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Erosional History of the New River, Southern Appalachians, Virginia

By

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EROSIONAL HISTORY OF THE NEW RIVER,
SOUTHERN APPALACHIANS, VIRGINIA

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(ABSTRACT)

Much of the bedrock surface of the Southern Appalachian Valley and Ridge Province is covered by a veneer of surficial deposits classified as alluvium, colluvium, and residuum. In this investigation the surficial geology of a 60-km^2 area of the New River drainage system was mapped at a scale of 1:24,000. The area is located within the Eggleston and Newport 7 1/2-minute topographic quadrangles in Giles County, southwest Virginia.

The data derived from mapping the surficial geology (particularly alluvial deposits), in conjunction with other field observations and with heavy-mineral analyses, are interpreted in terms of provenance, depositional environment (or accumulation), and preservation of the surficial deposits. In addition, these data are applied to an interpretation of the evolution of the New River drainage in the Valley and Ridge Province during the latter half of the Neogene.

The areal distribution of the surficial materials indicates that in a humid, temperate climate, deposits of surficial materials tend to be preserved if they overlie carbonate bedrock which weathers chemically, but tend to be eroded from shale and sandstone bedrock which weathers mechanically. In carbonate terrains where surface runoff is minimal, surficial materials are let down in place by solution and have been accumulating in a piecemeal fashion over a time period which in some areas may include all of Cenozoic time.

Analysis of the transparent heavy-mineral assemblages contained in the modern alluvium and older alluvial deposits of the area indicates that radiation-damaged zircon (intermediate and metamict) is unstable under conditions of subaerial weathering. Earlier workers have suggested that zircon is dissolved by acid ground water. This study supports these earlier suggestions and further demonstrates in a semiquantitative manner that the solution rate of radiation-damaged zircon may be a linear function of time as measured against either tourmaline or normal zircon. The estimated period of time over which the solution rate of zircon appears to be linear is on the order of 10 m.y.

The areal distribution and lithology of alluvial deposits provide evidence which can be used to reconstruct the late Cenozoic evolution of part of the New River drainage system within the Valley and Ridge Province. These data, in conjunction with assumptions involving lithologic and structural variations within the stratigraphic section which has been removed by erosion, suggest that the James and Roanoke Rivers have captured three northeastern tributaries of the New River during the latter half of the Neogene. Within this time period, no evidence was found of major changes in the course of the New River itself (except for meander loops) between Radford and Narrows.

CHAPTER 1

INTRODUCTION

Much of the bedrock surface of the Valley and Ridge Province of the Southern Appalachians is covered by a veneer of surficial materials broadly classified as alluvium (detritus transported by streams), colluvium (detritus which moves downslope primarily by gravitational mechanisms), and residuum (chemically resistant materials derived from underlying bedrock and formed in place). The distribution and petrography of surficial materials are affected by the nature of the parent materials, the processes by which the surficial materials were originally formed or deposited, and the erosional regime (including the effects of age) subsequent to their formation or deposition. Surficial materials, therefore, can provide a record of past climates, tectonic movements, drainage systems, and other components of erosional regimes. In this investigation, the surficial materials of a part of the New River drainage system in the Valley and Ridge Province of southwest Virginia were studied to determine the types of materials present and the processes affecting their distribution, and to reconstruct as much of the erosional history of the area as possible.

Primary emphasis is on the alluvium. Alluvial deposits are common in the carbonate valleys of the Valley and Ridge Province, and this study shows that under certain circumstances they can remain in place for millions of years. These factors, in conjunction with a new technique for determining provenance and relative age based on empirical data, have made it possible to reconstruct the evolution of part of the New River drainage system through a period of about the last 10 m.y.

The estimate of 10 m.y. is based on the modern erosion rate of the South Fork of the Shenandoah River, calculated by Hack (1965) to be 40 m/m.y. (130 ft/m.y.). Various rates of erosion have been calculated for the Eastern United States on the basis of a number of different types of data (Gilluly, 1964; Judson and Ritter, 1964; Doherty and Lyons, 1980). Although all these rates are of the same order of magnitude, the time period represented by the alluvium studied in this report can vary between 5 and 40 m.y., depending on which erosion rate is used. To facilitate comparison among alluvial deposits in the study area, the rate of 40 m/m.y. (130 ft/m.y.) was chosen because it was calculated for a nearby area with climate, terrain, and bedrock lithology similar to those of the study area.

The general characteristics of the surficial deposits (composition, shape, areal distribution, thickness, nature of boundaries) indicate that the mechanisms by which the deposits were formed need not have been very different from those operating in the area at the present time. Many investigators have postulated significantly different previous climates and (or) erosional regimes for the Appalachians to explain topographic forms and surficial deposits thought to be anomalous. Cooper (1961, p. 9), for example, suggested that large accumulations of sandstone boulders in obsequent valleys in Giles County were emplaced as rock glaciers during the Pleistocene. He thought that erosion under present climatic conditions could not adequately account for the volume of the deposits or large clast size. Fiedler (1967) agreed with Cooper's suggestion and further suggested that permafrost conditions may have prevailed at moderate elevations in Giles County during glacial maxima. Pierce (1966, p. 68), however, came to the conclusion that similar boulder accumulations in southern Pennsylvania probably were not relict rock glaciers. He based his conclusion on the observation that the volume of rock present in the Pennsylvania deposits was as much as an order of magnitude smaller than the amount present in rock glaciers in Alaska, as described by Wahrhaftig and Cox (1959).

As a second example, early workers suggested that the valleys of the major Appalachian rivers represented the Harrisburg or valley-floor peneplain of Tertiary age, proposed by Davis (1889). Stose and Miser (1922) assigned the New River valley in Montgomery County to the valley-floor peneplain and noted that the elevation is about 670 m (2200 ft). Thornbury (1965, p. 76) presented a brief review of several other studies in which topographic elements in particular regions of the Appalachians have been ascribed to cycles of peneplanation.

The concept of peneplanation has gradually become suspect as careful field studies have revealed alternative mechanisms to produce the landforms on which Davis based his concept of the geographic cycle. Rich (1933), Thompson (1941), and Cooper (1944) demonstrated the close correlation of ridge-crest elevation with bedrock structure and lithology. They suggested that the apparent accordance of ridge crests resulted not from a previous cycle of planation but from modern erosion processes working on rocks of similar structure and lithology. This is the viewpoint now accepted by the majority of American geologists, and the cyclic aspect of peneplanation as envisioned by Davis generally is held to be an unrealistic concept.

Many relatively flat areas of local to regional extent, however, are still frequently referred to as "old erosion surfaces," "high-level straths," "terraces," and so forth. The Piedmont physiographic province, the "Late Eocene surface" of the southern Rocky Mountains (Epis and Chapin, 1975), and the wide valley floors of the Valley and Ridge Province are examples. The valley floors usually are thought to be pre-Pleistocene erosion surfaces into which the rivers entrenched their channels as a result of accelerated erosion during the Pleistocene (60-120 m (200-400 ft) for the New River in the Great Valley) (Cooper, 1961, p. 4-10). Gambill (1974) suggested that, within the area of this study, "Valley hilltops . . . developed on the Knox outcrop belt, may represent remnants of a <u>former erosion surface</u> of Sinking Creek."

There is an alternative to the hypothesis that long periods of erosion uninterrupted by tectonic events or climatic changes must necessarily produce flat topography. Hack (1960), in the statement of his equilibrium concept of landscape, suggested that a maturely dissected surface, with topographic elements controlled primarily by lithology and structure, may be the end product of erosion in a humid climate rather than a relatively flat, old-age surface or a peneplain on which waste products accumulate and stagnate. Within this framework, the degree of flatness of one area as compared to that in another could be ascribed, in large part, to differences in bedrock rather than to differences in the ages of erosion surfaces.

The New River is known to many geologists as the headwater stream of the preglacial Teays River. Ray (1974, p. 11-21) reviewed the literature pertaining to the Late Tertiary drainage systems of the west side of the Appalachians and the disruption of these systems by glaciers during the Quaternary. The preglacial Teays River flowed northwestward from Huntington, West Virginia, across Ohio and Indiana to central Illinois, where it joined the preglacial Mahomet River; the Teays-Mahomet River then flowed to the ancestral Mississippi River.

The channel of the New River upstream from the limit of glacial advance undoubtedly has been modified as a result of both the initial disruption of the drainage and other effects of the recurrent advance of the glaciers, such as ponding along the glacial margin and alluviation. Study of these glacially induced channel modifications is beyond the scope of this investigation.

Location and Description of Study Area

The location of the study area is shown in figure 1 in relation to the drainage basin of the New River and the other major rivers of the Central and Southern Appalachians, and in relation to the Appalachian geologic provinces. This particular location was chosen because it was known that several alluvial deposits, presumably derived from the

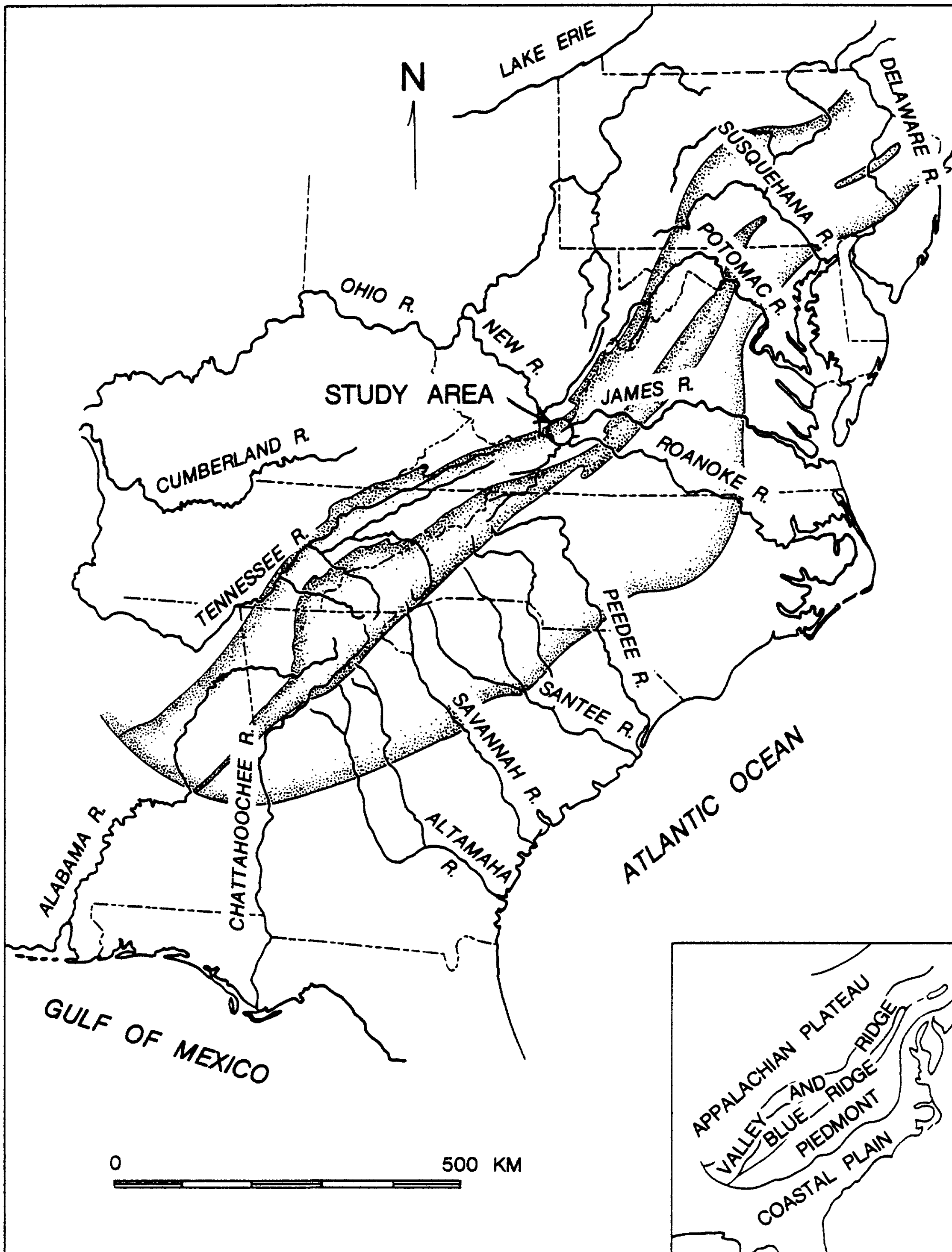

Figure 1.--Location of the study area, major rivers, and geologic provinces of the Central and Southern Appalachians.

New River, were present northwest of Spruce Run Mountain in Giles County, Virginia. These deposits occur in saddles and on knobs several hundred meters above the elevation of the modern New River. Mapping of the surficial deposits in this area, in conjunction with petrographic analyses of representative surficial materials, has made it possible to reconstruct the erosional history of the New River back through a considerable period of time.

New River drainage system

The New River is 550 km long and drains an area of approximately 19,500 km^2 in the Blue Ridge, Valley and Ridge, and Plateau Provinces of the Southern Appalachian system in North Carolina, Virginia, and West Virginia (fig. 2). Its major tributaries are the North and South Forks of the New River, the Little River, and the Greenbrier River. The New River heads in the Blue Ridge Province near Boone, North Carolina, at an elevation of 1525 m (5000 ft), flows northeastward along the Blue Ridge Upland for 105 km, and crosses into the southern extension of the Great Valley at Austinville, Virginia. The river then turns to the north and northwest and flows across the northeast-trending structural grain of the Valley and Ridge and Plateau Provinces.

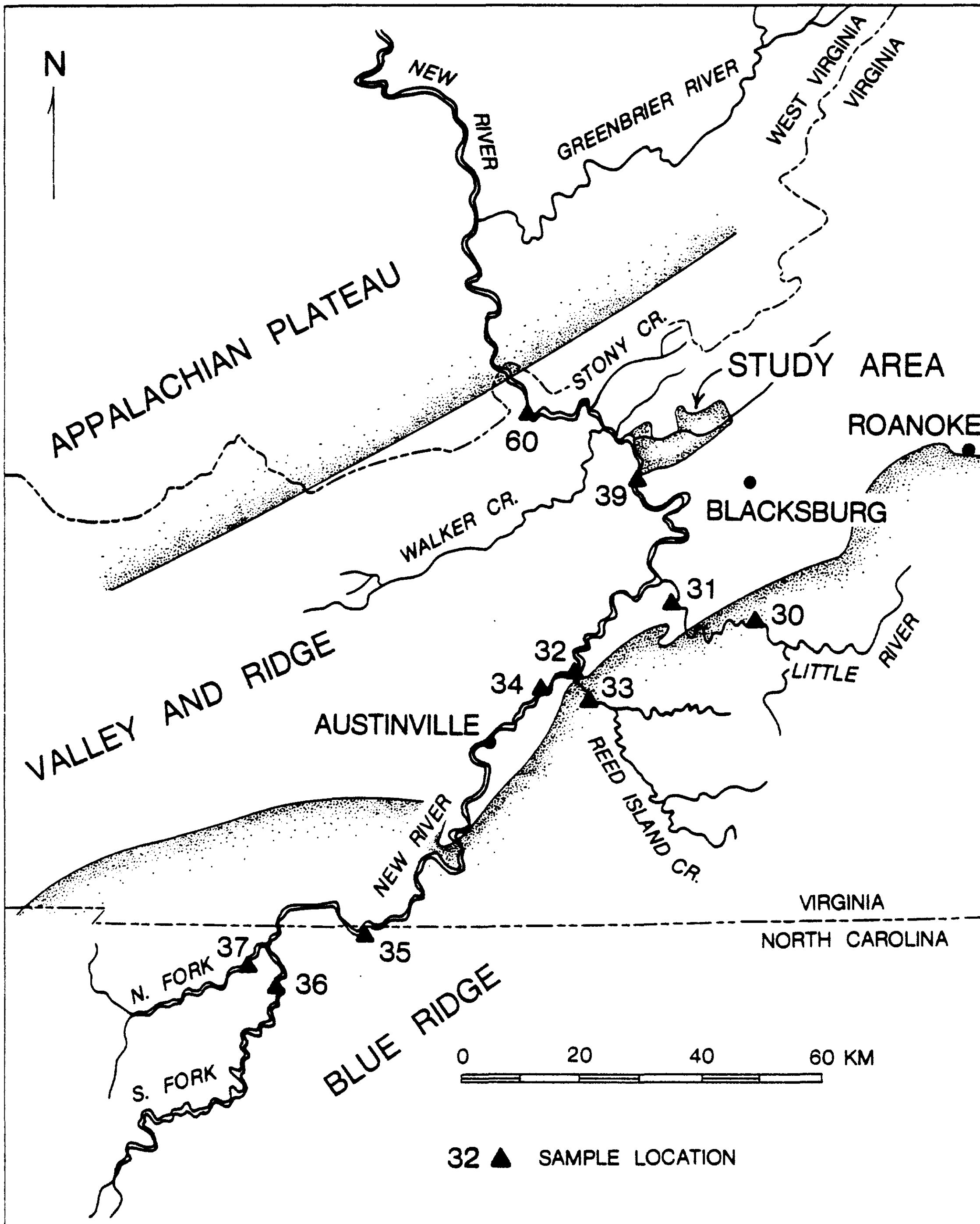

Figure 2.--Map of part of the New River in North Carolina, Virginia, and West Virginia showing sample locations of modern New River alluvium and location of the study area.

At the junction of the New River with the Gauley River at Gauley Bridge, West Virginia, the name changes to the Kanawha River. The Kanawha joins the Ohio River at Point Pleasant about 80 km northeast of Huntington, West Virginia, at an elevation of about 165 m (540 ft).

The bedrock in the New River drainage basin includes the Precambrian metamorphic complex (greenschist and amphibolite facies) of the southern Blue Ridge, folded and faulted Paleozoic (Cambrian through Mississippian) clastic and carbonate sedimentary rocks of the Valley and Ridge, and essentially flat lying Mississippian and Pennsylvanian clastic and carbonate sedimentary rocks of the Appalachian Plateau.

Map area

The map area comprises 60 km^2 of the Eggleston and Newport 7 1/2-minute quadrangles (fig. 3). It is bounded on the southwest by the New River, on the southeast by the Giles-Montgomery County line, and on the northeast by the Giles-Craig County line. The northwest boundary is irregular and corresponds variously to the crest of Clover Hollow Mountain, the base of Johns Creek Mountain, Sinking Creek, and the crest of Spruce Run Mountain.

This area was selected for detailed mapping because alluvial deposits of the New River were known to be present

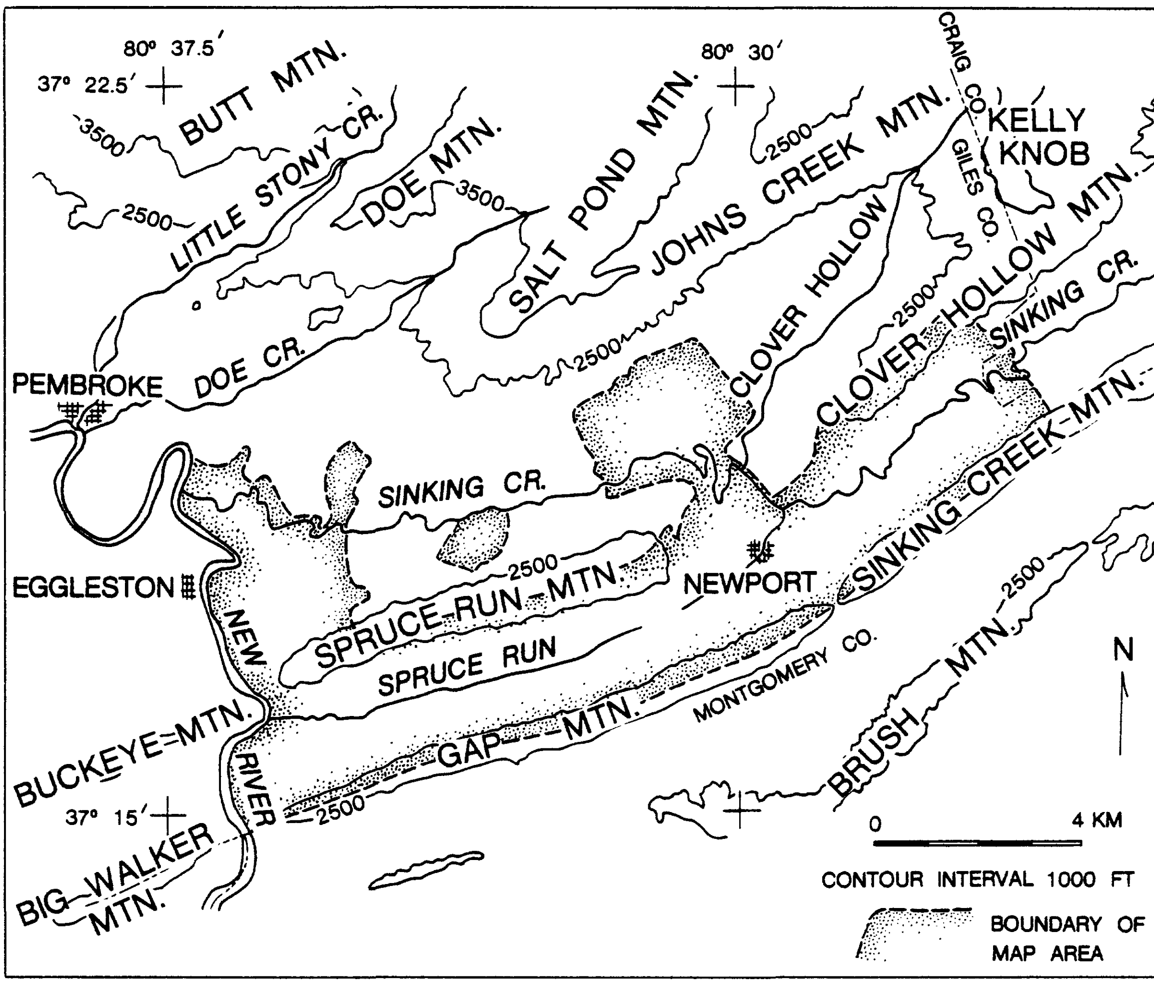

Figure 3.--Map showing the boundaries of the map area in relation to streams and ridges.

there at heights of as much as 183 m (600 ft) above the modern New River. An additional advantage is the presence of two parallel, ridge-forming belts of sandstone (Gap-Sinking Creek Mountain and Brush Mountain) which have acted as partial barriers between the area and stream systems heading in the Blue Ridge. These ridges have simplified the interpretation of the evolution of the drainage systems by restricting the course of the various rivers across the ridges to water gaps at specific locations.

