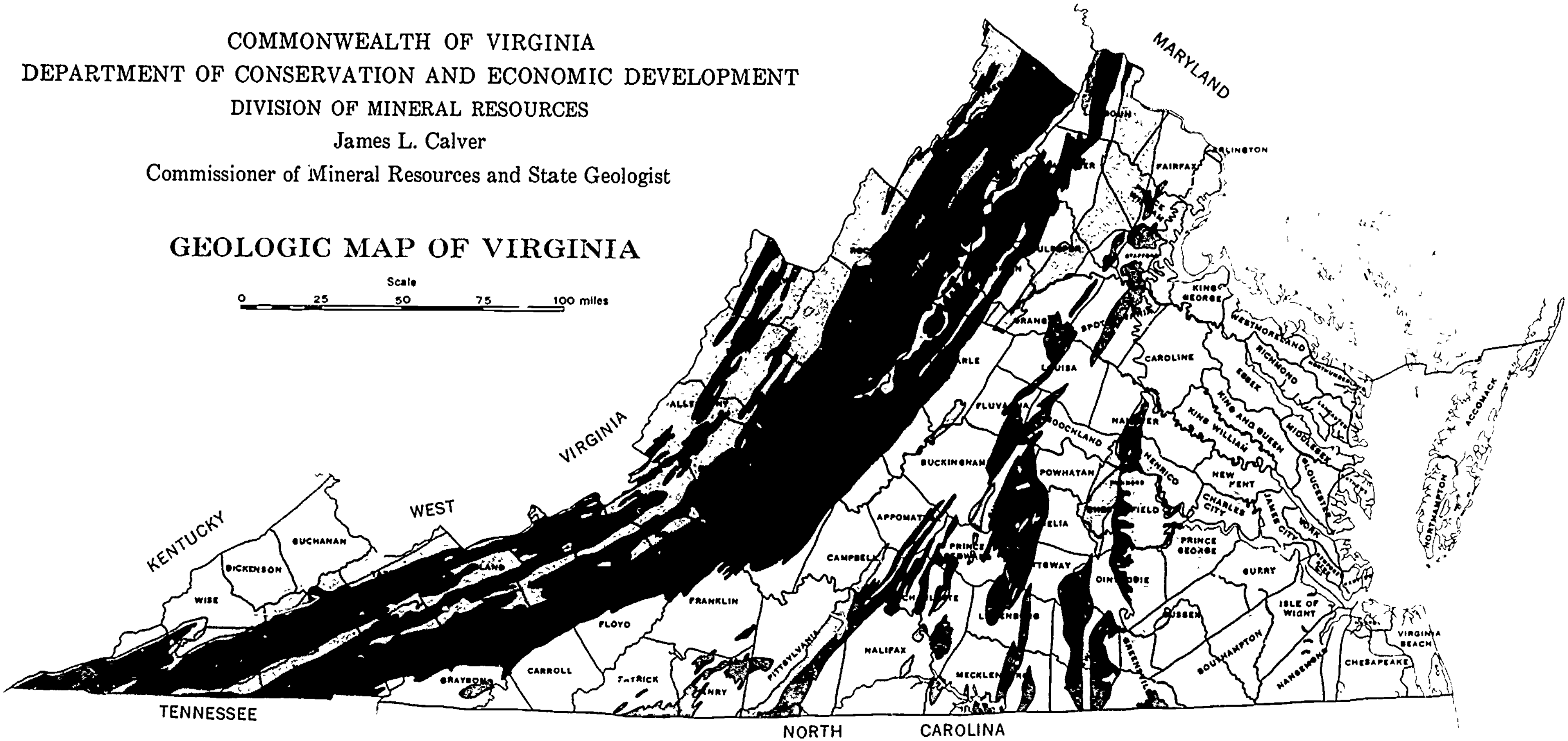
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

DIVISION OF MINERAL RESOURCES

James L. Calver

Commissioner of Mineral Resources and State Geologist

GEOLOGIC MAP OF VIRGINIA



CENOZOIC

QUATERNARY
(0-1 million years) Sand and gravel
Sand and gravel.

TERTIARY
(1-70 million years) Loose or partly indurated sand, clay, marl, and diatomaceous earth
Sand, clay, marl, and diatomaceous earth

MESOZOIC

CRETACEOUS
(70-135 million years) Partly indurated sand, clay, and sandstone
Sand and clay

TRIASSIC
(180-225 million years) Red and gray shales and sandstones intruded by diabase; some thin coal layers.
Crushed stone shale, and lightweight aggregate

PALEOZOIC

PENNSYLVANIAN
(270-310 million years) Sandstone, shale, and coal
Sand, coal, coke, lightweight aggregate, and natural gas.