The area is within the Valley and Ridge Province of the southern Appalachian Mountains and includes parts of the second and third strike valleys northwest of the Great Valley. The valleys are drained by Spruce Run and Sinking Creek. Both Spruce Run and Sinking Creek flow southwestward to the New River, although Sinking Creek crosses northwest from the second strike valley to the third between Clover Hollow and Spruce Run Mountains. Spruce Run is 8.5 km long and drains an area of 19 km^2. Sinking Creek is 45 km long and drains an area of about 200 km^2. Twenty-six kilometers of Sinking Creek is within the map area from its mouth at the New River northeast to the Giles-Craig County line. During the summer months, Sinking Creek sinks at a point about 8 km upstream from its mouth and emerges in a line of springs at the New River about 1.5 km southeast of the mouth of the creek (J. Saunders, written commun., 1973).

The maximum relief within the area is 475 m (1560 ft), but the average relief between ridge crests and valley floors is about 300 m (1000 ft). The bedrock is folded and faulted Middle Cambrian through Middle Devonian clastic and carbonate sedimentary rocks overlain in much of the area by a thin mantle of surficial materials.

Methods of Study

The methods of study included detailed mapping and petrographic study of surficial materials in a 60-km^2 area of Giles County; reconnaissance mapping of surficial materials in an area including parts of Giles, Craig, Montgomery, and Pulaski Counties (fig. 4); and isolated observations of surficial materials throughout the Appalachian Mountains, the Piedmont, and Coastal Plains of the Eastern United States. The distribution and preservation of surficial materials were correlated with processes dependent upon bedrock lithology and structure.

Nonopaque heavy minerals were identified in samples collected from representative surficial materials and modern streams as an additional descriptive parameter to aid in determining provenance and relative age. Fifty-seven samples were collected for heavy-mineral studies from alluvial, residual, and colluvial deposits in the Valley and Ridge

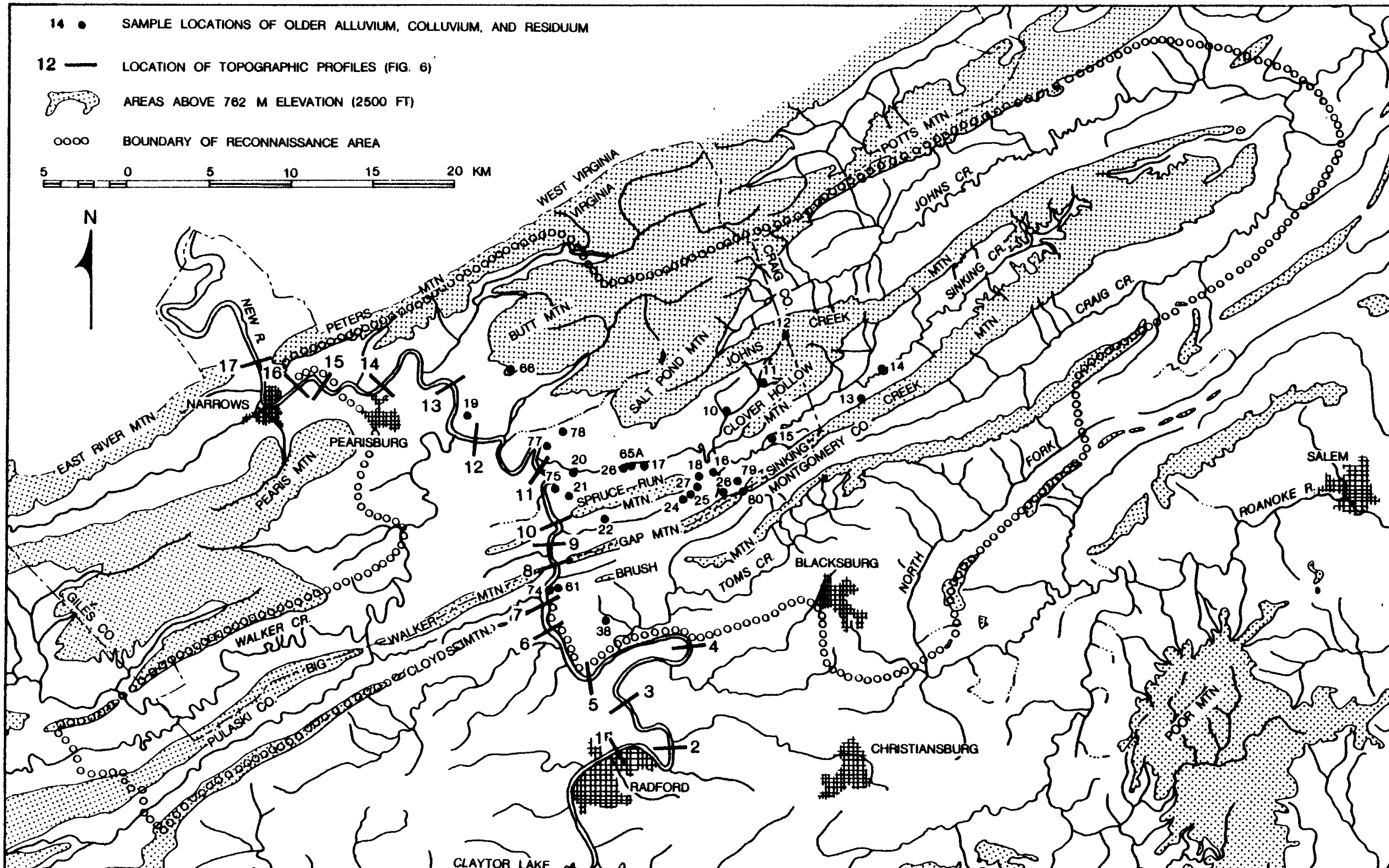

Figure 4.--Map of the New River in the Valley and Ridge Province showing the sample locations of older alluvium, colluvium, and residuum; the locations of topographic profiles of the New River valley; and the location of the reconnaissance area.

Province and from modern stream alluvium. The locations of the samples are shown in three illustrations. Samples collected within the area of the Eggleston and Newport 7 1/2-minute quadrangles are shown on the surficial geologic map (pl. 2). The locations of samples collected from the New River and from some of the Blue Ridge tributaries are shown in figure 2. Figure 4 shows the locations of samples discussed in the heavy-mineral analysis in Chapter 5. Descriptions of the sample locations are given in the appendix.

Metric units are used throughout this report. English units are given in parentheses following the metric units for measurements pertaining to elevation or height.

In this part of the Appalachians, segments of ridges separated along strike by water gaps and wind gaps usually have different names. Thus, Big Walker Mountain, Gap Mountain, and Sinking Creek Mountain are actually a single strike ridge. For the purpose of referring to more than one segment of a strike ridge, I have used the names of the segments (from southwest to northeast) separated by hyphens. Through this usage, for example, the ridge underlain by the Spruce Run syncline, northeast of the New River (pl. 1), becomes Spruce Run-Clover Hollow Mountain.

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CHAPTER 2

GENERAL GEOLOGY

The Appalachian Mountain system is a belt of Precambrian and Paleozoic rocks which trends generally northeastward from central Alabama to Newfoundland, a distance of about 3200 km. The system can be divided into four arcuate segments (concave to the southeast), each differing somewhat in its geologic history and style of deformation but each deformed during the Paleozoic. A detailed discussion of the geology of the Appalachians was presented by Rodgers (1970) and a more general discussion by King (1977). Specific topics of the Central and Southern Appalachians were covered in Fisher and others (1970).

The area of this study is near the northeast end of the most southerly of the arcuate segments, termed the Southern Appalachians (fig. 1). The Southern Appalachians extend from central Alabama to southern Virginia (750 km). The next arcuate segment to the northeast, the Central Appalachians, extends from southern Virginia to near New York City (650 km). The Central and Southern Appalachians have an average width of 300-500 km and are bounded on the east and southeast by the Atlantic Coastal Plain. On the south, west, and northwest the boundaries are the Gulf Coastal Plain and the stable continental interior.

Geology and Physiography of the Central and Southern Appalachians

The Central and Southern Appalachians have had different tectonic and erosional histories, but they are similar in that each consists of four distinct geologic provinces. The provinces parallel the trend of the Appalachian system and are, from southeast to northwest, the Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau Provinces.

Piedmont Province

The Piedmont Province is bounded on the southeast at the Fall Line by the sedimentary overlap of the Atlantic and Gulf Coastal Plains and on the northwest by the Blue Ridge. It is underlain by metamorphosed eugeosynclinal rocks of late Precambrian to early Paleozoic age, Precambrian basement rocks, and Paleozoic mafic and granitic intrusives. A number of grabens and half-grabens filled with red Triassic-Jurassic(?) continental sediments are present within the Piedmont and under the Coastal Plain. Numerous diabase dikes and some mafic sills and plutons emplaced during the Triassic-Jurassic(?) tensional episode are also present.

Fisher (1970, p. 295) compared the map shape of the Piedmont to that of ". . . a wild duck swimming gracefully northward. From its beak in central New Jersey to its tail in Alabama, it stretches 1350 km. At its neck in northern Virginia, it is only 16 km across, but at its belly in the Carolinas it widens to nearly 240 km."

Topographically, the Piedmont Province consists of gently rolling hills with local relief in the range of 50-100 m (150-300 ft). Within a given area, many hill crests reach similar elevations so that, viewed from a high point, the surface of the Piedmont has the appearance of a plain. The general slope of the province is to the southeast and south in the direction of flow of the major rivers. The elevation at the northwest edge of the Piedmont varies from 230 m (750 ft) in Pennsylvania and Maryland to 300-450 m (1000-1500 ft) from Virginia southwestward. The southeastern edge of the Piedmont along the Fall Line shows a similar increase in elevation to the southwest--from 75 m (250 ft) in northern Virginia to 150 m (500 ft) in South Carolina and Georgia, and as much as 210 m (690 ft) in Alabama.

Although the structural trend of rocks within the Piedmont is northeast, the courses of most of the larger streams show little structural control and the drainage pattern is primarily dendritic. Exceptions are the Yadkin, Roanoke, and James Rivers, which flow northeast along strike for considerable distances after leaving the Blue Ridge, and the Potomac and Delaware Rivers, which flow southwest along the Fall Line before turning to the southeast across the Coastal Plain.

Blue Ridge Province

Northwest of the Piedmont is the Blue Ridge Province. The Blue Ridge is a continuous, characteristically mountainous belt of metamorphosed Precambrian and lowermost Cambrian rocks which extends from southeastern Pennsylvania to northwestern Alabama, a distance of about 1100 km. Its northwestern boundary is the Valley and Ridge Province. This boundary corresponds approximately to a change in style of deformation, from penetrative on the southeast to less penetrative but folded and faulted in the Valley and Ridge to the northwest. The boundary between the Blue Ridge Province and the Piedmont to the southeast is the border faults of the Gettysburg and Leesburg Triassic basins in Pennsylvania, Maryland, and Virginia. In southern Virginia, the southeast boundary is the James River synclinorium, and from North Carolina to Alabama it is the Brevard zone.

The Central Blue Ridge, from South Mountain in Pennsylvania to Roanoke, Virginia, is an anticlinorium overturned to the northwest with a core of older Precambrian plutonic gneisses (which include some charnockitic rocks) and with younger Precambrian metasedimentary and volcanic rocks on its flanks (Espenshade, 1970). The younger Precambrian metasedimentary rocks unconformably overlie the basement gneiss complex. They are from 30 to 365 m thick, and consist primarily of graywacke, conglomerate, slate, and phyllite. The metasediments are, in turn, overlain by metabasalts of the Catoctin Formation between southern Pennsylvania and the James River in Virginia. The Catoctin is as much as 550 m thick, and was considered by Espenshade (1970, p. 205) to be most probably late Precambrian in age.

The south end of the Central Blue Ridge, between the James River and Roanoke, is allochthonous and is separated from the Valley and Ridge Province, to the northwest, by thrust faults. Considerable controversy has arisen over the years as to whether the Blue Ridge north of the James River is allochthonous or autochthonous, because there are no apparent thrust faults in this area. Gwinn (1970) and Harris (1979) recently presented evidence that this part of the Blue Ridge is also allochthonous.

The Central Blue Ridge is narrow, ranging from about 7 km wide in Pennsylvania and Maryland to 30 km wide in

Virginia. The Central Blue Ridge physiographic province is even narrower, from 3 to 20 km wide, because only the western limb of the anticlinorium and (in central Virginia) the western half of the core form mountainous topography. Most of the eastern limb and core form rolling hills which are within the Piedmont physiographic province. The elevation of the Blue Ridge is relatively low between South Mountain and Front Royal, Virginia, 520-675 m (1700-2200 ft), but between Front Royal and Roanoke elevations of 900-1200 m (3000-4000 ft) are common.

Structure of the Southern Blue Ridge (south of Roanoke) is quite different from that of the Central Blue Ridge. Here it is readily apparent that the Precambrian rocks have moved northwestward over the Paleozoic rocks of the Valley and Ridge along large thrust faults. Displacement of some of the thrust sheets is on the order of tens of kilometers.

As discussed by Bryant and Reed (1970), the Precambrian basement of the northwestern part of the Blue Ridge, in southwestern Virginia and western North Carolina, consists principally of 1000- to 1100-m.y.-old plutonic granitic rocks (for example, the Cranberry Gneiss), at least some of which are probably granitized sedimentary and volcanic rocks. The southeastern part of the Southern Blue Ridge consists mainly of upper Precambrian metasedimentary and metavolcanic rocks (mica schist, mica gneiss, and amphibolite). Distinction between the basement complex and the upper Precambrian rocks in this area is not clear because of the metamorphic overprint.

On the northwestern side, the upper Precambrian rocks are less metamorphosed and are clearly unconformable on the older Precambrian basement rocks. These upper Precambrian units include metasedimentary rocks of the Ocoee Group and Lynchburg Formation and the interlayered metasedimentary and metavolcanic rocks of the Mt. Rogers Formation. The Ocoee Group is as much as 12,000 m thick; the Mt. Rogers Formation is as much as 3000 m thick. Latest Precambrian(?) and Early Cambrian-age clastic rocks of the Chilhowee Group are exposed in windows beneath the Blue Ridge thrust sheet and in thrust sheets of the Unaka belt northwest of the Blue Ridge.

The Southern Blue Ridge is much wider than the Central Blue Ridge, reaching widths of more than 100 km in North Carolina and Tennessee. The Blue Ridge geologic and physiographic provinces are approximately coincident between Roanoke and northern Georgia. However, the southwestern extension of the Blue Ridge geologic province in Georgia and Alabama, the Ashland-Wedowee belt, is not mountainous, and is part of the Piedmont physiographic province. Much of the Southern Blue Ridge physiographic province is an area of rugged mountains. Relief on the order of 1000 m

(3000 ft) is common, and many summits have elevations of 1400-1800 m (4600-5900 ft). Mount Mitchell, the highest summit in the eastern United States, with an elevation of 2037 m (6683 ft), is within the province.

In addition to structural differences, the drainage of the Southern Blue Ridge is also quite different from that of the Central Blue Ridge. The Atlantic-Gulf of Mexico drainage divide is northwest of the Central Blue Ridge but near the southeastern edge of the Southern Blue Ridge (fig. 1). The Central Blue Ridge (including the Reading Prong, the northeast extension of the Blue Ridge geologic province in eastern Pennsylvania and New Jersey) is crossed by five southeast-flowing rivers which head in the Valley and Ridge and (or) Plateau Provinces--the Delaware, Susquehanna, Potomac, James, and Roanoke. Short, high-gradient tributaries flow northwestward and southeastward from the crest of the narrow Blue Ridge Mountains between the five major water gaps.

In contrast, the major rivers of the southeastern United States have their headwaters in the Southern Blue Ridge physiographic province. Most of the drainage is southwest, to the Gulf of Mexico; however, the arrangement of the rivers around the Southern Blue Ridge is approximately radial. The Atlantic-Gulf of Mexico drainage divide is at the crest of the Blue Ridge escarpment, as much as 25 km northwest of the boundary between the Blue Ridge and Piedmont geologic provinces. Tributaries of the Pee Dee, Santee, Savannah, and Altamaha Rivers drain this 25-km-wide strip toward the southeast. The Chattahoochee and Alabama Rivers flow southward and southwestward from the southwestern end of the Blue Ridge and the Ashland-Wedowee belt directly to the Gulf of Mexico. About three-fourths of the main body of the Southern Blue Ridge highlands is drained to the west and northwest by tributaries of the Tennessee River. The drainage of the remaining one-fourth is to the north and northeast, by the New River and its tributaries. Both the Tennessee and New Rivers flow to the Gulf of Mexico by way of the Ohio River.

Although the structural trend of the Southern Blue Ridge is northeast, the drainage pattern is predominantly dendritic, similar to that of the Piedmont. In fact, the topography of the part of the Blue Ridge drained by the New River is very similar in appearance to that of the Piedmont, being only slightly hillier but 500-600 m (1600-2000 ft) higher in general elevation.

Valley and Ridge and Appalachian Plateau Provinces

The remaining two provinces of the Appalachian system, the Valley and Ridge and the Appalachian Plateau, are underlain by a thick sequence of Paleozoic miogeosynclinal sedimentary rocks. The rocks of Cambrian through Middle Ordovician age are primarily carbonate units; those of Late Ordovician through Permian age are primarily clastic units, although relatively thick limestone sequences are present in the Silurian through Mississippian. The rocks have been intensely folded and faulted in the Valley and Ridge Province on the southeast but only very gently folded in the Appalachian Plateau to the northwest. The boundary between the provinces is a narrow transition zone called the Appalachian structural front.

The different degrees of deformation are largely responsible for the characteristic topography of each of the provinces. Differential erosion of the rock units in long, northeast-oriented folds and fault blocks has resulted in the topography which gives the Valley and Ridge Province its name; i.e., a parallel arrangement of linear, even-crested ridges separated by valleys which are somewhat wider than the ridges. The stream pattern is trellis.

The Appalachian Plateau is characterized by a dendritic drainage pattern for the larger streams with steep-sided, V-shaped stream valleys and flat-topped interfluves. Within a given area, most of the interfluves are underlain by the same resistant, nearly flat lying sandstone layer and therefore tend to be accordant. This is the feature that gives the province the name "Plateau," although in reality it is an area of very high relief. The high relief and dendritic drainage pattern make the Appalachian Plateau one of those areas where the saying "You can't get there from here" is particularly applicable.

In general, from the Blue Ridge northwest to the Appalachian Plateau the rocks become structurally lower and stratigraphically higher. Thus, Precambrian and Lower Cambrian rocks are exposed in the Blue Ridge, Cambrian through Mississippian rocks in the Valley and Ridge, and Mississippian through Permian in the Plateau. This, as well as the degree of deformation, controls the topography. For example, chemical weathering of the predominantly carbonate units in the outcrop belt of Cambrian through Ordovician rocks just northwest of the Blue Ridge has formed the Great Valley--a broad valley (as much as 40-50 km wide) which extends more or less continuously from Pennsylvania to Tennessee. Also, the rugged topography and high average elevation (about 600 m (2000 ft)) of the Appalachian Plateau are due in large part to the preponderance of carboniferous sandstone in the stratigraphic section.

There is a significant difference in structural style between the Central and the Southern Valley and Ridge Provinces, similar to the difference between the Central and Southern Blue Ridge. In the Central Appalachians the deformation of the Valley and Ridge is characterized by anticlines and synclines, asymmetric or overturned to the northwest. Faults are present but are subordinate in number to folds, although drill data indicate that thrust faults are present at depth (Gwinn, 1970). In contrast to relatively simple folding in the Central Valley and Ridge, the deformation of the Southern Valley and Ridge is characterized by southeast-dipping thrust faults and high-angle reverse faults. Some of the thrust faults, such as the Pulaski and Saltville, are hundreds of kilometers long. Although the change in structural style from folding to faulting is gradational along strike, in general it is centered about the town of Buchanan, 40 km northeast of Roanoke, Virginia.

The drainage and topography of the Central and Southern Valley and Ridge are very similar, in spite of the difference in structural style. The ridges in the Central Valley and Ridge tend to be more continuous than those in the Southern Valley and Ridge, where the ridges are more often terminated by faults. The drainage pattern is trellis in both parts of the province.

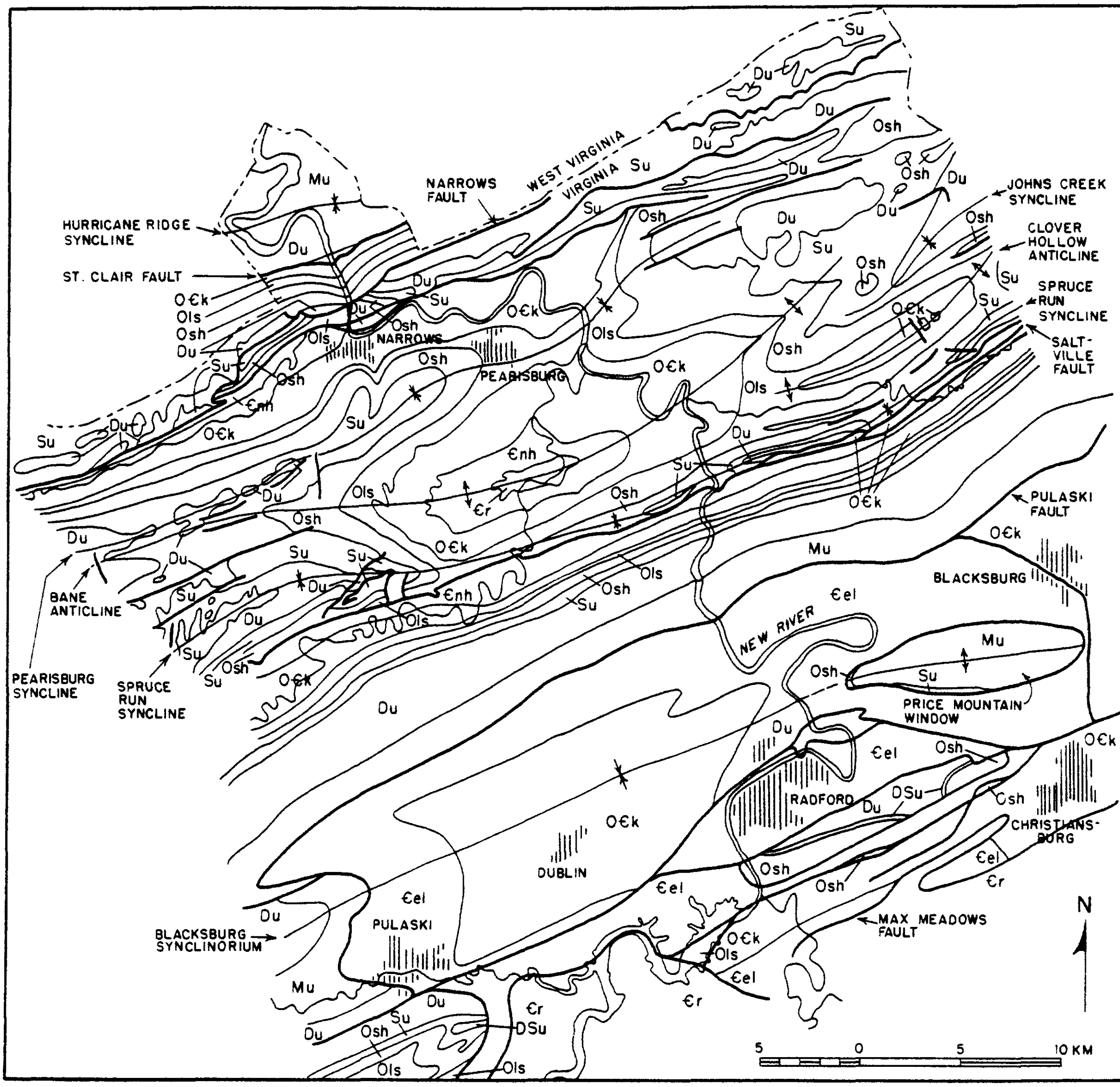
Bedrock Geology

Reconnaissance area

The area investigated in reconnaissance (fig. 4) is within the Valley and Ridge Province, and includes parts of Giles, Craig, Montgomery, and Pulaski Counties, Virginia.

Figure 5 is a geologic map of this area, compiled from Butts (1933), Cooper (1961), Eckroade (1962), and Bartholomew and Lowry (1979). Discussions of the stratigraphy and structure of the reconnaissance area were given by Cooper (1961, 1963, 1964), Rodgers (1970, p. 39-47), and Lowry (1971, 1979).

The area can be readily separated into two east-northeast-trending parts on the basis of structure and topography. The southeastern part is a broad valley, about 20 km wide, between the Blue Ridge on the southeast and Cloyds-Brush Mountain on the northwest. This is the southwestern extension of the Great Valley. The bedrock consists primarily of carbonate rock and shale of the Cambrian Rome and Elbrook Formations and the Cambrian and Ordovician Knox Group (Cooper, 1963; Lowry, 1971; Bartholomew and Lowry, 1979). These units are exposed in a complex system of imbricate thrust sheets between the Blue Ridge fault and the northwest edge of the Pulaski fault. Limestone, shale, and sandstone units ranging in age from Middle Cambrian through Mississippian are exposed in windows. The more resistant units exposed in windows, such as the Price Mountain window, form low hills with relief of 50-150 m (150-500 ft).



EXPLANATION

MISSISSIPPIAN	Mu	UNDIVIDED, SANDSTONE AND SHALE		CONTACT
DEVONIAN	Du	UNDIVIDED, SANDSTONE AND SHALE		FAULT
	DSu	UNDIVIDED, THIN QUARTZITE AND CHERT		ANTICLINE
SILURIAN	Su	UNDIVIDED, MOSTLY SANDSTONE		SYNCLINE
ORDOVICIAN	Osh	MIDDLE AND UPPER ORDOVICIAN SHALE UNITS		
	Ols	MIDDLE ORDOVICIAN LIMESTONE UNITS		
	O€k	KNOX GROUP, LIMESTONE AND DOLOMITE		
CAMBRIAN	€nh	UPPER CAMBRIAN NOLICHUCKY SH. AND MIDDLE CAMBRIAN HONAKER DOLOMITE		
	€el	MIDDLE AND UPPER CAMBRIAN ELBROOK FM., DOLOMITE		
	€r	LOWER AND MIDDLE CAMBRIAN ROME FM., SHALE AND DOLOMITE		

Figure 5.--Generalized geologic map of the New River valley in the Valley and Ridge Province, southwest Virginia.

The northwestern part of the reconnaissance area is structurally simpler, because there are no imbricate thrust sheets. The main structural elements in this area are the Saltville fault block and the Narrows fault block. The Saltville fault block lies between the Pulaski fault southeast of Cloyds and Brush Mountains and the Saltville fault on the southeast side of Buckeye, Spruce Run, and Clover Hollow Mountains. The Saltville fault in this area is a high-angle reverse fault dipping about 55° southeast. The rock units of the Saltville fault block dip southeast and consist of the complete stratigraphic sequence of the area from the Middle Cambrian Nolichucky and Honaker Formations to the Lower Mississippian Maccrady Formation. The topography developed on this sequence is typical of the Valley and Ridge and consists of narrow ridges underlain by resistant units (Cloyd Conglomerate and the Juniata Formation, Tuscarora Sandstone, Rose Hill Formation, and Keefer Sandstone) alternating with narrow valleys underlain by nonresistant units (Devonian shale and Cambrian and Ordovician shale and carbonate). The topographic relief is 200-300 m (650-1000 ft).

The Narrows fault block is characterized by a series of plunging anticlines and synclines in stratigraphic units ranging in age from Early Cambrian through Middle Devonian. From southeast to northwest the folds are the Spruce Run syncline, Clover Hollow anticline, Johns Creek syncline, Bane anticline, and Pearisburg syncline. The topography developed on the Narrows fault block in this area is a broad valley (20 km by 10 km) elongate to the northeast and flanked by mountainous areas on the northeast, northwest, and southwest. Structurally, the valley is the result of unroofing of the Clover Hollow anticline and the doubly plunging Bane anticline, which has exposed relatively nonresistant Cambrian and Ordovician shale and carbonate units. The adjacent mountains are quite high, about 1200 m (4000 ft), and are underlain by structurally lower Upper Ordovician, Lower Silurian, and Lower Devonian clastic units.

Detailed map area

The bedrock geology of the area of the detailed part of this study has been mapped by Hobbs (1953), Ovenshine (1961), and Gambill (1974). Formation descriptions are given in table 1, modified from Gambill (1974). Table 2 lists the thicknesses of the formations measured by Hobbs, Ovenshine, and Gambill. Plate 1 is a compilation of the three geologic maps, with some modifications in the area mapped by Hobbs and Gambill. The modifications are: (1) repositioning the trace of one of the splays of the Saltville fault southeast of Clover Hollow Mountain on the basis of field observations in this study, (2) a

Table 1.--Stratigraphy of the New River valley in Giles County, Virginia (modified from Gambill, 1974)

System	Series		Formations	Description
Devonian Silurian				Undifferentiated Millboro Shale, Huntersville Chert, Rocky Gap Sandstone of Early Devonian age and Tonoloway Limestone of Late Silurian age.
	Wenlockian		Keefer Ss.	White to reddish-white, fine- to medium-grained, medium- to thick-bedded orthoquartzite; cross-bedding and local *Scolithus* structures common.
	Llandoverian		Rose Hill Fm.	Maroon, iron-rich, thin- to medium-bedded sandstones and shales; quartz grains cemented with crystalline hematite.
			Tuscarora Ss.	White to light-gray orthoquartzite and quartzitic sandstone, in part, conglomeratic; cross-bedding, ripple marks, and local *Scolithus* structures common.
Ordovician	Cincinnatian		Juniata Fm.	Dark-red and olive-green shales and thin-bedded, brownish-red siltstones and sandstones; light-brown to white medium-bedded sandstone at top.
			Martinsburg Fm.	Interbedded dark-gray, thin-bedded, coarse-grained, skeletal limestone and brown shale at base; grades to yellow-brown shale; minor siltstones and sandstones at top.
	Champlainian		Eggleston Fm.	Brown and gray, thin-bedded limestones, siltstones, and shales; several interbedded bentonites, some with subjacent silicified cuneiform jointed beds.
			Moccasin Fm.	Red and green calcareous, silty mudstone and interbedded sandstone and conglomeratic sandstone; in part fracture-cleaved.
		Middle Ordovician Limestones	Witten Ls.	Gray, locally cross-bedded intraclast, ooid, and skeletal grainstones, and algal mat boundstones.
			Benbolt Ls.	Black, argillaceous skeletal packstones and wackestones and gray, skeletal grainstones at top.
			Pearisburg-Lincolnshire Ls.	Black, cherty, skeletal packstones and wackestones, gray skeletal grainstones and algal mat boundstones.
			Five Oaks-Elway Ls.	Black, very cherty skeletal limestones; gray argillaceous lime mudstones; and gray lime mudstones with birdseye textures.
			Blackford Fm.	Gray and red, medium- to thick-bedded, argillaceous dolomite and dolomitic limestones; basal chert and dolomite conglomerate.
			Major Unconformity	
	Canadian		Upper Knox Dol.	Gray, medium- to thick-bedded cherty dolomite with interbedded limestones.
Cambrian	Croixian		Copper Ridge Fm. (Lower Knox)	Gray, thin- to medium-bedded cherty dolomite with interbedded rusty-brown, carbonate-cemented sandstones and oolitic chert.
			Nolichucky Shale	Light-brown shale and/or gray dolomitic shale.
	Albertian		Honaker Dolomite	Dark- to light gray, thick-bedded dolomite.

Table 2.--Thickness of exposed Paleozoic units, New River valley, Giles County, Virginia

[Leaders (---) indicate no data]

		Hobbs (1953) (m)	Ovenshine (1961) (m)	Gambill (1974) (m)
	Devonian-------------	------------	[1] 20	[2] >152
Silurian	Keefer Ss------------	30-37	46	30-46
Silurian	Rose Hill Fm----------	27-34	73-82	30-46
Silurian	Tuscarora Ss----------	46-52	18-37	30-46
Ordovician	Juniata Fm------------	104-113	30-53	46-61
Ordovician	Martinsburg Fm--------	302-311	366	305-396
Ordovician	Eggleston Fm----------	------------	9-32	15-30
Ordovician	Moccasin Fm-----------	15-21	20-66	15-46
Ordovician	Middle Ordovician ls--	280-287	229-396	152-405
	Knox Group------------	792	716	579-701
Cambrian	Nolichucky Sh---------	------------	15	15
Cambrian	Honaker Dol-----------	------------	299	>427

[1]Rocky Gap Sandstone.

[2]Devonian, undifferentiated.

reinterpretation of the sense of movement and length of the northwest-trending fault which offsets the southwest end of Clover Hollow Mountain, and (3) the extension northeastward of the thrust fault mapped by Ovenshine northwest of Spruce Run Mountain to the northwest side of Clover Hollow Mountain. (This fault is shown on Gambill's cross section C-C', but not on his map.)

Approximately 1830-2130 m of carbonate rock, shale, and sandstone, ranging in age from Middle Cambrian to Early Devonian, is exposed in the area. Carbonate units are dominant in the Middle Cambrian through Middle Ordovician part of the section. The Upper Ordovician rocks grade upward from shaly limestone to shale to muddy sandstone. The Lower Silurian units are orthoquartzite and hematite-cemented sandstone. The Rocky Gap Sandstone is the only recognizable Lower Devonian formation in the area. The Tonoloway Limestone of Late Silurian and Early Devonian age may be present in the area, although it was not recognized by Hobbs, Ovenshine, or Gambill. Cooper (1961) described this formation northwest of the study area.

Two major unconformities are represented in this part of the Appalachians. One is between the Lower Ordovician Knox Dolomite and Middle Ordovician limestones; the other is between the Lower Silurian Keefer Sandstone and the Lower Devonian Rocky Gap Sandstone. This second unconformity is between the Tonoloway Limestone and the Rocky Gap Sandstone if the Tonoloway is present.

The structures present in the area were discussed in the preceding section. They strike generally N. 50° E. in the northeast half of the area and N. 75° E. in the southwest half.

The ridges within the area are underlain by the Upper Ordovician through Lower Devonian clastic sequence. The most resistant unit in this sequence is the Tuscarora Sandstone (Cooper, 1944, p. 217) and, in most instances, it is the unit which forms ridge crests. Over synclinal mountains, however, such as Kelly Knob, Spruce Run-Clover Hollow Mountain, and Butt Mountain, the Rose Hill Formation commonly underlies the topographically highest parts of the mountains. Facies-controlled beds of chert and calcareous sandstone within the Cambrian and Ordovician carbonates form low ridges and knobs in the valleys. Karst topography is present over all the carbonate units.

CHAPTER 3

SURFICIAL GEOLOGY

General Description

More than 90 percent of the area is covered by a veneer of various types of surficial materials which can be broadly classified as colluvium, alluvium, and residuum. For the most part, the surficial deposits are fairly thin. Thick residuum is not common on the limestones. The thickest deposit of residuum noted in this study is at sample locality 18 along U.S. route 460 and is about 8 m thick. Some alluvial deposits have been eroded to the point where they are only one or two layers of cobbles thick. However, on the average the surficial deposits are 1-5 m thick.

The areal and vertical extent of the deposits depends on their original depositional shape, the lithology of the bedrock, and subsequent weathering and erosion. Surficial deposits tend to be preserved if they overlie carbonate bedrock which weathers chemically. Deposits on rocks which weather mechanically, such as the Upper Ordovician, Lower Silurian, and Devonian sandstone, the shale unit of the Martinsburg Formation, and the sandstone of the Copper Ridge Formation, tend to be removed by surface runoff.

Most of the transported surficial materials are locally derived from resistant Paleozoic bedrock within the Valley and Ridge Province. Less resistant lithologies such as limestone and shale clasts are usually present but do not survive transport distances of more than a few kilometers (Hack, 1957). Alluvial materials deposited by rivers which head in the Blue Ridge Province contain clasts of vein quartz, metaquartzite, and Lower Cambrian orthoquartzite and metaquartzite in addition to clasts supplied by tributary streams heading in the Valley and Ridge Province. The ages of the surficial materials range from modern to probably several million years old, based on the 300-m (1000-ft) height above the New River of one of the older alluvial deposits. Because most alluvial deposits are well drained and oxidized, datable materials such as wood, bones, pollen, and ostracodes are rarely preserved. No datable organic material, indigenous to the alluvial deposits, was found in the study area.

Description of Map Units

The map units are defined on the basis of composition, amount of stream polish if present, and shape of the pebble-size and larger clasts. Other diagnostic features such as sorting and bedding, or the lack of it, are not usually apparent. Seven categories of surficial materials, which are adequate for mapping purposes in the study area, are: Blue Ridge-derived alluvium, Valley and Ridge-derived alluvium, colluvium, boulder streams, first-stage alluvium, second-stage alluvium, and residuum and bedrock (pl. 2).

Deposits of larger perennial streams

Blue Ridge-derived alluvium

Alluvium deposited by rivers which head in the Blue Ridge contain 30 to 60 percent cobbles of vein quartz and metaquartzite, ovoid to discoid in shape. Other large clasts, which are predominantly Lower Paleozoic sandstone, are generally very well rounded. The surfaces of most vein quartz, metaquartzite, and orthoquartzite clasts are very well polished, and many of these clasts show arcuate percussion marks. Some of the boulders composed of very fine grained vitreous Lower Silurian orthoquartzite develop a distinctive butterscotch-colored rind (10YR 6/4, Goddard and others , 1948). The Blue Ridge-derived quartzose clasts and some Lower Silurian orthoquartzite clasts have not been much altered by weathering, and most are fresh throughout when broken. However, in older alluvial deposits the less well cemented Paleozoic sandstone clasts, such as the Juniata Formation, are case hardened and crumble to loose sand when broken.

The Blue Ridge-derived quartzose clasts are of three main types: one is composed of white, pale-yellow or pale-red, medium to coarsely crystalline, equigranular, interlocking quartz with rare muscovite flakes; the second is metaquartzite clasts which may be the Erwin Quartzite of the Chilhowee Group; the third is a peculiar variety of quartz which appears to have been sheared. Some clasts of the third type consist of rotated augens of clear quartz in a matrix of nonoriented finely crystalline quartz or separated by subparallel undulating layers of finely crystalline quartz. Other sheared clasts consist of clear quartz containing one to three sets of parallel to subparallel shear planes spaced at 1-mm to 1-cm intervals. Thin-section study of this second variety of sheared quartz shows that the crystals in each clast have only one or two crystallographic orientations and that two-phase fluid inclusions are commonly present.

The source of the sheared quartz lithology in the Blue Ridge is not known. It is likely that it is an uncommon though widely distributed lithology in metamorphic rocks and is concentrated in streams because of its resistance to abrasion. For example, this lithologic type is also present in gravels of the Atlantic Coastal Plain derived from Piedmont rocks and in gravels derived from shear zones associated with metamorphic core complexes in the southern Basin and Range Province of the southwestern United States.

Within the study area, alluvium derived from the Blue Ridge was deposited by the New River and two former tributaries which joined it from the northeast and which have been progressively captured by the Roanoke River. Alluvium of the two former tributaries from the northeast is lithologically identical to New River alluvium for the purposes of field identification. They can be differentiated, however, by the characteristics of the contained zircon population and the percentage of rutile in their heavy-mineral assemblage (Chap. 5, this report), and on geomorphic grounds. The former tributaries are informally named the County Line River and the Blacksburg River.

Valley and Ridge-derived alluvium

This type of alluvium is deposited by moderate-size perennial streams (>5-10 km in length) which have their headwaters in the Valley and Ridge Province. The clasts are predominantly Lower Silurian sandstone and orthoquartzite and the Rose Hill Formation. Other less resistant lithologies, such as the Lower Ordovician Copper Ridge Formation, the Upper Ordovician Juniata Formation, and colloform chert aggregates from the Cambrian and Ordovician Knox Dolomite, are locally common. Vein quartz and metaquartzite cobbles, incorporated by reworking of Blue Ridge-derived alluvium, are rare, but one or two can be found in most good exposures such as extensive roadcuts or freshly plowed fields.

The orthoquartzite clasts are more or less well rounded and polished, depending on the size of the stream. The other less pure sandstone clasts, including those of the

Rose Hill Formation, are fairly well rounded but are not polished.

Deposits of the ridge flanks

Surficial materials on steep flanks of the ridges compose a gradational sequence ranging from colluvium to alluvium. All of these materials traditionally have been called colluvium. Field evidence, however, indicates that the dominant mechanism of downslope movement is fluvial rather than gravitational. For this reason the surficial materials of the ridge flanks have been separated into three categories: colluvium, first-stage alluvium (including boulder streams), and second-stage alluvium.

Colluvium

This material is composed primarily of boulders and cobbles of Upper Ordovician and Lower Silurian sandstone and orthoquartzite which break away from the outcrop by frost wedging and sapping, and move downslope by sheet wash and gravitational mechanisms. Colluvial deposits are confined to the narrow zone between ridge crests and the upper limit of ravine incisement on the flanks of the ridges. The map boundaries for colluvium were drawn from aerial photographs.

First-stage alluvium

These deposits are composed of large clasts of Upper Ordovician and Lower Silurian sandstone and orthoquartzite derived from colluvium; they occupy the upper and middle portions of ridge flanks which have been incised by stream erosion. The clasts were transported down the ridge flanks primarily by fluvial mechanisms. Some of the boulders are as much as several meters across, but most measure about 0.5 m or less. The orthoquartzite boulders tend to be more nearly equidimensional than Rose Hill boulders because the orthoquartzite units are thicker bedded. Rose Hill boulders are usually in the form of flags. The amount of stream polish is minimal but increases downslope. Smooth faces and slickensided surfaces on some boulders can be mistaken for stream polish.