MISSISSIPPIAN-DEVONIAN
(310-400 million years) Sandstone, shale, limestone, gypsum, and coal
Coal, coke, silica sand, gypsum, shale, cement, salt brine, and natural gas

SILURIAN-ORDOVICIAN
(400-500 million years) Limestone, dolomite, shale, and sandstone
Lime, crushed stone, cement, shale, and petroleum

CAMBRIAN
(500-600 million years) Dolomite, limestone, shale, and sandstone.
Crushed stone, sand, zinc, lead, and shale.

PRECAMBRIAN

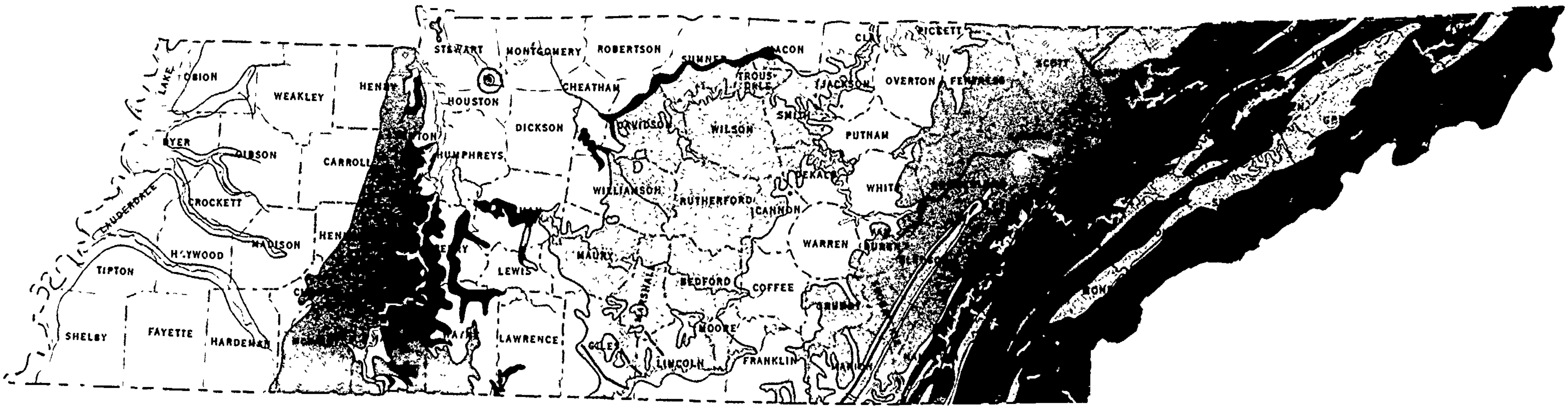
VIRGINIA BLUE RIDGE COMPLEX
(Older than 600 million years) Granite and gneiss
Crushed stone

ROCKS OF UNCERTAIN AGE

GRANITE and GNEISS
Granite, granodiorite, augen-gneiss, granite gneiss.
Crushed stone

METAMORPHIC ROCKS and IGNEOUS INTRUSIVES
Schist, slate, phyllite, quartzite, marble, metamorphosed arkose and conglomerate; greenstone, diorite, and gabbro.
Crushed stone, soapstone, anorthosite, slate, dimension stone, kyanite, feldspar, aplite, and titanium minerals.

Williams & Heintz Map Corporation, Washington, D.C.