Accumulations of first-stage alluvium funneled into steep-sided ravines are termed boulder streams. The ravines are occupied by intermittent to perennial streams, and the alluvium shows an apparent though slight reduction in the size of clasts downslope, and minor development of stream polish. The stream polish is usually present on only one surface of the clasts. The progressive reduction in clast size and increasing development of stream polish are assumed to indicate that fluvial transport is an important mechanism in the erosion and deposition of boulder streams. Some of the major boulder streams and intervening bedrock interfluves on the middle and upper ridge flanks are shown on plate 2 but, in much of the area shown as first-stage alluvium, boulder streams are not differentiated because of their narrow width and complex pattern.

Second-stage alluvium

This unit is intermediate between and gradational with first-stage alluvium and Valley and Ridge-derived alluvial deposits. It is lithologically similar to the first-stage alluvium, with locally derived admixtures of Copper Ridge sandstone, chert nodules, and botryoidal masses of goethite and manganese oxide. The clasts range in size from pebbles to small boulders and tend to be slightly rounded. Many orthoquartzite clasts are polished on one or more surfaces. Second-stage alluvium is not a recognizable unit in most of the area, and no attempt was made to map it except in a few places where it has considerable areal extent. In general, first-stage alluvium becomes mixed with older deposits of Valley and Ridge-derived alluvium a short distance after crossing the contact from clastic bedrock to carbonate bedrock, and this admixture obscures the development of second-stage alluvium.

Residuum and bedrock

This map unit is used to designate areas in which there are no transported surficial materials. Bedrock is self explanatory. The residuum of the area consists of clay and chert derived from weathering of carbonate units.

Some parts of the area are paved with lag deposits composed of pebble-size angular chert. Most of the residuum, however, is clay containing some chert nodules and fragments, underlain by limestone and dolomite solution pinnacles.

CHAPTER 4

DEPOSITIONAL MECHANISMS AND GEOMORPHIC PROCESSES

The following sections are analyses of modern erosional mechanisms in the study area, and the characteristics of the resultant surficial materials are compared with those of their older counterparts.

Alluvium of Perennial Streams

Alluvium deposited by the New River, its Valley and Ridge tributaries, and the two captured tributaries from the northeast covers about 25 percent of the area mapped in detail. Alluvium of these three stream systems is similar in that it was deposited by perennial streams which had moderately low gradients, although the streams differed in size (discharge).

Modern alluvium of the New River and the Valley and Ridge tributaries is confined to stream channels, narrow flood plains, and point bars inside meanders. Map patterns of the better preserved older alluvial deposits indicate that they were deposited in essentially the same ways as were those of the modern alluvium. Remnants of channel, flood-plain, and point-bar deposits have been left behind by the mechanisms of stream capture, meander cutoff, extension and migration of meanders, and lateral migration of streams accompanied by downcutting.

Morphology of the New River

In the Valley and Ridge Province, between Claytor Lake and the Appalachian Plateau, the New River flows across two broad carbonate-floored valleys and cuts through four ridges (fig. 4). The principal towns along this stretch of the river are Radford, Eggleston, Pembroke, Pearisburg, and Narrows (figs. 3, 4). The course of the New River across this part of the Valley and Ridge Province may be divided into three segments on the basis of sinuosity and gradient. Physical parameters of each of the three segments are given in table 3. Figure 6 shows the landforms adjacent to the New River by means of seventeen profiles, 2 km long, drawn perpendicular to the river. Locations of the profiles are shown in figure 4.

From Radford to Cloyds-Brush Mountain, the New River flows across the Great Valley, which is underlain mostly by Cambrian and Lower Ordovician carbonate and shale units exposed in thrust sheets of the Pulaski fault system. This part of the Great Valley is about 40 km long and 20 km wide, elongate in a northeast-southwest direction. It is bounded on the southeast by the Blue Ridge and on the southwest and northwest by ridges underlain by Paleozoic sandstones. The northeast boundary, between Blacksburg and

Table 3.--Parameters of the New River in the Southern Valley and Ridge Province

River segment	River distance (km)	Straight-line distance (km)	Sinuosity[1]	Gradient (m/km)	Average river width (m)	Flood-plain width (m)	Bluff height (m)
Radford to Cloyds-Brush Mountain.	31	13	2.3	0.6	160	0-600	25-100
Cloyds-Brush Mountain to Big Walker-Gap Mountain.	2.6	2.3	1.1	2.3	350	0-300	35-60
Big Walker-Gap Mountain to East River-Peters Mountain.	39	24	1.6	1.0	145	0-500	30-100
Radford to East River-Peters Mountain.	73	39	1.9	1.2	160	110 (avg.)	25-100

[1]Sinuosity = river distance/straight-line distance.

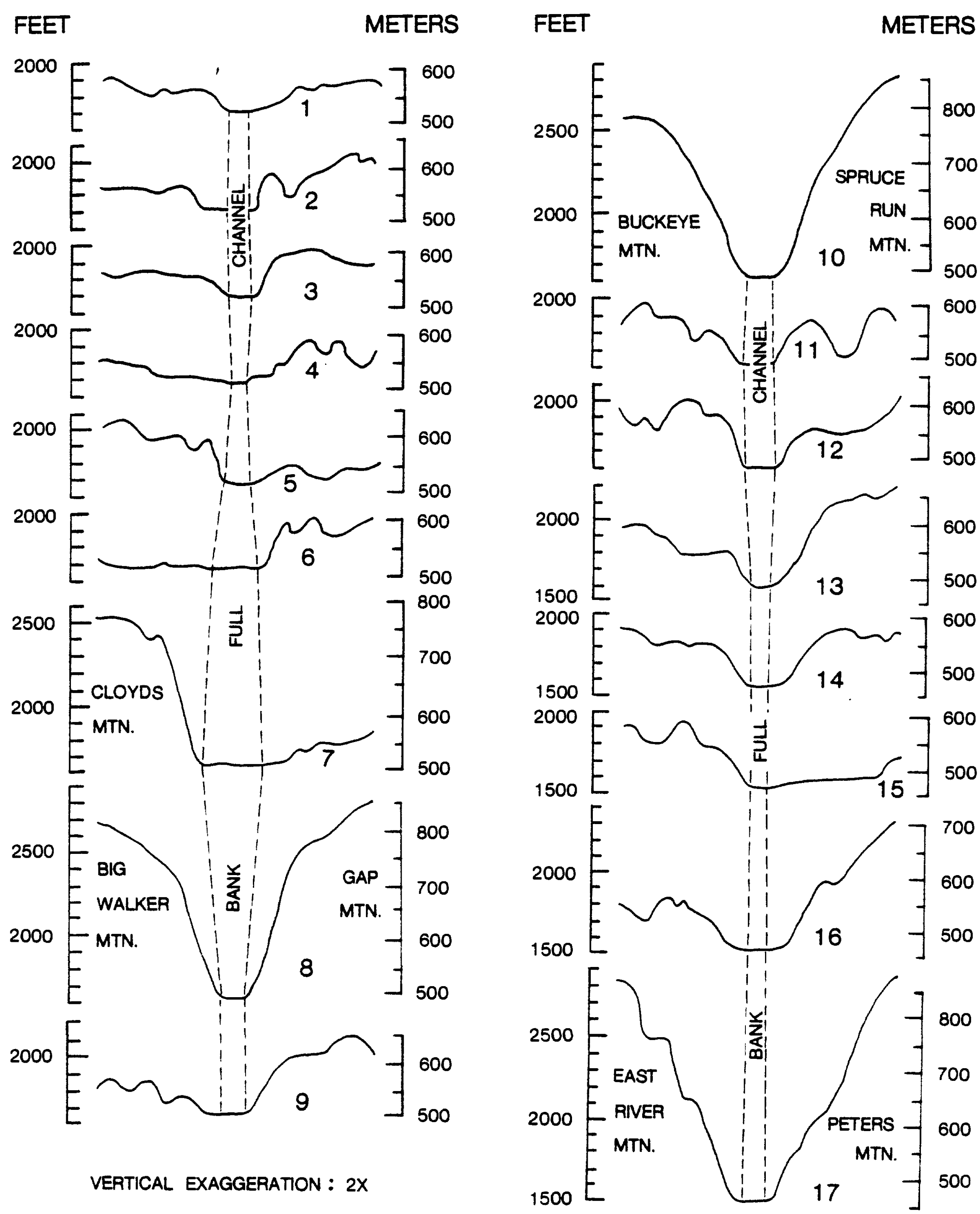


Figure 6.--Topographic profiles drawn perpendicular to the New River between Radford and Narrows. Each profile is 2 km long. Locations are shown in figure 4.

Christiansburg, is the Atlantic-Gulf of Mexico drainage divide. The elevation of much of the valley is 575-675 m (1880-2200 ft). The drainage pattern is predominantly dendritic, as a result of the uniform resistance to erosion of most of the bedrock of the valley.

The course of the New River is slightly northeast of the middle of the valley. At Radford the elevation of the river is 524 m (1720 ft); at Cloyds-Brush Mountain it is 506 m (1660 ft). The gradient of the river is 0.6 m/km (3 ft/mi), and the sinuosity is 2.3. The low gradient and high sinuosity are the result of two rather anomalous large meanders. Inspection of the topography as shown on the Radford North 7 1/2-minute topographic map indicates that the meanders are being extended and are migrating downstream, with no apparent tendency toward being cut off. The larger of the two meanders has been extended 4.5 km to the northeast and has migrated 1.5 km downstream.

The width of the flood plain is variable, ranging from 0 to 600 m, but in general the flood plain of the New River in the Great Valley is wider than in the valley between Eggleston and Pearisburg. Bluffs 25-100 m (80-300 ft) high are present outside the bends in the river along 75 percent of the distance between Radford and Cloyds-Brush Mountain.

In the next segment downstream from the Great Valley, the New River cuts through two major ridges. The relief in the water gaps is 268 m (880 ft) at Cloyds-Brush Mountain and 357 m (1170 ft) at Big Walker-Gap Mountain. Within this 2.6-km-long segment the gradient increases abruptly to 2.3 m/km (12 ft/mi) as the river flows over shale and sandstone units ranging from Upper Ordovician through Lower Mississippian. The river is wide (as much as 550 m) and quite shallow, particularly where it crosses Mississippian bedrock, and numerous low rapids are present over resistant sandstone ledges. The most prominent rapids are developed over the outcrop belt of the Tuscarora Sandstone in the gap between Big Walker and Gap Mountains, locally called the Upper Narrows. Some of the rocks project 3 m (10 ft) above normal water level and have plunge pools more than 7 m (20 ft) deep on their downstream side. In the carbonate valleys upstream and downstream from this segment the New River is much narrower and deeper, ranging from 80 to 350 m wide, averaging about 200 m wide.

The modern course of the New River through Cloyds-Brush Mountain is offset 1.5 km to the southwest relative to its water gap through Big Walker-Gap Mountain. The topography and the presence of alluvial deposits northeast of the river indicate that the two water gaps were alined when the river was about 100 m (300 ft) higher than it is now. The elevations of the alluvial deposits suggest that the river may have migrated to its present location in three discrete stages.

In its third segment between Big Walker-Gap Mountain and East River-Peters Mountain, the New River again crosses a broad carbonate-floored valley. This valley has been formed by unroofing of the Clover Hollow and Bane anticlines and the structurally high Spruce Run and Pearisburg synclines. The valley is 10 km by 20 km, elongate to the northeast, and is bounded on all sides by ridges underlain by Silurian sandstone. The Atlantic-Gulf of Mexico drainage divide is located along the ridges and mountains to the northeast. This valley is somewhat hillier than the Great Valley, although the general elevation of the valley floor is similar, about 575-675 m (1880-2200 ft). The drainage pattern is a combination of dendritic and trellis.

The course of the New River is across the northeastern half of the valley, over Middle Cambrian to Upper Ordovician carbonate and shale units. The river flows over shale and interbedded limestone (Upper Ordovician Martinsburg Formation) in the water gap between Buckeye Mountain and Spruce Run Mountain, 2.5 km northwest of the Upper Narrows. The base of the lowest sandstone unit underlying this synclinal ridge, the Juniata Formation, is about 175 m (575 ft) above the elevation of the river.

The course of the river is sinuous, but the meanders have a low amplitude (1-2 km), so the gradient is higher (1.0 m/km (5 ft/mi)) and the sinuosity is lower (1.6) for this segment of the river as compared to the Great Valley segment. There are two relatively young cutoff meanders--one at Pembroke and another at Bluff City, northwest of Pearisburg. Both meanders are small, having an amplitude of about 1 km.

Bluffs 30-100 m (100-300 ft) high are present along much of the river, although they are more commonly present and higher outside of bends. Bluffs developed in carbonate units of the Knox Group east of Eggleston are shown in figure 7. The flood plain is very narrow between Big Walker-Gap Mountain and Pearisburg, usually less than 150 m and often less than 100 m. Between Pearisburg and East River-Peters Mountain the flood plain is wider, reaching a maximum width of about 500 m.

The New River leaves the Valley and Ridge Province through a water gap between East River Mountain and Peters Mountain known as the Narrows. Elevation of the river at this point is 463 m (1520 ft). Maximum relief present at the water gap is 560 m (1840 ft) within 2.5 km.

Figure 7.--Bluffs in carbonate rock along the New River near Eggleston. The bluffs are about 60 m (200 ft) high and develop castellated forms.

Examples of Blue Ridge-derived alluvial deposits

The Blue Ridge-derived alluvium of the area is interpreted to be point-bar, channel, and flood-plain deposits left behind by the rivers by the mechanisms of lateral migration with downcutting, meander cutoff, and stream capture.

The distribution of New River alluvium indicates that the river channel was confined and that the river did not meander widely over a carbonate plain of low relief. The alluvium is restricted to bands 3-4 km wide on either side of the river and consists of many individual deposits less than 0.5 km^2 in area. The extent of individual younger alluvial deposits can be distinguished on the basis of topography. With increasing age, however, the topographic boundaries become subdued, and individual deposits coalesce to form a veneer of alluvium. For this reason the boundaries of adjacent individual alluvial deposits of the New River (and the other streams as well) are not shown on plate 2 even in the areas where the boundaries are distinct.

An example of alluvial deposits interpreted to have been formed by lateral migration of the New River at the southwest end of Brush Mountain is shown in figure 8. The alluvium of both the younger and the older deposits is probably a combination of channel, flood-plain, and poorly developed point-bar deposits. These environments are

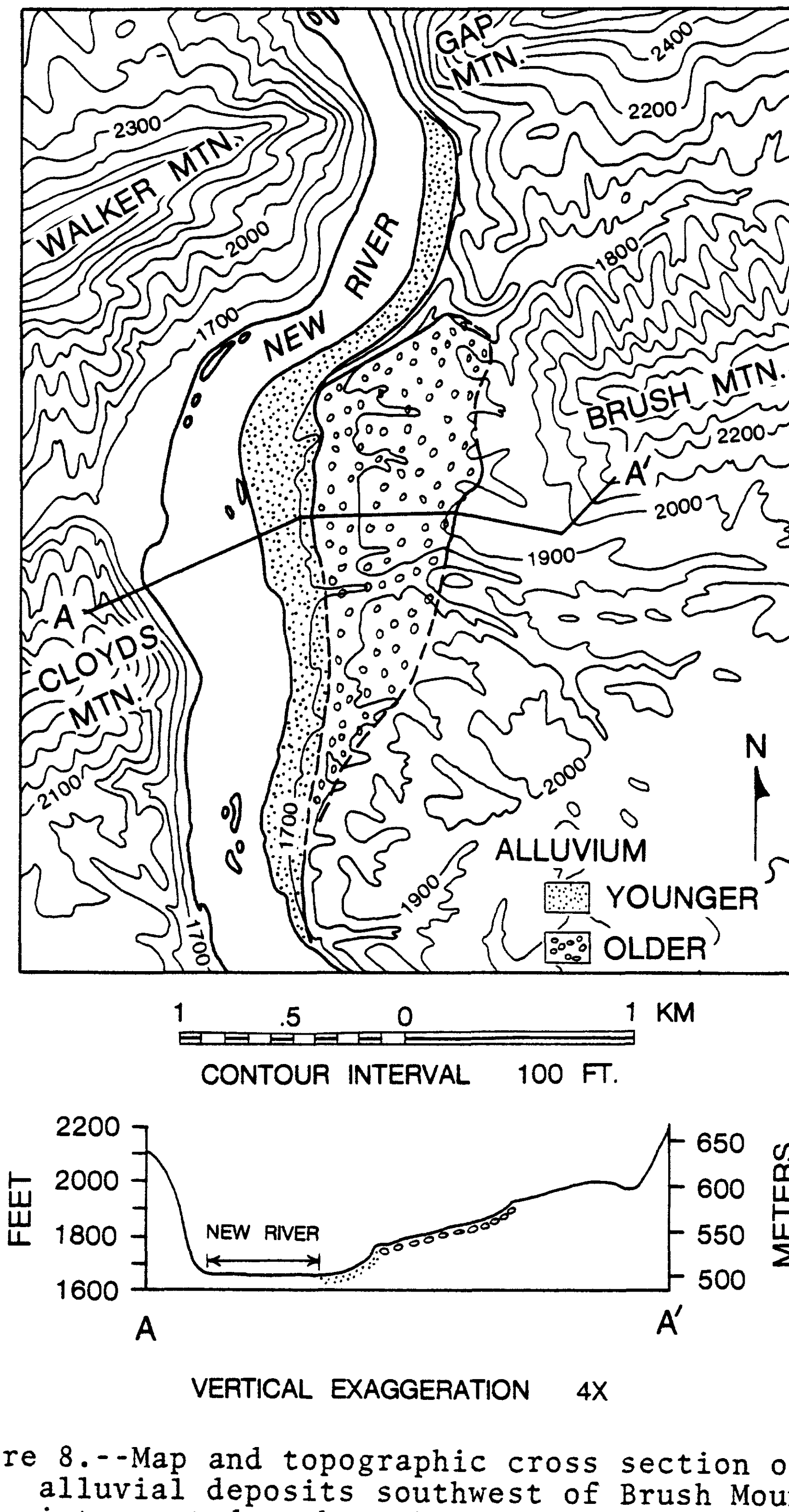


Figure 8.--Map and topographic cross section of two alluvial deposits southwest of Brush Mountain interpreted to have been developed by lateral migration of the New River.

inferred from the areal distribution of the alluvium, although the alluvium is not well enough exposed to distinguish depositional environments.

Figure 9 shows a point-bar deposit that formed as a result of extension of a meander on the northeast side of the New River across from Eggleston. The cross sections of the deposit in this figure and in figure 8 show escarpments at 536 m and 530 m (1760 ft and 1740 ft) separating older from younger alluvium. The escarpments could have resulted from relatively abrupt shifts in the location of the river channel, or they could represent an increase in the rate of downcutting of the New River. The first interpretation is preferred because similar escarpments are present at many different heights above the New River in the study area, and it is not reasonable to call on an increased rate of downcutting to explain each of them.

The town of Pembroke is on a relatively young cutoff meander of the New River. The topographic form of the cutoff meander is seen on the Pearisburg 7 1/2-minute topographic map. A much older body of New River alluvium, as much as 180 m (600 ft) above river level, occurs north of Spruce Run Mountain. It is presumed to be an abandoned meander loop, because it is bounded on two sides by large areas of Valley and Ridge alluvium in such a way that no other explanation seems possible (fig. 10;

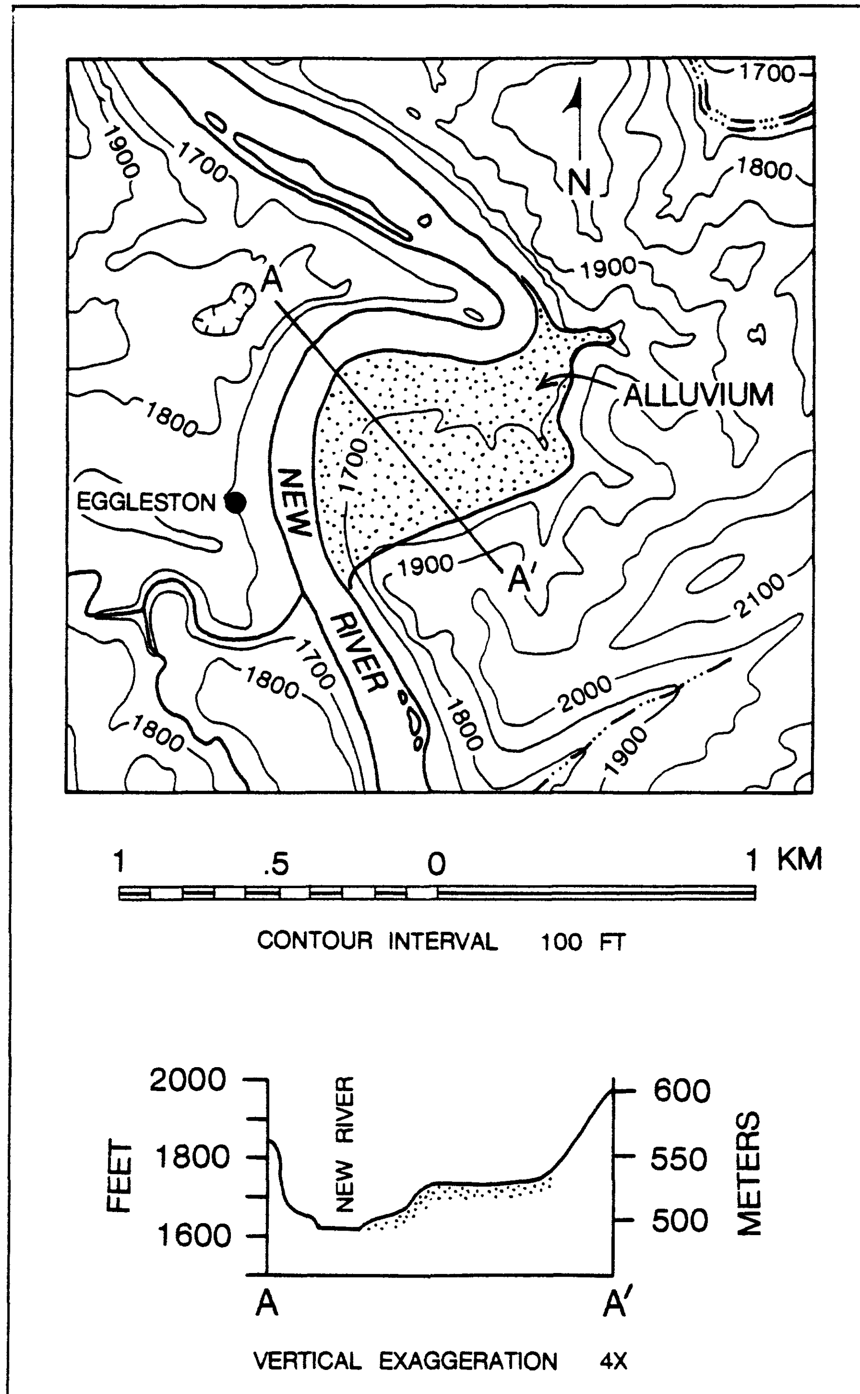


Figure 9.--Map and topographic cross section of an alluvial deposit near Eggleston interpreted to be a point bar developed by extension of a meander of the New River.

pl. 2). The vertical dimension of the deposit has been altered considerably by solution of the underlying Middle Ordovician limestone. However, the alluvium does not appear to have been reworked laterally to any great extent, so the map pattern may be similar to the original depositional pattern. The reason for suggesting that these deposits represent a meander loop is that this is the only solution which adequately explains most of the characteristics of the deposits. The problem is to explain the presence of an approximately equidimensional deposit of New River alluvium bounded on the northeast and southwest by rectangular-shaped deposits of Valley and Ridge alluvium. The southwest contact is sharp; the northeast contact is gradational.

Two basic solutions to the problem are shown in figure 10. Figure 10A shows the instance in which the New River alluvium is deposited as the river flows to the northwest. The Valley and Ridge alluvium is deposited by a tributary (probably Sinking Creek) entering the New River from the northeast and by another tributary, equivalent in size to Sinking Creek, entering the river from the southwest. The difficulty with this solution is that whenever the New River moved southwestward to its present location it would have removed the Valley and Ridge alluvium between the former and present locations. A variation of this solution

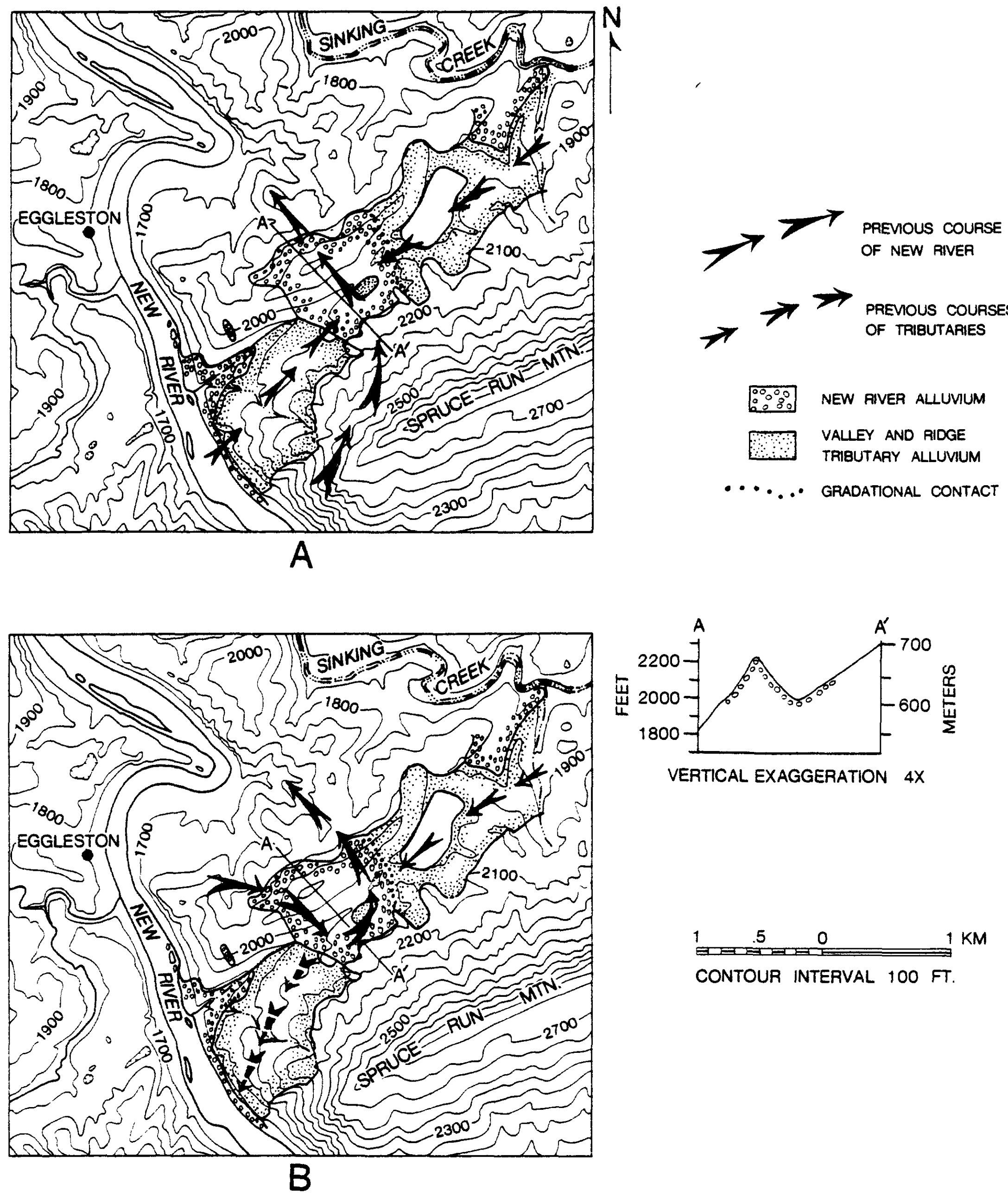


Figure 10.--Maps of alluvial deposits east of Eggleston showing two alternative stream configurations by which the alluvium may have been deposited. A, Two Valley and Ridge tributaries entered the New River, one from the southwest and one from the northeast. B, One tributary entered the New River from the northeast and abandoned the lower part of its channel after it intersected a meander bend of the river. Broken arrows show abandoned channel.

would preserve the Valley and Ridge alluvium by extending Sinking Creek to the southwest as the New River migrated in that direction to its present location. The problem with this variation is that Sinking Creek would have removed (or at least reworked) the New River alluvium just as the New River would have removed the Valley and Ridge alluvium in the previous instance.

The second type of solution (fig. 10B) shows the New River flowing northwestward near its present location and Sinking Creek entering the river from the northeast. As a meander loop developed in the New River, it extended itself first to the southeast and then to the northeast (fig. 10B). When the meander intersected Sinking Creek, the lower part of the channel of Sinking Creek was abandoned, and the creek then entered the New River at the northeast side of the meander loop. This solution explains both the distribution of the alluvium and the nature of the contacts between the New River and the Valley and Ridge alluvium; i.e., a sharp contact on the southwest, a gradational contact on the northeast, and no reworking of the three deposits.

In areas such as the unglaciated Appalachians where degradation rather than aggradation has been the dominant fluvial process throughout the Cenozoic era, a large percentage of the alluvial deposits preserved above the modern flood plains was probably deposited during very large floods. Alluvium deposited during small to moderate floods of 1-year, 50-year, or even 100-year recurrence frequency will very likely be re-entrained into the sediment load of the stream system during the next larger flood. However, alluvium deposited by a 1000-year flood has a greater probability of being preserved by virtue of the low recurrence frequency of very large events. It is probable that parts of a stream will have migrated far enough laterally in 1000 years that the next flood of equal or larger magnitude will not reach all the alluvium deposited by the previous 1000-year flood.

Although most of the alluvial deposits in the study area are poorly exposed and no bedding can be seen, the size of some of the clasts is evidence for transport under high-energy conditions. Quartzite boulders 0.5 m in diameter are common in deposits of New River alluvium. The kinds of sediments and sedimentary structures seen in the few well-exposed alluvial deposits in the area all indicate rapid deposition under high-energy conditions; e.g., large-scale crossbedding, lenticular, coarse-grained, fining-upward sequences, poor sorting, and low clay content.

A rather spectacular example of a flood deposit, interpreted to be a type of channel bar, used to be present along Montgomery County road 652, 1.8 km east of Longshop, at an elevation of about 590 m (1940 ft) (Radford North

7 1/2-minute quadrangle map). The alluvium was removed sometime during 1976-77, probably for fill. Figure 11 is a sketch traced from a panoramic photograph of the outcrop. The deposit is a cyclic, fining-upward sequence with one complete cycle and the base of a second exposed in the original outcrop. The horizontal dimension of the complete cycle was about 30 m and the apparent dip of bedding was fairly constant at about 25° south. The original vertical dimension of the sequence is not known, although 4.5 m was exposed at the north end of the outcrop. The clasts range in size from cobbles (long axis 12 cm) at the north end of the sequence to clayey silt and fine sand at the south end. A number of smaller fining-upward cycles, 0.3 to 1 m thick, are superimposed on the major cycle in the transition zone between bouldery sediment and clay, silt, and sand. The smaller cycles contain a large component of coarse sand and pebbles. In general, the entire sequence is poorly sorted, with abundant fine sand and silt and minor clay throughout.

The thickness of the graded sequences, the large size of basal clasts, and the high angle of the bedding make it unlikely that this alluvium was deposited during mean flow conditions. The constant bedding angle, clast size, and absence of scour and channeling suggest that this sequence represents a single high-energy depositional event of short

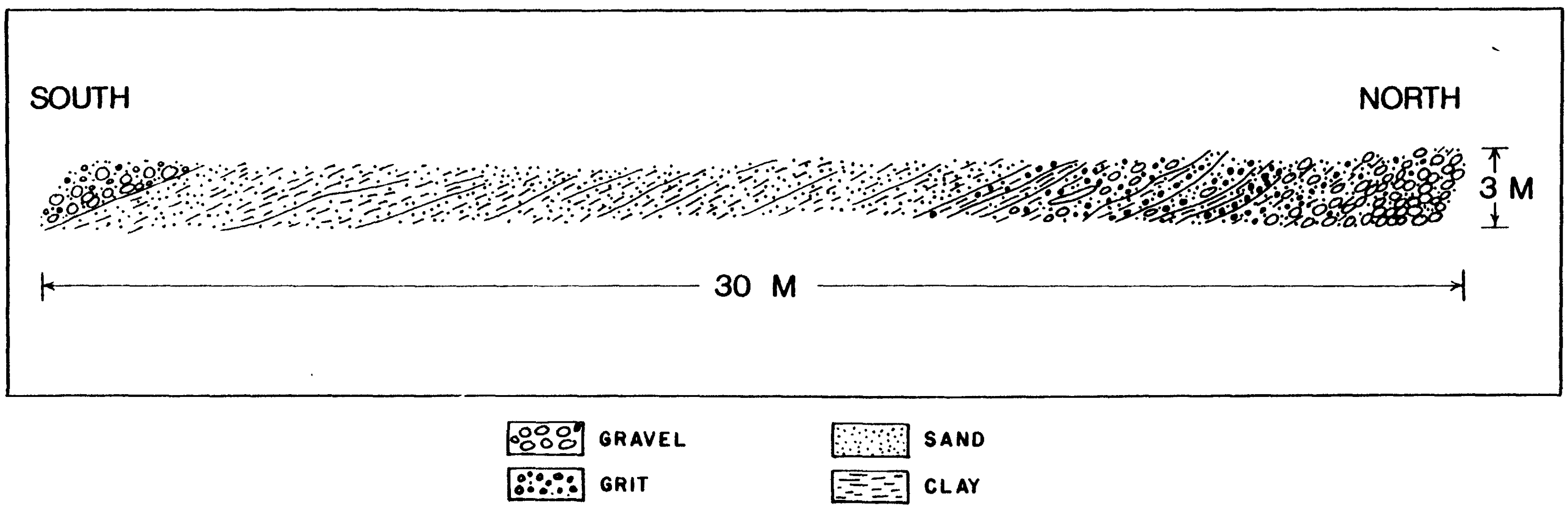


Figure 11.--Sketch of bedding characteristics and sediment size in an alluvial deposit interpreted to be a flood deposit.

duration, most likely a large flood. Deposits with similar features which formed during the Lake Missoula flood have been interpreted by Baker (1972, p. 34-42) to be expansion bars, although the similarity should in no way be taken to imply any comparison in the magnitude of the floods.

A large proportion of the alluvial deposits are remnants of channel, flood-plain, and point-bar deposits left behind following stream capture. Most of these deposits are quite old and poorly exposed; many have been disturbed by reworking or by being let down in place by solution. Thus, scant evidence remains that can be used to infer depositional environments. However, alluvium deposited by a former tributary of the New River, the Blacksburg River, is present in the wind gap between Sinking Creek and Gap Mountains and can be interpreted to be a channel deposit on the basis of its location at the lowest point in the gap. The chronology of stream capture and its alluvial remnants are discussed in Chapter 6.

Morphology of the Valley and Ridge tributaries

The principal tributary streams in the detailed study area are Spruce Run and Sinking Creek. These streams are shown on plates 1 and 2 and in figures 3 and 4. The gradient and sinuosity and longitudinal profiles are shown in figure 12.

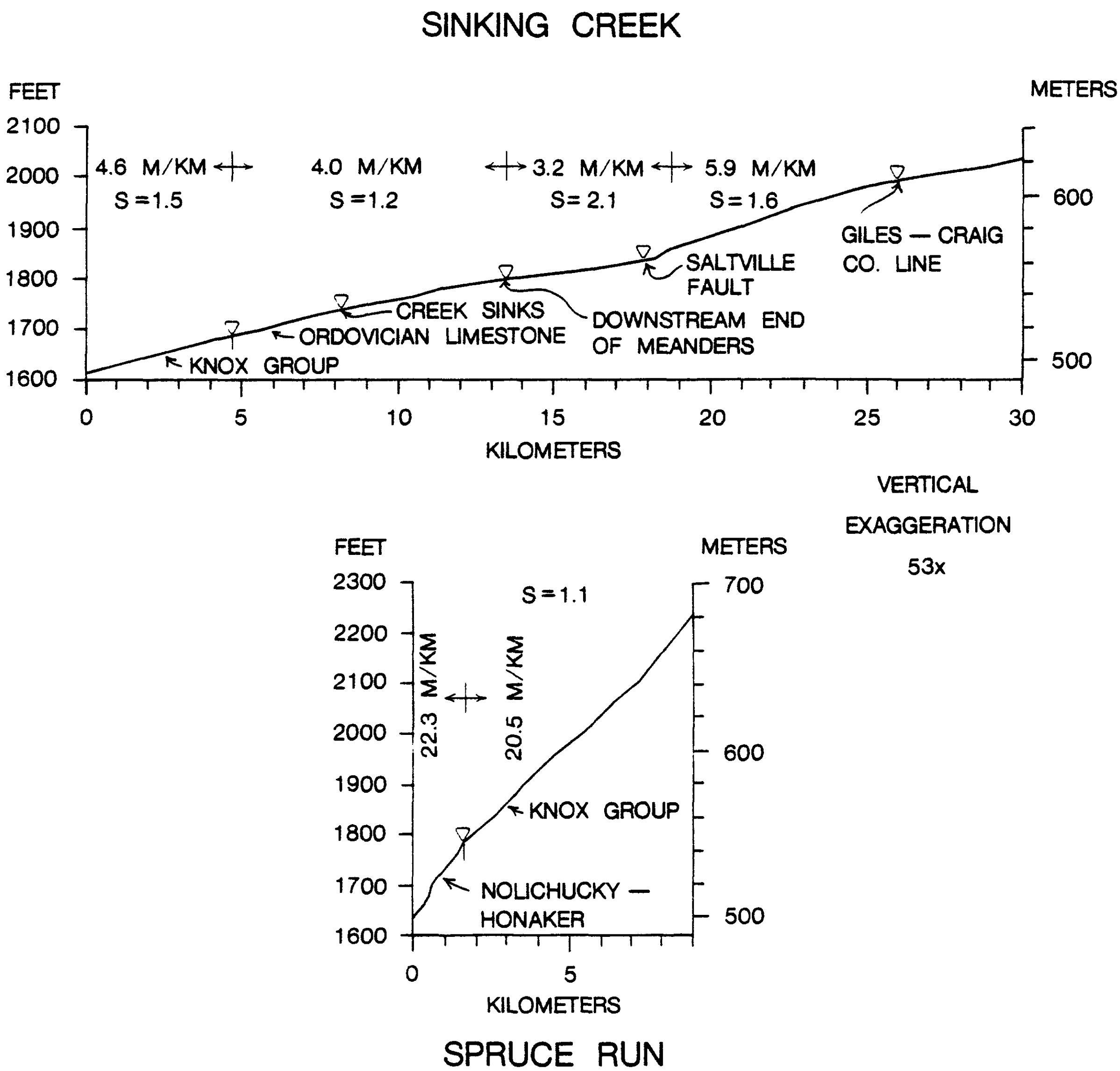


Figure 12.--Longitudinal profiles of Sinking Creek and Spruce Run. S, sinuousity.

Spruce Run, the smaller of the two streams, is about 8.5 km long and flows southwestward to the New River in a strike valley about 3 km wide between Gap Mountain on the southeast and Spruce Run Mountain on the northwest. The stream flows over carbonate rock of the Knox Group in the upper 7 km of its course and over the Honaker Dolomite in the lower 1.5 km. This lower 1.5 km is entrenched and is bordered by steep bedrock slopes 30-45 m (100-150 ft) high. In contrast, the upper part of Spruce Run valley is quite open and has the cross-sectional shape of a broad "U," although the active flood plain of the stream is narrow, less than 200 m wide, with an average width of perhaps 50 m. The stream is no more than 3 m wide and less than 0.5 m deep during average flow. Spruce Run has a steep gradient, as is to be expected for a stream this small. The gradient of the upper part is 20.5 m/km (108 ft/mi), the lower entrenched part is 29.5 m/km (156 ft/mi), and the overall gradient is 22.3 m/km (118 ft/mi). The sinuosity is 1.1. Spruce Run flows year round in spite of its small drainage basin (about 19 km^2), and it does not lose a noticeable amount of water to underground drainage through the carbonate bedrock.

Sinking Creek is 45 km long, and its drainage basin covers an area of about 200 km^2. It is a relatively small stream, 0.5-1.0 m deep with an average channel width of

5-10 m. The flood plain is narrow, ranging from 0 to 300 m, with an average of about 65 m. Sinking Creek can be separated into three segments for the purposes of description.

The upper 32.5 km of Sinking Creek drains the northeastern part of the same strike valley as does Spruce Run. This part of the valley is bordered on the southeast by Sinking Creek Mountain and on the northwest by Clover Hollow-Johns Creek Mountain. Within the detailed study area southwest of the Giles-Craig County line, Sinking Creek flows over the Knox Group, Nolichucky Shale, and Honaker Dolomite, crossing the contact separating the Knox from the Nolichucky and Honaker seven times. The sinuosity of this part of Sinking Creek is 1.6; the gradient is 5.9 m/km (31 ft/mi).

About 1.0 km northeast of the community of Newport, Sinking Creek turns northwest and flows across strike through a wide gap between Spruce Run Mountain and Clover Hollow Mountain. The course of this part of the creek is over the Knox Group and the Moccasin, Eggleston, and Martinsburg Formations which are exposed between three splays of the Saltville fault. This segment of Sinking Creek is exceptional because it has developed a deeply incised meandering course on the outcrop belt of the shaly Moccasin, Eggleston, and Martinsburg Formations. The sinuosity of this short segment of the creek is 2.1, and both the channel gradient and the straight-line gradient are considerably lower than in the strike valley upstream. The channel gradient, 3.2 m/km (17 ft/mi), is only slightly more than half the gradient upstream. Sinking Creek is bordered by very steep bedrock slopes in this area, particularly on the outside of meander loops. The steepest slope is about 90 m/120 m, or a 75-percent grade.

In its third and final segment, Sinking Creek again flows southwest, generally parallel to strike. The appearance of this valley is considerably different from the narrow strike valley to the northeast in which Sinking Creek has its headwaters. This is a very broad valley underlain by Cambrian and Ordovician carbonate rocks exposed by unroofing of the Clover Hollow and Bane anticlines (p. 24 and pl. 1, this report). After entering the valley, Sinking Creek flows over Middle Ordovician limestone units for a straight-line distance of 6.8 km. The creek does not meander in this interval (sinuosity = 1.2) and the gradient is lower (4.0 m/km (21 ft/mi)) than that of the first segment of Sinking Creek (5.9 m/km (31 ft/mi)). The lower gradient may be caused by the addition of two small but perennial streams and a number of springs which enter the creek in the area of the second segment, thus increasing the discharge.