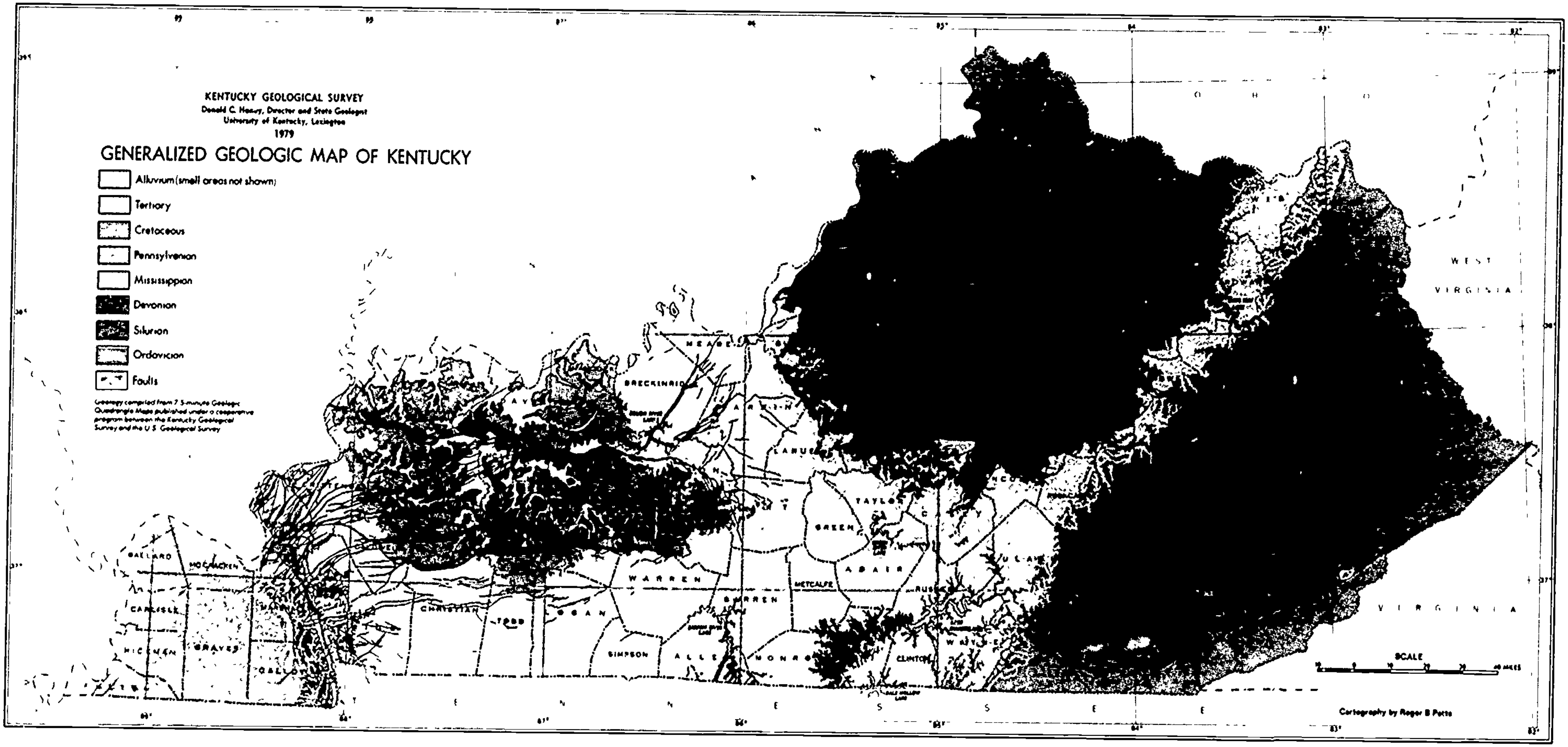


Scale

0 25 50 75 100 miles

CENOZOIC		MESOZOIC	PALEOZOIC						PRECAMBRIAN	
QUATERNARY	TERTIARY	CRETACEOUS	PENNSYLVANIAN	MISSISSIPPIAN	DEVONIAN-SILURIAN	ORDOVICIAN	ORDOVICIAN-CAMBRIAN	CAMBRIAN	SEDIMENTARY AND METAMORPHIC ROCKS	IGNEOUS AND METAMORPHIC ROCKS
Sand, silt, clay, gravel and loess	Sand, silt, clay and gravel	Sand, clay, silt and gravel	Sandstone, shale, conglomerate, siltstone and coal	Limestone, chert, shale, siltstone, sandstone and dolomite	Limestone, chert, shale, sandstone	Limestone, shale, dolomite, siltstone, sandstone and claystone	Dolomite, limestone, shale, chert, siltstone and sandstone	Shale, dolomite, limestone, sandstone, conglomerate, quartzite, arkose, graywacke and siltstone	Sandstone, conglomerate, siltstone, arkose, graywacke, quartzite, phyllite, slate and schist	Metamorphosed lavas and tuffs, metagabbro, rhyolites, diorite, granite, granitic gneisses, monzonite, quartz latites, anorthosite and diabase

GENERALIZED GEOLOGIC MAP OF TENNESSEE



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