In the last 3.0 km (straight-line distance) above its mouth at the New River, Sinking Creek flows across the Knox Group. This part of the creek meanders, although not greatly, and is entrenched. Inspection of the geologic map of this area (pl. 1) shows that the entrenched part of Sinking Creek begins about ±0.5 km (upstream or downstream) from the point where the creek crosses the Knox-Middle Ordovician limestone contact. Unlike the very low gradient (3.2 m/km (17 ft/mi)) of the entrenched meandering channel developed on the Ordovician shale units, the gradient of this final entrenched and meandering part of Sinking Creek is slightly higher (4.6 m/km (24 ft/mi)) than the gradient immediately upstream.

Sinking Creek sinks in the area between the Knox-Middle Ordovician limestone contact and U.S. route 460, about 2.8 km to the east. The creek begins to sink in the spring, is dry throughout the summer months except after heavy rainfall, and begins to have surface flow again in the fall. In general, the decrease in discharge is gradational over a distance of a few hundred meters, and the location of the sink is seasonally variable. Thus, on the average, Sinking Creek will sink farther downstream in early May than in late May, for example.

The brief descriptions given above of a few of the characteristics of Sinking Creek and Spruce Run demonstrate the variability of the streams. Some of the variation is dependent upon lithology, some on structure, and some on sediment load--and probably some of the variation is controlled by other unknown and (or) unconsidered factors.

Examples of Valley and Ridge-derived alluvial deposits

On the southeast side of Sinking Creek between Giles County roads 700 and 730 (pl. 2) there is a Sinking Creek alluvial deposit which may have resulted from lateral migration of the creek in response to increased erosion during the Pleistocene. Although only part of this deposit was mapped in detail, it is in general a linear deposit 100-400 m wide and 5 km long which appears to have been formed by lateral migration of this part of Sinking Creek to the northwest. The lateral migration may have been caused by an increase in the amount of coarse detritus supplied by streams on the northwest flank of Spruce Run Mountain during the Pleistocene. A sample of alluvium (sample 65a) taken near the top of the deposit is about 1.5 m.y. old on the basis of its zircon:tourmaline ratio (Chap. 5, fig. 33).

Fresh exposures of the deposit made during widening of U.S. 460 indicate that it is in part an overbank deposit mixed with braided-stream deposits at the mouths of the small intermittent streams which drain the flank of Spruce

Run Mountain. The overbank deposits are monotonous sequences of silty to pebbly sediment with poorly defined but laterally continuous bedding. The braided-stream deposits show channeling, high-angle crossbedding, and lenticular fining-upward sequences with small boulders and cobbles at the base which may have been deposited as mudflows.

As mentioned previously in the description of the Valley and Ridge-derived alluvium, sparse numbers of vein quartz and metaquartzite clasts are present in most Valley and Ridge-derived alluvial deposits within the study area. These clasts have been incorporated into the Valley and Ridge alluvium by reworking of both New River alluvial deposits and alluvial deposits of the two former northeastern Blue Ridge tributaries (County Line River and Blacksburg River).

For example, sample locality 20, a Sinking Creek alluvial deposit, contains reworked New River alluvium. This deposit, which is about 1 km east of the New River and is bordered on the south by New River alluvium, contains 8 percent cobble-size, Blue Ridge-derived quartzose clasts (appendix). In addition to its proximity to the modern New River and to older New River alluvial deposits, the relatively high percentage of rutile (12 percent; table 4) in the heavy-mineral assemblage of sample 20 is a further indication that this deposit contains an admixture of New River alluvium. As discussed in Chapter 5, the heavy-mineral assemblages of older New River alluvial deposits contain an average of 23 percent rutile, whereas those of older Valley and Ridge and Blacksburg River alluvial deposits contain an average of only 2-3 percent rutile.

Over most of the area, however, the reworked Blue Ridge-derived quartzose clasts were originally deposited not by the New River but by its two former northeastern tributaries. This inference is based on geomorphic and petrographic evidence, as discussed in Chapters 5 and 6. Briefly, the County Line River flowed in the valley between Clover Hollow Mountain and Sinking Creek Mountain, from the vicinity of the Giles-Craig County line to the vicinity of Newport (fig. 35), and was captured more than 10 m.y. ago. The Blacksburg River first flowed southwestward in Spruce Run valley (fig. 35) but later flowed northwestward through the gap separating Spruce Run Mountain from Clover Hollow Mountain and joined the New River near Pearisburg (fig. 36). The Blacksburg River was captured about 6 m.y. ago.

The present areal distribution of the alluvial deposits may, in part, reflect the former courses of these two rivers. Inspection of the map patterns of the alluvial deposits (pl. 2) shows that Spruce Run valley has a more continuous veneer of Valley and Ridge alluvium than the rest of the area. The less continuous alluvial cover in that part of Sinking Creek valley northeast of Spruce Run valley could be the result of earlier capture of the County Line River as compared to that of the Blacksburg River. Thus, more time has been available for removal of the alluvium left behind by the County Line River. Another factor which could be a cause of the greater amount of alluvial cover in Spruce Run valley is the relative size of Spruce Run and Sinking Creek. Spruce Run is considerably smaller than Sinking Creek and perhaps has not been competent to remove much of the alluvium left behind by the Blacksburg River.

Deposits of the Ridge Flanks

The term "ridge flank" as used in this study pertains to the upper 200-300 m (600-1000 ft) of the ridges between the ridge crest and the relatively gentler topography of the valley floor. For the most part, the ridge flanks are not agriculturally useful and are forested, although in a few places pastures have been cleared to within 100 m (300 ft) of the ridge crests.

Parts of the southeast flank of Spruce Run Mountain, including the ridge crest, have been cleared, because on this side of the ridge the Tuscarora Sandstone has been cut out by the Saltville fault (pl. 1); the area is therefore not too bouldery for pasture.

At about 50 m (150 ft) below the ridge crests the flanks are incised by the heads of steep-sided ravines cut into bedrock. The ravines are formed by unbranched streams, oriented perpendicular to the strike of the ridges and separated by interfluves 200-400 m wide. The depth of the ravines ranges from about 15 to 35 m (50-120 ft). Few ravines have perennial waterflow, but most can be termed damp.

The bouldery surficial materials on the flanks of the ridges in the Appalachians have traditionally been called colluvium, which implies that the method of transport is chiefly mass wasting. However, the field evidence of the study indicates that these surficial materials are transported predominantly by water during floods. The most obvious evidence is the presence of significantly more detritus in ravines than on interfluves. In fact, probably more than 50 percent of the interfluves are devoid of any surficial materials, including soil. It could be argued that colluvial detritus is concentrated in ravines because the sides of the interfluves are steeper than their crests and colluvium would preferentially move down the steeper slope. This argument does not explain, however, the scarcity of detritus on the crests of the interfluves.

No matter how the detritus gets to the ravines, once it is there it will be transported dominantly by water and is, by definition, alluvium. Another observation which supports the hypothesis that much of the coarse-grained debris on ridge flanks is actually alluvium is the presence of one or two stream-polished facets on many boulders (fig. 13). Stream-polished facets are not present on colluvial boulders on or near ridge crests or in talus deposits. In the downhill direction on ridge flanks, however, the number of boulders with polished facets increases and the number of facets per boulder increases.

Thus, the term "colluvium" has been incorrectly applied, and "first-stage alluvium," "boulder streams," and "second-stage alluvium" are suggested as terms which more accurately reflect the downslope movement of these materials. The term colluvium is used in a restricted sense as described in a previous section (p. 42) for accumulations of rock on very steep, smooth slopes near the crests and at the ends of ridges, where ravines are not developed.

Colluvium

The area mapped as colluvium on plate 2 is relatively small, 3.0-3.5 km^2, as compared to the total map area and as compared to the areas mapped or described as colluvium by previous investigators (Fiedler, 1967; Gambill, 1974). Except for two scree deposits, the colluvium within the reconnaissance area is confined to narrow bands along the

Figure 13.--Sandstone boulder showing facets developed by abrasion in place in a small stream, northwest flank of Gap Mountain near Divide Ridge.

ridge crests. The colluvial deposits are fairly thin and consist of material ranging from sand to boulders. Because of their size (as much as several meters in diameter), the boulders are the most obvious components.

Two scree deposits are present in the study area--one beneath Barneys Wall on the northwest side of the valley of Little Stony Creek and the other at the southwest end of Spruce Run Mountain above the New River (pl. 2). These deposits are probably colluvial, because there is no ravine incisement at either place--just very steep, smooth slopes. The scree deposit at the southwest end of Spruce Run Mountain lies directly below the outcrop of Upper Ordovician and Lower Silurian sandstones in the axis of the Spruce Run syncline. The rocks are highly fractured at this point. No structural complexities are reported in the area of Barneys Wall which might result in greater than normal fracturing. This scree deposit is thought to owe its development simply to local high relief, about 275 m (900 ft).

Scree deposits have been cited as remnants of Pleistocene periglacial weathering conditions. Hack (1965, p. 32-44) described a number of scree accumulations in the Shenandoah Valley and concluded that many large scree areas are probably preserved from the Pleistocene but that some screes are actively forming under present climatic conditions. Scree is rare in the Southern Appalachians, and its existence probably depends in large part on frost wedging. It is doubtful, however, that the scree deposits in the study area are remnants of the Wisconsin glacial stage which ended about 10,000 years B.P., because vegetative cover is minimal to absent. It is more likely that they are being actively formed at the present time, or that they are remnants of the Little Ice Age, which lasted from about 1500 to 1920 A.D. (Sugden and John, 1976).

First-stage alluvium and boulder streams

The distribution of the first-stage alluvium and boulder streams on the flanks of the ridges is determined by lateral migration of ravines on the upper and middle slopes and by stream capture on the lower slopes.

Distribution on lower slopes

The mechanism for transporting first-stage alluvium on the lower slopes of the ridges is similar to that described by Hack (1960, 1965) for streams draining from the northwest side of the Blue Ridge into the Shenandoah Valley. In the present study area, steep-gradient streams (ravines developed on the lower part of the Juniata Formation and the upper part of the Martinsburg Formation) carry large volumes of first-stage alluvium during flash floods. Where the streams cross from the shale units onto the calcareous lower Martinsburg Formation, Eggleston Formation, and Middle Ordovician limestones, much of the water goes into underground solution systems. The remaining water is not adequate to carry the alluvium and it is dropped. Intermittent streams capable of removing some of the smaller clasts often develop at the edges of boulder streams in the carbonate valleys. However, the volume of alluvium introduced during flooding is too great to be carried away by these streams, and the valleys eventually become choked with boulders.

Small streams flowing on carbonate bedrock and eroding headward from the major subsequent streams carry no appreciable quantity of clastic material and therefore have lower gradients than those in the boulder-choked valleys (Hack, 1957). At an equal horizontal distance from a subsequent stream, a small stream on carbonate bedrock will therefore be topographically lower than one flowing in a boulder-choked valley. Eventually the stream with the lower gradient will capture the drainage of the valley filled with boulders and in turn become boulder-choked. The process will then be repeated by another stream flowing on bedrock. By this mechanism, the lower slopes of the ridges are coated with first-stage alluvium which is the remnant of the boulder streams in the overloaded stream valleys.

An example resulting from this process is the configuration of two boulder streams at the northeast end of Spruce Mountain (fig. 14). The drainage of the northern boulder stream has been captured by the one to the south. The northern stream is no longer being supplied with alluvium, and the boulder-stream deposit ends on top of a spur at an elevation of about 760 m (2490 ft), 20 m (70 ft) above the valley of the active southern boulder stream. Figure 15 shows the profiles of the two streams. The gradient of the southern stream, between 610 and 762 m (2000 and 2500 ft), is much lower than that of the northern stream in the same elevation interval: 89 m/km (470 ft/mi) versus 157 m/km (830 ft/mi). Based on reconstructions of the gradient and former course of the captured stream, the capture probably took place when the former stream was at an elevation of between 832 and 878 m (2730 and 2880 ft). This point of capture corresponds to an elevation of between 768 and 786 m (2520 and 2580 ft) for the modern stream and indicates that in the region of capture and upstream from it the modern stream has eroded 30-90 m (100-300 ft) vertically and about 200 m laterally since the time of capture. Taking 90 m (300 ft) at the capture point as the maximum amount of erosion and 21 m (70 ft) at the upper limit of the stranded boulder-stream deposit as the minimum, and using the average rate of vertical erosion

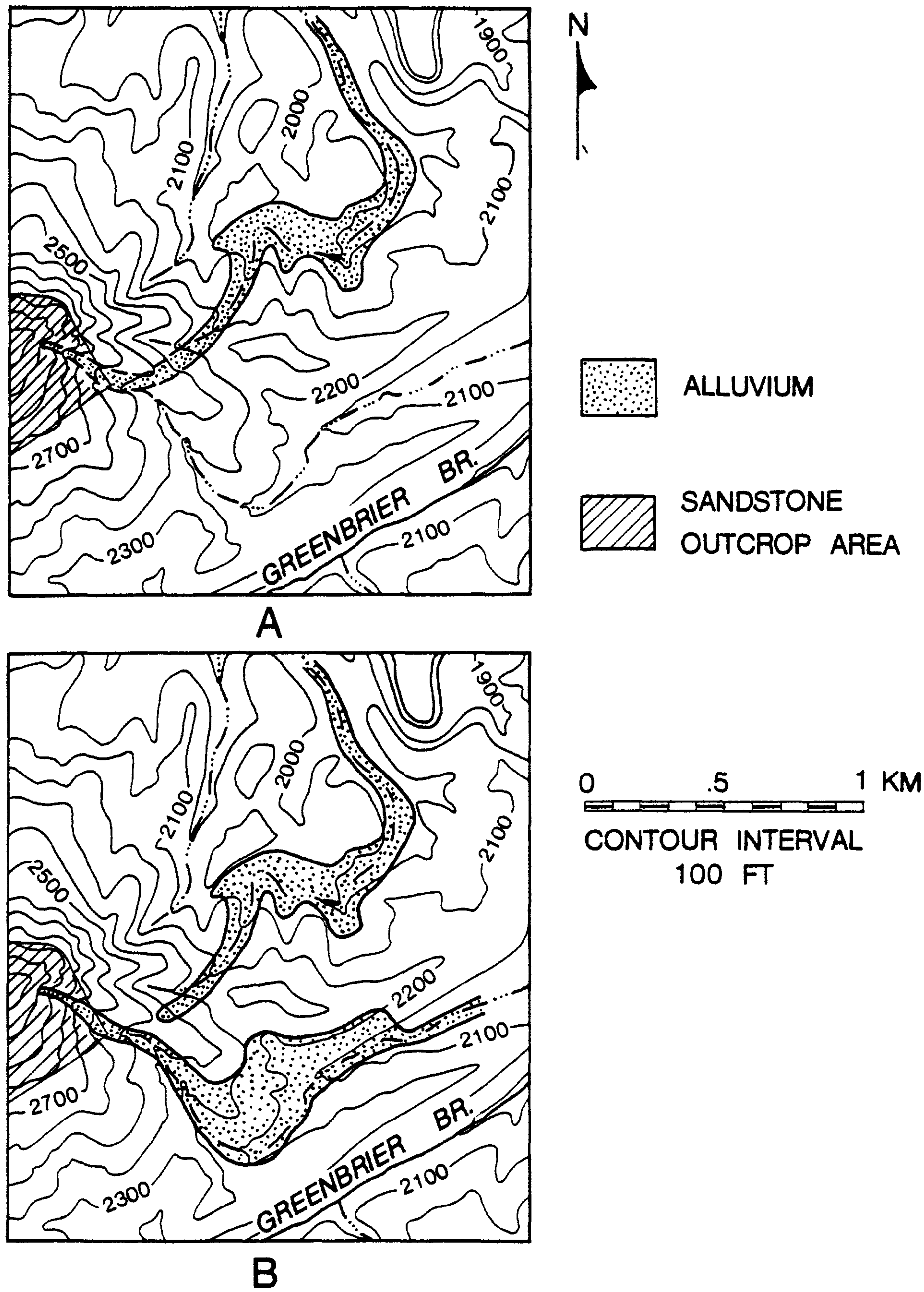


Figure 14.--Distribution of boulder streams and second-stage alluvium interpreted to be the result of stream capture at the northeast end of Spruce Run Mountain. A, Drainage configuration before capture. B, Drainage configuration and distribution of alluvium after capture.

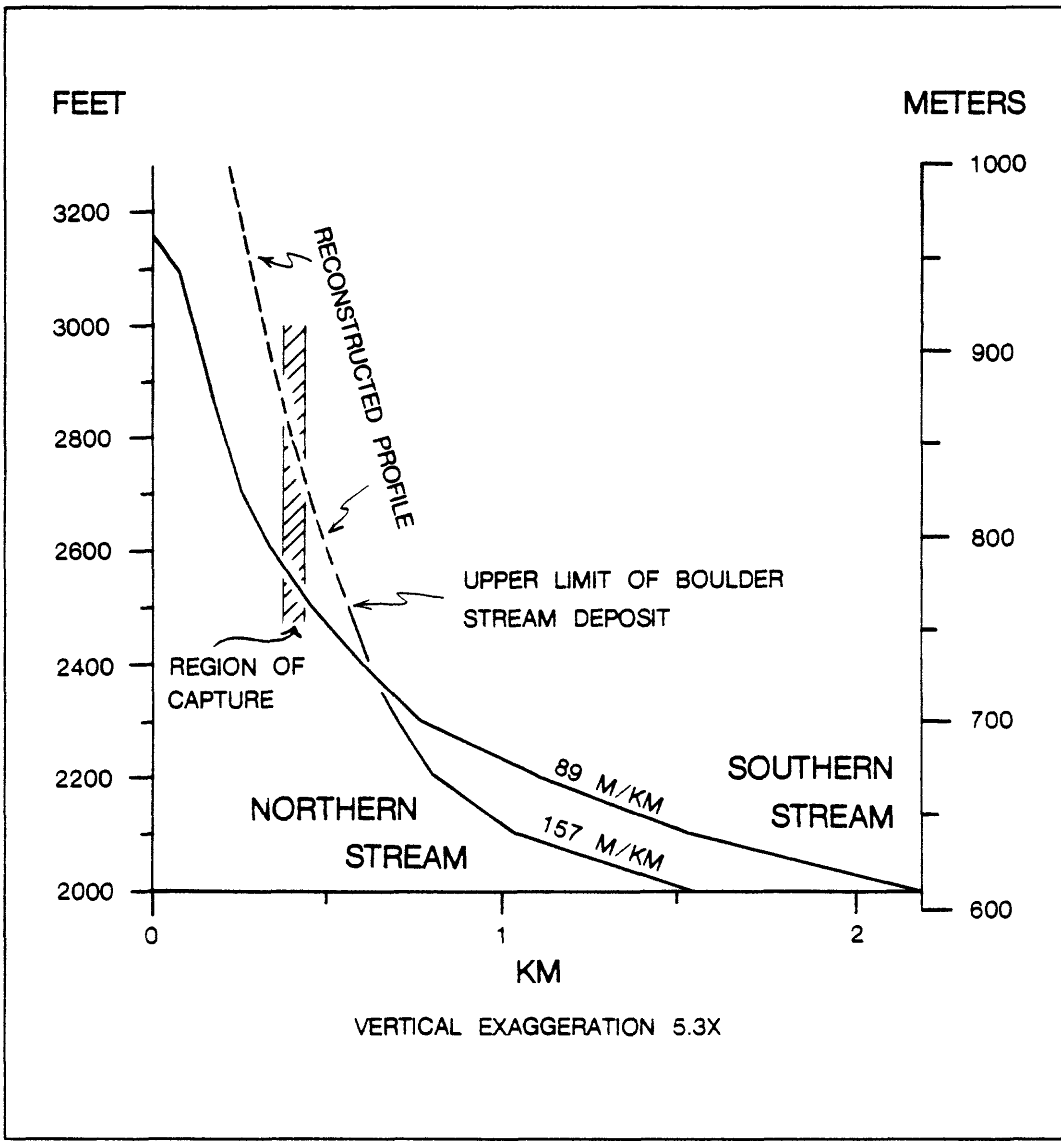


Figure 15.--Longitudinal profiles of streams shown in figure 14 illustrating that the southern stream has the lower gradient.

calculated by Hack for the Shenandoah Valley, 40 m/m.y., as a rough estimate, the capture occurred 0.5-2 m.y. B.P. The importance of this estimate is that it shows that surficial deposits tend to retain their original shape for a considerable period of time after the conditions under which they were formed have changed. The upper part of the northern boulder stream between 700 and 762 m (2300 and 2500 ft) is no longer in a valley, but the surficial materials still have the map pattern of the original valley.

Distribution on upper and middle slopes

Lateral migration of ravines, similar to the "gully gravure" described by Bryan (1940), is the principal mechanism of erosion and transport on the upper and middle slopes of the ridges. Ravines are formed on the nonresistant shale of the Upper Ordovician Martinsburg Formation. As the ravines become filled with more and larger clasts of sandstone from the tops of the ridges than can be transported during periodic small floods, the streams maintain their grade by cutting laterally into the Martinsburg shale at the sides of the ravines. This causes the ravines to migrate in one or both directions perpendicular to the direction of streamflow and to leave behind lag deposits of first-stage alluvium in the form of wide boulder streams. As lateral migration and downcutting continue, the middle or side of the lag deposit will eventually be stranded on an interfluve.

An example of the distribution of two boulder streams on the northwest side of Gap Mountain resulting from this process is shown in figure 16. The stream on the southwest has migrated laterally about 90 m to the northeast. The southwest edge of the boulder stream associated with this stream is on an interfluve about 20 m (60 ft) above the floor of the ravine. The boulder stream on the northeast is being extended both northeast and southwest by lateral migration of the streams on both sides, producing an interfluve in the middle of the boulder-stream deposit.

Eventually, the bedrock spur between the two boulder streams will be eroded by lateral migration of the ravines on either side, and this section of the ridge will be drained by a single stream. By that time the outer boundaries of the old boulder streams will have lost their distinctive shape and will be classified as first-stage alluvium.

The processes of stream capture on the lower ridge slopes and lateral migration of streams on the middle and upper slopes probably are not independent of each other. To some extent, lateral migration will be aided by the repositioning of stream channels on the lower slopes caused by stream capture.

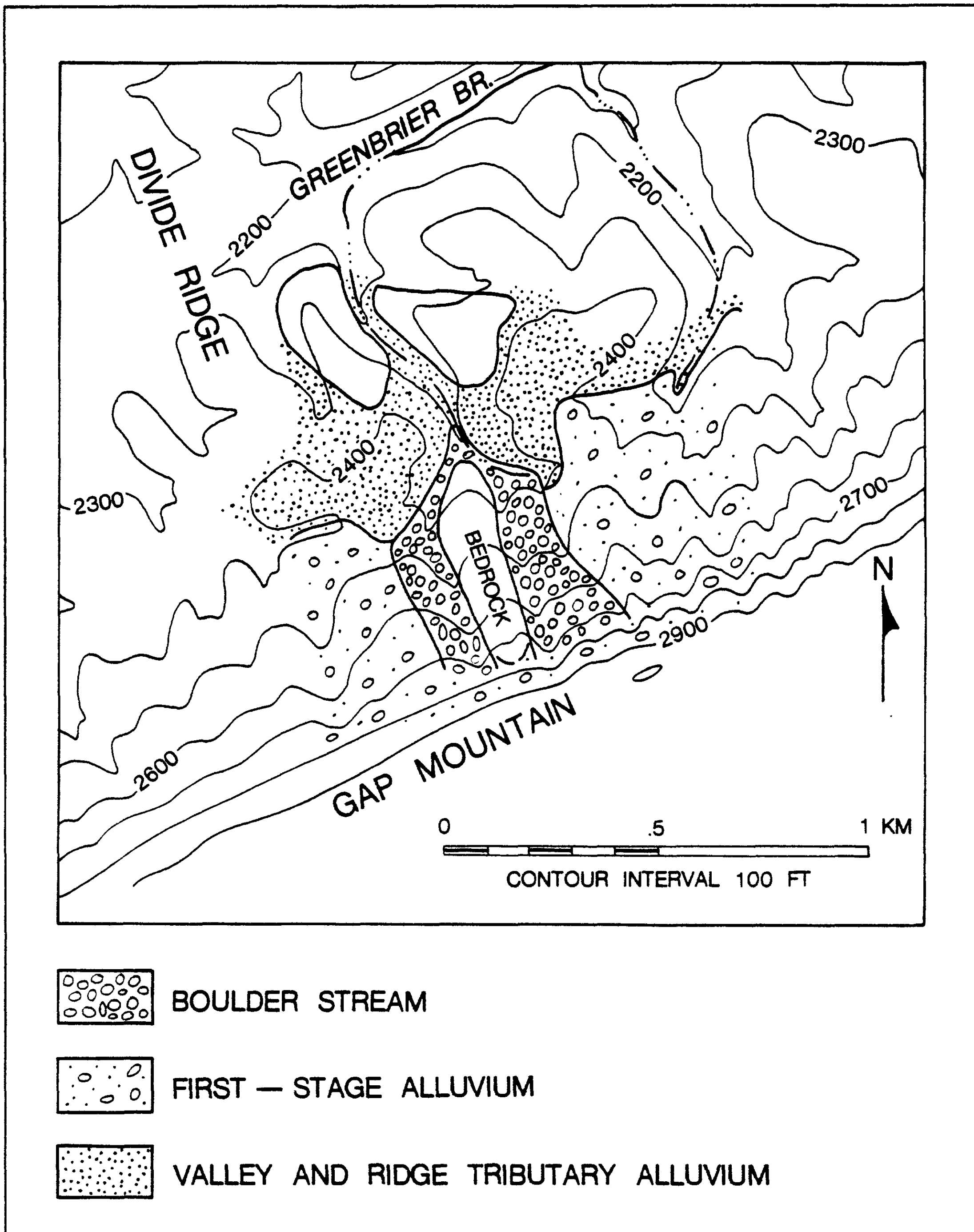


Figure 16.--Map of the distribution of first-stage alluvium in two boulder streams near the head of Spruce Run valley showing the relationship of the boulder streams to the present topography.

Effects of climate

The modern erosional regime appears to be adequate both for producing colluvium and for transporting the first-stage alluvial materials down the ridge flanks at a rate approaching equilibrium. For all practical purposes, boulders are transported only during floods and only if they are in valleys. Although large boulders may move steadily downslope at a slow rate by mass wasting, this movement is minimal as compared to the tens of feet they may be moved in a single flood. Under some flood conditions, coarse-grained debris may be transported down the ridge flanks as bedload if there is enough water in the channel. However, a well-documented and perhaps more effective mode of downslope movement, particularly in incipient gullies on the middle and upper flanks of ridges, is by debris avalanche. Hack and Goodlett (1960, p. 42-56) gave excellent descriptions of the effects of debris avalanches and other evidences of erosion which resulted from a violent summer rainstorm in 1949 in the Central Appalachians of Virginia.

By the mechanism of continuing random stream capture and lateral migration outlined, it is assured that all materials at a given time either are moving sporadically in stream valleys or are stranded on interfluves waiting for the next stream capture or lateral migration. The transport process is aided by disintegration of silica cement in the stranded boulders. Many of the boulders in deposits which are not presently in stream valleys are highly weathered and crumble to sand when hit with a hammer. Often, where stream polish is present on the more weathered boulders, the outer 1-2 cm of the boulder tends to spall in patches, removing part of the stream-polished surface.

The accumulation of large sandstone boulders on ridge flanks in the Southern Appalachians is usually cited as evidence of more rigorous erosion during Pleistocene glacial stages. Although some of the boulders may well have reached their present location during the Pleistocene, most of the boulder deposits owe their existence to the nature of the bedrock rather than to changes in climate. Without exception, in the study area, significantly large boulder accumulations are underlain by carbonate bedrock. The mechanism for the accumulation is the decrease in runoff due to increased subsurface drainage in carbonate rock. The large boulders move downslope on clastic bedrock by gravitational mechanisms, by transport during large floods, and by undercutting during smaller floods. When the boulders reach carbonate bedrock, the rate of downslope movement is decreased because, in the absence of appreciable surface runoff, only the relatively slow gravitation mechanisms of downslope movement are operable. Thus, the boulders tend to pile up and stagnate on spurs and knobs underlain by carbonate bedrock where surface runoff is minimal. The accumulations do not represent any one time period but probably range in age from Holocene through Tertiary.

It is doubtful that very much of the colluvium and first-stage alluvium presently on ridge flanks resulted from increased production of colluvial materials during Pleistocene glacial maxima. Certainly the mean annual temperature was lower by several degrees during glacial stages, and the production of colluvium by frost wedging probably increased. However, the amount of runoff, and therefore the competency of fluvial erosion, was also increased by the reduced rate of evaporation throughout the year and the greater depth of frozen soil in the winter. Thus, the overall rate of erosion probably increased during glacial stages, and it is suggested that fluvial erosion was probably able to keep up with the increased rate of production of colluvium.

Fiedler (1967) suggested that the deposits termed "boulder-stream" in the present study were emplaced as rock glaciers during glacial maxima. He further suggested that, because the limit of Wisconsin glaciation was only 200 km to the north of Giles County, it was cold enough at higher elevations in Giles County for interstitial ice to form in colluvial deposits, and the colluvium then moved downslope in the form of rock glaciers.

There are difficulties with the hypothesis that rock glaciers could have formed in southwest Virginia. Modern rock glaciers and deposits which can be interpreted to have been rock glaciers have been reliably identified only within the bounds of glaciated areas. The southern limit of the Wisconsin ice sheet does not imply that it was cold enough for glaciation at this boundary. Rather, it implies that it was too warm. The presence of patterned ground on Butt Mountain (Wayne Newell, oral commun., 1978) should be noted, however. Patterned ground is usually evidence of permafrost.

Another problem concerns the thickness of rock glaciers. Data presented by Wahrhaftig and Cox (1959, p. 399) on the height of talus at the front of active rock glaciers in the Alaska Range indicate that the height ranges from 30 to 120 m (100-400 ft), with an average height of 60 m (200 ft). The boulder accumulations in Giles County are only about one-tenth as thick.

Because the occurrence of bouldery debris on ridge flanks in the Southern Appalachians can be explained by fluvial mechanisms presently operative, including debris avalanching, I prefer the interpretation that this material is fluvial in origin.

Second-stage alluvium

Clearly distinguishable deposits of second-stage alluvium, large enough to be mapped, are present only in the upper part of Sinking Creek valley between the Spruce Run syncline and Gap-Sinking Creek Mountain (pl. 2). Alluvium derived from the Valley and Ridge and Blue Ridge is not as widespread in this area. In the rest of the map area, remnants of these more mature alluvial deposits mask the progressive development of second-stage alluvium being transported by small streams on the lower slopes of the ridges.

The main differences between first- and second-stage alluvium are functions of time, transport distance, and type of material available for transport. The larger clasts in second-stage alluvium are somewhat better rounded and polished than those in first-stage alluvium and the boulders are smaller. Abrasion in place has been suggested by Schumm and Stevens (1973) as a mechanism for producing these changes in short transport distances. Many orthoquartzite boulders with relatively smooth surfaces display white to light-gray marks which appear to be fossil tracks, or burrows (fig. 17). The markings are about 1 cm wide and commonly range from 10 to 30 cm long. Although these trace fossils are also present on boulders in first-stage alluvium and in Valley and Ridge alluvium, they seem to be most obvious on boulders in second-stage alluvial deposits.

Figure 17.--Sandstone boulder showing branched markings interpreted to be leached trace fossils, Doe Creek west of Salt Pond Mountain.

Second-stage alluvium contains a greater percentage of sand, silt, and clay than does first-stage alluvium. The greater amount of silt and clay is derived from weathering of Upper Ordovician shales and Cambrian and Ordovician carbonates. Much of the sand probably is derived from disintegration of clasts of some of the less resistant Upper Ordovician, Lower Silurian, and Devonian sandstones.

Second-stage alluvium is present in the valleys of modern small streams draining the lower ridge slopes, and it also occurs as remnants on valley sides, interfluves, and knolls. The mechanism for the transport and accumulation of second-stage alluvium probably is by stream capture, as discussed in the previous section, in combination with Bryan's "gully gravure." In most cases, capture of a tributary from the headwaters of a small stream does not completely rob the stream of water. Most small streams still receive runoff from one or two remaining tributaries. Thus, second-stage alluvium is not necessarily stranded following a stream capture, as first-stage alluvium usually is. It seems likely, though, that there would be some adjustments to the stream channel as a result of the decrease in discharge; one adjustment, for example, might be lateral migration of the stream. This, together with other adjustments, would tend to leave alluvial deposits stranded on the sides of small valleys.

Two second-stage alluvial deposits in the map area are of particular interest. The deposit on Keister Hill, southwest of the end of Clover Hollow Mountain (pl. 2), is a veneer of rounded and slightly polished Lower Silurian sandstone cobbles and small boulders. This deposit is about 1.5 km from the closest outcrop of Silurian sandstone at the end of Clover Hollow Mountain and is separated from the outcrop by a saddle 64 m (210 ft) lower in elevation than the top of Keister Hill. The alluvium was probably deposited by a small stream draining the end of Clover Hollow Mountain (similar to the streams described previously at the northeast end of Spruce Run Mountain), when Sinking Creek was eroding at a higher elevation and the gap between Clover Hollow Mountain and Spruce Run Mountain was not so wide. This remnant of alluvium has been preserved by its location on the top of a hill underlain by carbonate rock where there is no surface runoff.

A similar occurrence of alluvial clasts, now separated from their source area, is at the southwestern edge of the Valley and Ridge alluvial deposit overlying sample locality 18 (pl.2; appendix) (W. D. Lowry, written commun., 1980). The clasts are composed of siliceous oolite from the Copper Ridge Formation. The nearest outcrop of the Copper Ridge Formation is 0.4 km southeast of the alluvial deposit (pl. 1) and is separated from it by a small, northeast-trending valley about 55 m (180 ft) deep. Lowry noted that this geometry is a clear indication that the siliceous oolite clasts were transported to their present location by a northwestward-flowing stream which predated the small northeast-trending valley.

The most extensive deposit of second-stage alluvium is on the southeast side of Clover Hollow Mountain, southwest of the Giles-Craig County line (pl. 2). The deposit is unusual in several respects: it is large, about 1.0 km^2; it appears to have been deposited by a number of intermittent streams; and many of the boulders are nearly a meter across.

The characteristics of the deposit are determined by the intense fracturing of the Silurian sandstone upslope from the deposit and by the absence of the shale of the Martinsburg Formation. The Saltville fault in this area has stepped upsection through the Martinsburg Formation and brings the Knox Dolomite very nearly into contact with the Juniata Formation (pl. 1). The Silurian sandstone on the footwall of the fault is highly fractured (Gambill, 1974) and appears to be eroding more rapidly here than elsewhere along the ridge. More rapid erosion is evidenced by the narrowing of the ridge, by a saddle along the crest of the ridge above the alluvial deposit, and by the concavity in the ridge flank occupied by the deposit. Colluvium and first- and second-stage alluvium are probably being produced in this area faster than the materials can be removed by intermittent streams.

The absence of a wide belt of shale below the sandstone outcrop prevents the surface runoff from being concentrated in ravines, and instead many very small intermittent streams carry the alluvium a short distance downslope before sinking underground in the carbonate bedrock. In its general appearance and mode of accumulation, this deposit of second-stage alluvium can be called an alluvial fan.

The second-stage alluvium extends 0.4 km downslope to Sinking Creek, which is apparently removing the alluvium. The gradient of Sinking Creek increases abruptly at the point where the boundary of the alluvial deposit reaches the creek. Figure 18 shows the profile of Sinking Creek, both with and without meanders, between Huffman and Newport, a distance of 8.7 km. There is no change in bedrock in the area of the gradient increase, so the increase probably reflects an adjustment which allows the creek to transport the coarse detritus supplied by the second-stage alluvial deposit.

Preservation of Alluvial Deposits

The alluvial deposits are progressively less well preserved with increasing age. Most of the younger alluvial deposits, at elevations of as much as about 75 m (250 ft)

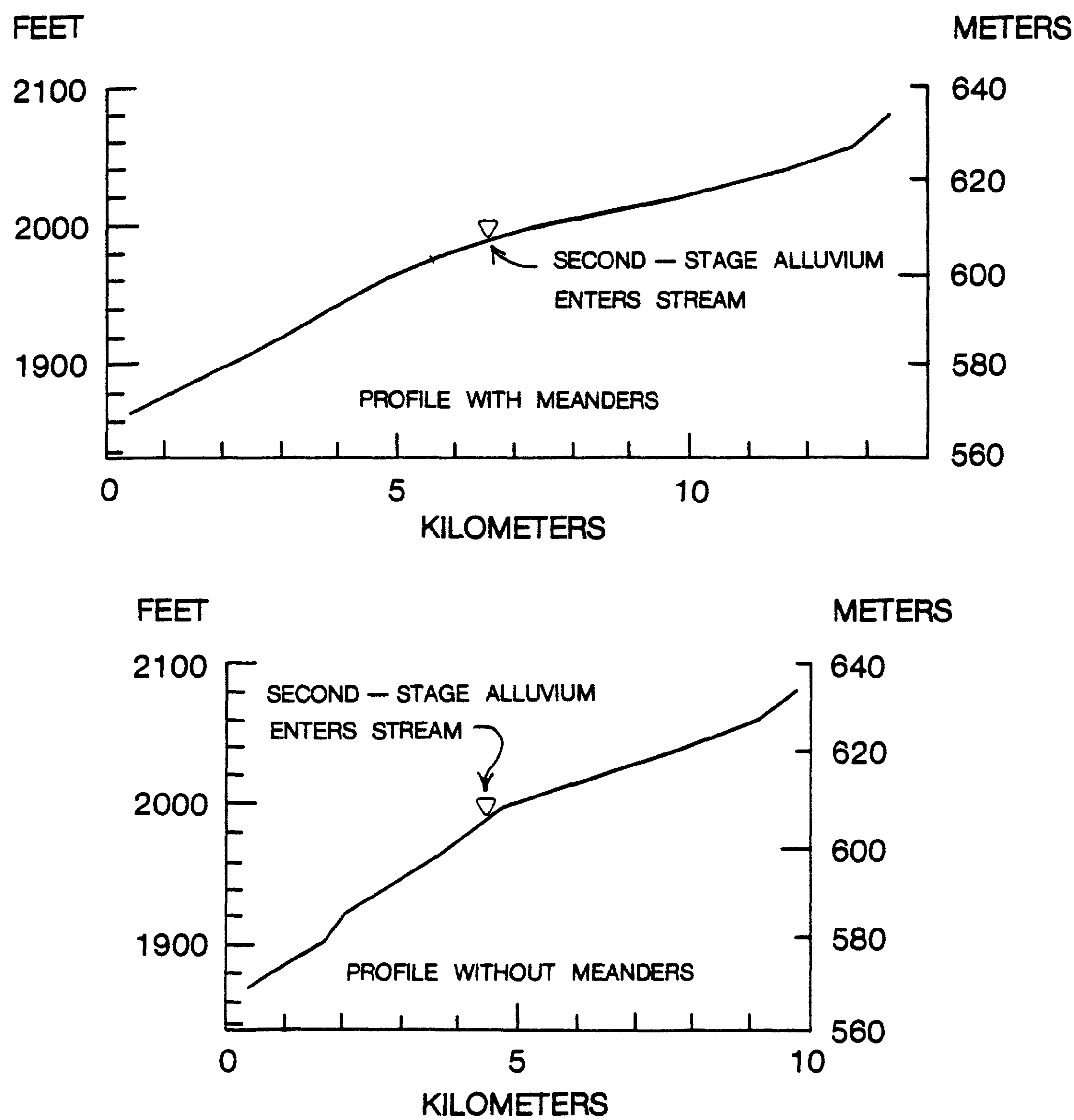


Figure 18.--Longitudinal stream profiles of Sinking Creek (both with and without meanders) showing the increased gradient where coarse detritus enters the stream southwest of the Giles-Craig County line, Virginia.

above the modern drainage, have retained parts of their original depositional outline, and bedding can be seen in good exposures. With increasing age the alluvial deposits become thinner, bedding is obliterated, and the depositional outline becomes altered and obscured. Thinning of the deposits is probably caused by (1) disintegration of clasts composed of relatively less resistant lithologies (shale, chert, weakly cemented sandstone), (2) solution of carbonate clasts and unstable sand and silt-size minerals (feldspar, ferromagnesian minerals, et cetera), (3) removal of some of the smaller size material by surface and subsurface drainage, and (4) compaction.

The principal processes involved in obliteration of bedding are the various thinning mechanisms, solution of carbonate bedrock beneath the deposits, burrowing animals and insects, plant roots, frost wedging, and so forth. The oldest alluvial deposits are commonly elliptical in map pattern and consist of scattered cobbles and pebbles in a silty soil. Many of the oldest deposits are on topographic knobs and saddles where runoff is minimal.

Nearly all the alluvial deposits are nonindurated, although four indurated deposits have been found within or near the study area. The locations of these deposits are: (1) in the wind gap between Gap Mountain and Sinking Creek Mountain (sample loc. 80); (2) at the southwest end of

Brush Mountain, 1.2 km northeast of the New River (fig. 19); (3) about 10 m (30 ft) above Stony Creek along Giles County road 635 northeast of Goldbond (Lindside 7 1/2-minute topographic quadrangle); and (4) in a bluff above the New River near Narrows, Virginia (Hale, 1961). The indurated deposits are incompletely cemented by goethite, and all of them overlie clastic bedrock. Newell and Rice (1978, fig. 5C) mentioned that alluvial deposits of the Cumberland River in Kentucky are cemented by limonite into hardpans at some localities. The Cumberland River deposits overlie shale, siltstone, sandstone, and coal of the Breathitt Formation (Lower and Middle Pennsylvanian).

This occurrence suggests that the presence of iron oxides as cementing agents in alluvium is dependent on bedrock type and may be controlled by pH or ground-water circulation. With the exception of these four deposits and deposits of relatively young alluvium which are underlain by Mississippian sandstone and shale between the northwest edge of the Pulaski thrust sheet and the base of Brush Mountain, the rest of the alluvial deposits are underlain by carbonate rock.

The effect of solution of carbonate bedrock on the preservation of alluvial deposits is to lower the deposits topographically by solution and to tend to preserve the deposits because of the decreased amount of surface runoff

Figure 19.--Boulder of goethite-cemented alluvium from an indurated New River alluvial deposit at the southwest end of Brush Mountain. The boulder contains well-rounded, Blue Ridge-derived clasts in a coarse sand matrix.

on carbonate rock as compared to clastic rock. The best documented example of these effects is a belt of isolated deposits of clay residuum mixed with carbonaceous material and gravel that extends from Nova Scotia to Alabama. The deposits range in age from late Cretaceous to early Tertiary. Pierce (1965) described one of these deposits of late Cretaceous age in the Great Valley in Pennsylvania and listed the ages, locations, and references to five other deposits. An additional deposit of the same type, located in Virginia, has been described by Sears (1957). Pierce noted that "All Appalachian lignitic accumulations and associated deposits either overlie carbonate bedrock (or, in Nova Scotia, sulfate bedrock) or they lie at the stratigraphic position of the base of the soluble rock already removed by solution."

Estimates of the amount of erosion that has occurred in the Appalachians during the Tertiary indicate that these deposits have been lowered, essentially in place, several thousand meters. Analyses discussed in Chapter 5 of this report indicate that the oldest sampled alluvial deposit within the present study area has been lowered about 130 m (425 ft), and that the average rate of lowering of the land surface by solution is about 13.5 m/m.y. (45 ft/m.y.). Using 40 m/m.y. (130 ft/m.y.) as the assumed total erosion rate for the area, then over carbonate bedrock one-third of the erosion rate is attributable to chemical processes and two-thirds to mechanical processes.

An implication of this statement is that mechanical erosion must be one-third less effective on carbonate rock than on clastic rock, assuming that the modern landforms are in approximate equilibrium. Obviously, if the rate of mechanical erosion were equal for both rock types and the rate of solution were simply added to this rate for carbonate rocks, the relief between areas of clastic rock and areas of carbonate rock would constantly increase through time and would eventually reach alarming proportions. Reversing this argument, if mechanical and chemical erosion were not to some extent additive, then areas of carbonate rock would not necessarily be valleys. It is well known that in arid climates where solution is minimal, carbonate rock is fairly resistant to erosion.

It is probably reasonable to assume, however, that mechanical erosion is reduced over areas of carbonate bedrock, although the amount of reduction may vary as a function of climate, lithology, and topography. The question, then, is how does the presence of a significant component of solution retard mechanical erosion?

One possible way is by means of subsurface drainage. Reduction in the amount of surface drainage will reduce the amount of surface erosion that results from mechanical abrasion. In addition, abrasion may be less effective in subsurface channels because of the smaller average grain size of the alluvium present in subsurface streams. Another factor is that the sculptured bedrock banks of subsurface streams may be more stable than bedrock banks of surface streams which are particularly subject to undercutting and rapid erosion on the outside of bends.

A final consideration in the problem of apportioning the total erosion rate of carbonate bedrock between mechanical and chemical means is that there is probably a very large component of solution which is hidden and which has no immediate effect on the elevation of the land surface. This hidden component of solution is the innumerable solution cavities of all sizes which extend from very near the land surface to considerable depths--on the order of hundreds of meters.

For example, in the unglaciated Appalachians the volume of carbonate rock removed in solution has probably been considerably larger during warmer interglacial and interstadial periods than during the cooler glacial periods. The changes in the solution rate may not have had proportional effects on the elevation of the land surface, however, because much of the rock would have been dissolved from underground solution cavities. Many solution cavities do not collapse and thus will not affect the elevation of the land surface till they intersect it.

The solution rate of 13.5 m/m.y. (45 ft/m.y.) is meant to be used as only a very rough approximation. It is, however, within the range of solution rates experimentally determined by Trudgill (1973). Using a technique of monitoring the weight loss of limestone tablets inserted under the soil at the soil-bedrock interface, Trudgill concluded that the rate of limestone solution under calcareous brown earths in Ireland is 0.1-1.0 m/m.y. (0.3-3.3 ft/m.y.). Under acid mineral soils, the rate is about 25 m/m.y. (80 ft/m.y.). In addition to solution of limestone at the alluvium-bedrock interface, lowering of alluvial deposits in place is accomplished by collapse of some solution cavities beneath the deposits.

The New River alluvial deposit north of Spruce Run Mountain and across the river from Eggleston, which was interpreted to be a point bar in a previous section (p. 57), is a good example of the way in which solution can alter the vertical dimension of alluvial deposits. Figure 10 shows this deposit in map view and in cross section. Boundaries of this deposit have been interpreted to have retained the form of a meander loop. The cross section shows 70 m (230 ft) of vertical relief on the deposit; the maximum relief developed on the deposit is 98 m (320 ft). The analysis of solution rates discussed in Chapter 5 indicates that the highest part of the deposit has been let down about 120 m (395 ft) since the time it was deposited. Lowering of the deposit and the relief developed on it must have been the result of solution of the underlying Middle Ordovician limestone. If the major factor involved in the lowering and formation of relief on the deposit had been erosion by surface streams, the original boundaries of the deposit would have been more altered.

The effect of carbonate bedrock (as opposed to clastic bedrock) on the preservation of alluvial deposits is illustrated in figure 20. This figure shows the distribution of carbonate and clastic bedrock in the map area in relation to the distribution of Blue Ridge and Valley and Ridge alluvium and second-stage alluvium. Except for two small areas of relatively young second-stage alluvium overlying the upper half of the Martinsburg Formation and a goethite-cemented alluvial deposit overlying the Tuscarora Sandstone, the distribution of clastic bedrock and alluvium is mutually exclusive. The probable reason for the absence of alluvium on clastic bedrock is that it has been removed by surface runoff. The shale and sandstone units in the area have low porosity and permeability, steep slopes, and very thin soils, all of which promote rapid runoff. In addition to the absence of Valley and Ridge, Blue Ridge, or second-stage alluvium on clastic bedrock, there is also very little colluvium, first-stage alluvium, or residuum. Except for

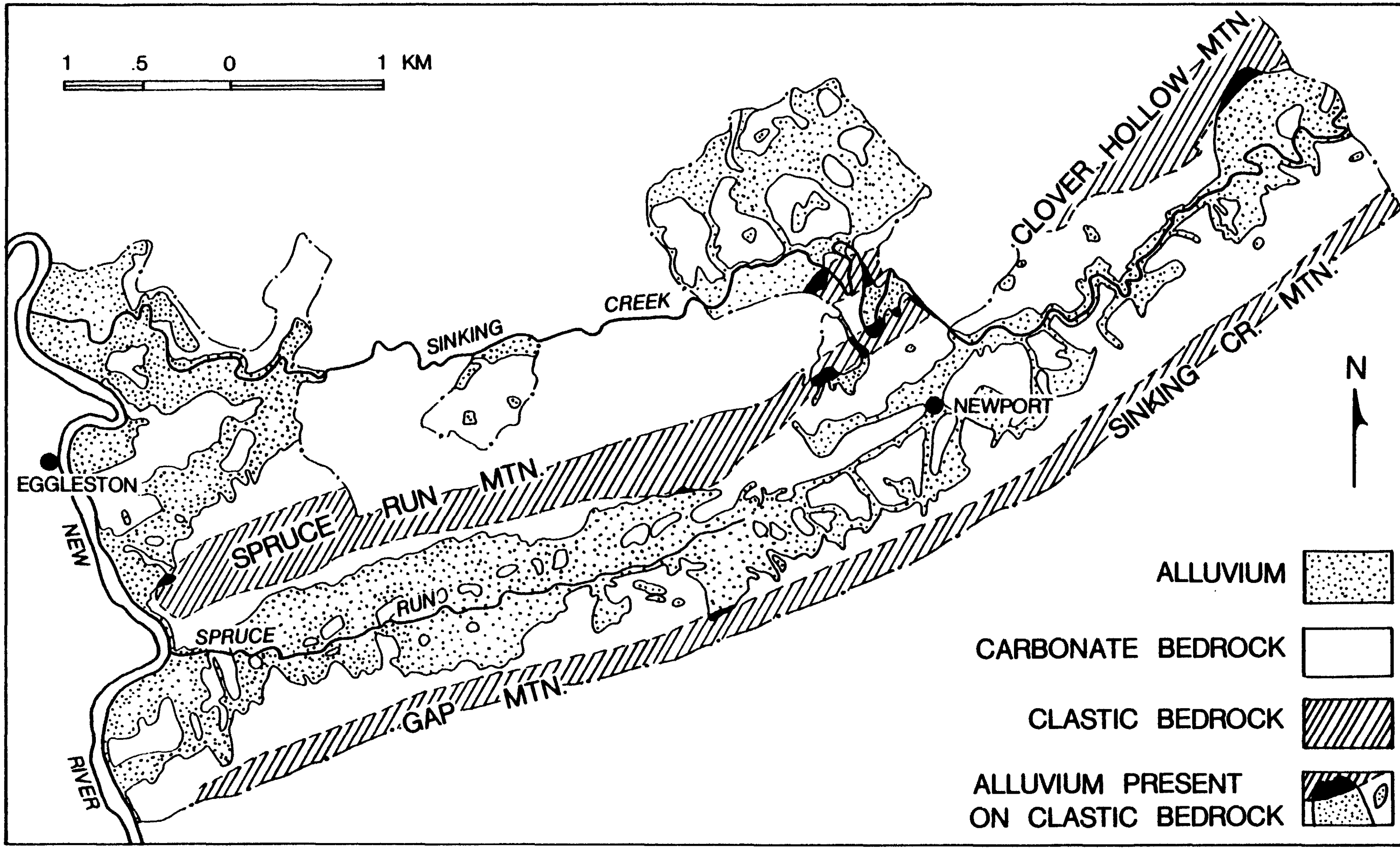


Figure 20.--Areal distribution of alluvial deposits in the study area in relation to clastic versus carbonate bedrock type. Alluvial deposits include Blue Ridge- and Valley and Ridge-derived alluvium and second-stage alluvium. The lower part of the Martinsburg Formation (pl. 1) is included in the carbonate bedrock area.

accumulations of surficial materials in and around ravines, the upper slopes of the ridges are bare, with a thin rocky soil. Occasional torrential rains remove the soil and leaf debris and expose the shales and thin-bedded sandstones of the upper Martinsburg and Juniata Formations on interfluves.

The outcrop areas of clastic rock are confined primarily to the upper and middle slopes of the ridges. It could be argued that the absence of alluvium on clastic bedrock results from the absence of perennial streams on the middle and upper ridge slopes. However, even in the shale-floored subsequent valleys of the Appalachians which do have perennial streams, the volume of older alluvium seems to be less than in carbonate valleys. The only shale units with significant amounts of alluvial and residual cover are units which are in part calcareous shale such as the Lower Cambrian Waynesboro Formation in the Shenandoah Valley (King, 1950). Three areas are described in which alluvium was deposited on clastic bedrock and from which the alluvium has been removed or is in the process of being removed at a faster rate than on adjacent carbonate bedrock.

The first area is on the northwest side of Sinking Creek Mountain and is underlain by the Juniata and Martinsburg Formations (fig. 21). The goethite-cemented alluvial deposit on the south at an elevation of 760 m (2495 ft), underlain by Tuscarora Sandstone, and the alluvial deposit

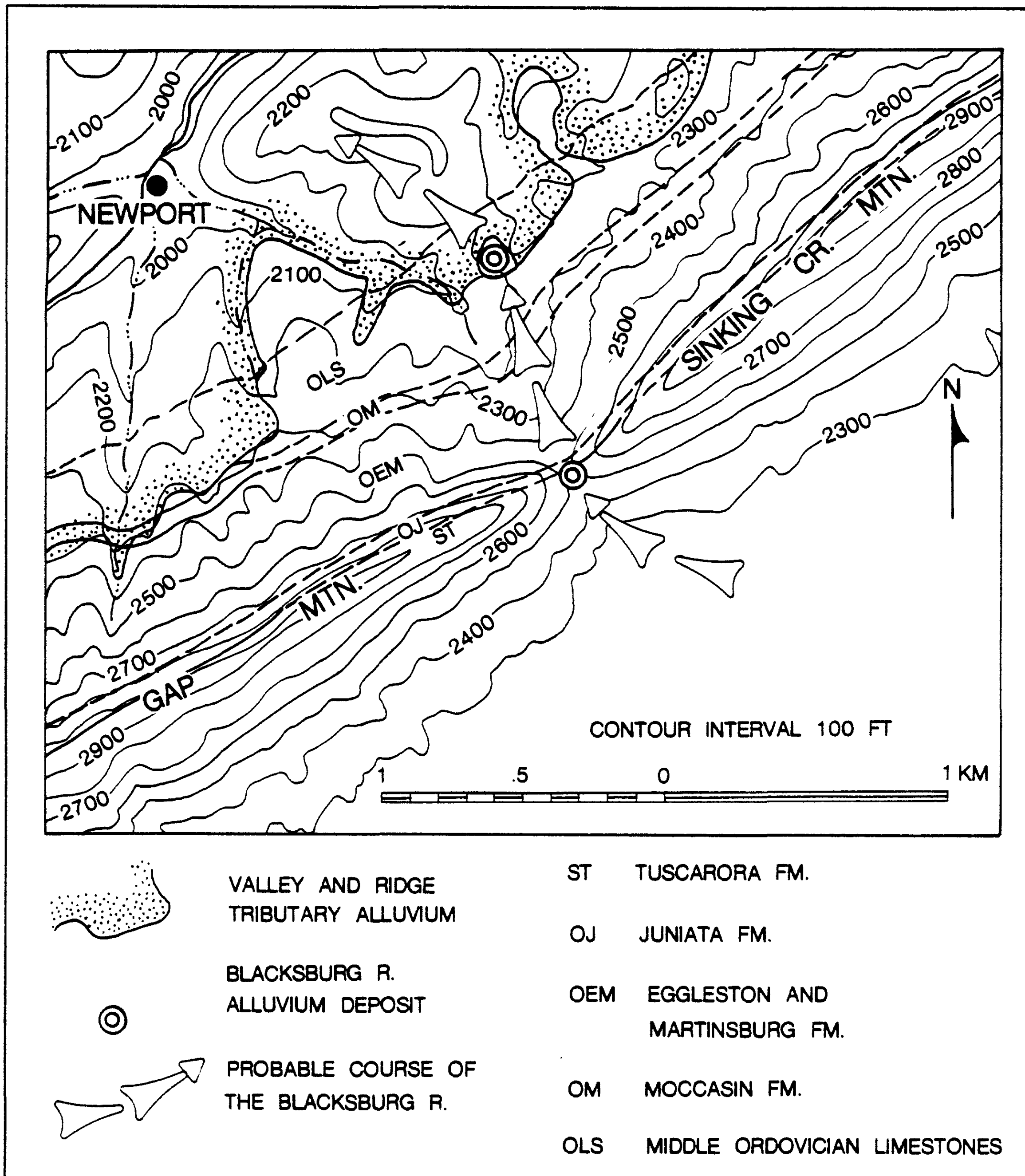


Figure 21.--Map showing areal distribution of alluvial deposits of the Blacksburg River southeast of Newport in relation to bedrock formations.

on the north at an elevation of 678 m (2225 ft), underlain by Middle Ordovician limestone, were both deposited by the Blacksburg River, one of the former tributaries to the New River from the northeast. The zircon:tourmaline ratios of the two deposits (Chap. 5) indicate that they are about the same age. Therefore, the Blacksburg River must have flowed across the belt of clastic bedrock between the deposits. Also, the river was captured shortly after depositing these two deposits (Chap. 6) and must have left channel deposits on the intervening clastic rock. The only surficial material now present in the area between the two deposits is first-stage alluvium. This suggests that the Blue Ridge-derived alluvium of the Blacksburg River has been removed except where it is cemented or overlies carbonate bedrock.

The second example is an alluvial deposit of the New River and is located at the base of Brush Mountain (fig. 22). The deposit overlies both Mississippian clastics and limestone and dolomite of the Cambrian Elbrook Formation at the edge of the Pulaski thrust sheet. On the Mississippian clastic rock, the maximum elevation of the alluvium is approximately 625 m (2050 ft). There the alluvium consists of widely scattered individual quartzose cobbles on slopes and isolated concentrations of quartzose cobbles and pebbles on spurs and saddles. In contrast, the alluvium overlying the Elbrook Formation is as much as 3 m thick

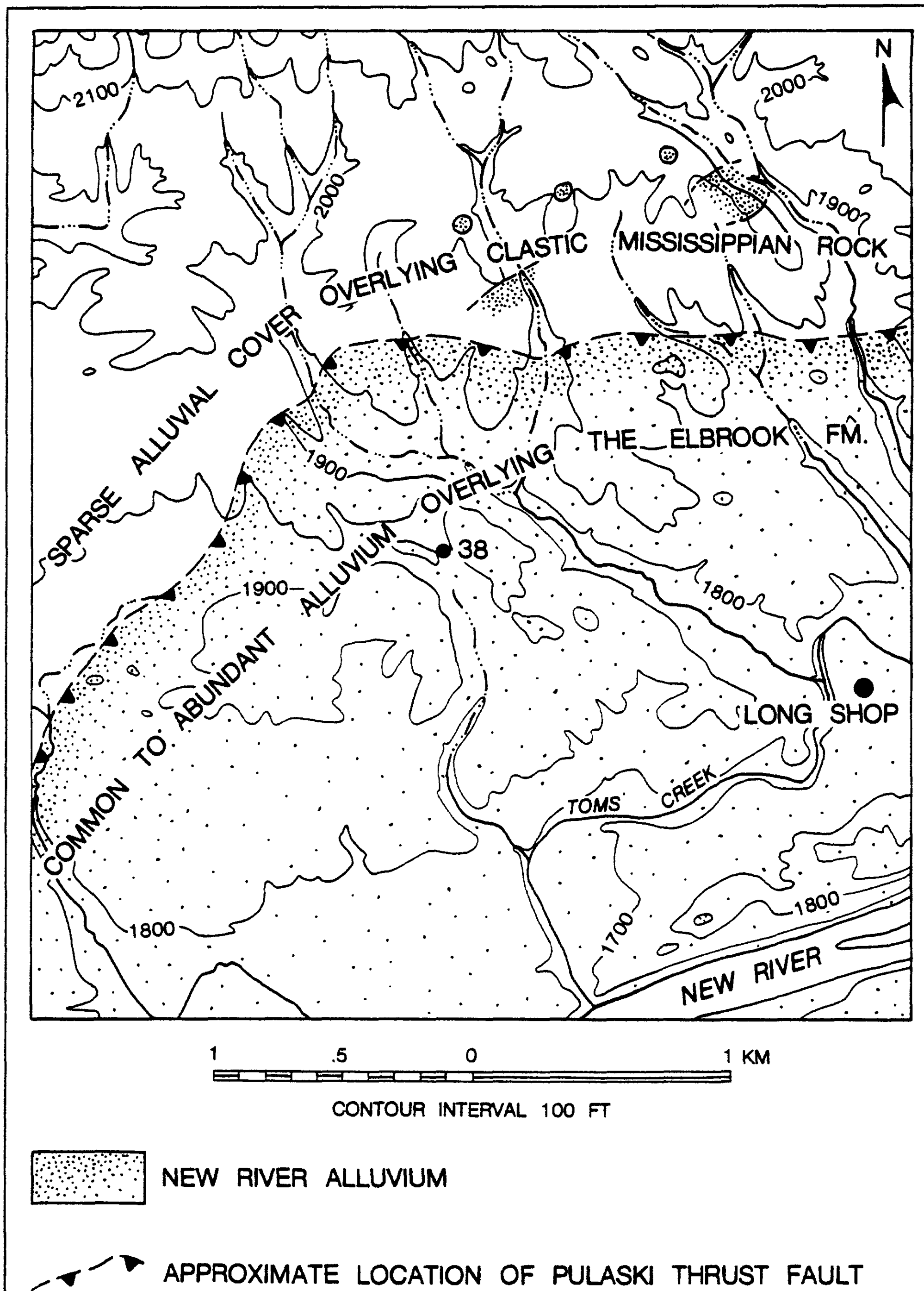


Figure 22.--Map of an area in Montgomery County between Brush Mountain and the New River showing the difference in relative abundances of alluvial deposits on carbonate bedrock of the Pulaski thrust sheet versus those on clastic bedrock of the Saltville fault block.

(sample loc. 38); it consists of sandstone, vein quartz, metaquartzite and other metamorphic rock clasts, and unsorted sand, silt, and clay, and reaches a maximum elevation of 585 m (1920 ft). Reconnaissance mapping indicates that this is a single alluvial deposit. Therefore, the difference in maximum elevation and degree of preservation of the alluvium on the two types of bedrock is interpreted to be the result of two basically different modes of erosion. On clastic bedrock all but the most resistant of the larger clasts have been removed by disintegration and surface runoff. On carbonate bedrock the deposit has been lowered in place approximately 40 m (130 ft), with minimal reworking of the alluvium by surface streams. The metamorphic rock clasts in this part of the deposit are so highly weathered that they crumble to powder when touched. If the alluvium had been reworked to the lower elevation, these metamorphic clasts would not have survived.

The third area is the outcrop belt of the Upper Cambrian Copper Ridge Formation of the Knox Group on the northwest side of Spruce Run. Most of Spruce Run valley is blanketed with a layer of Blue Ridge-derived alluvium deposited by the tributaries from the northeast, reworked Blue Ridge-derived alluvium, and alluvium deposited by Spruce Run. However, the blanket of alluvium is conspicuously absent from the low knolls underlain by the Copper Ridge

Formation (pl. 2). Because the outcrop belt of the Copper Ridge was almost certainly covered with alluvium (and still is, in places), as was the rest of Spruce Run valley, preferential removal of the alluvium is interpreted to be the result of the greater component of clastic material in the unit than that in the stratigraphically higher and lower carbonate units. The Copper Ridge is a feldspathic sandstone and, although it is not a very resistant unit, mechanical weathering and surface runoff are probably more important in its erosion than in the erosion of the surrounding carbonate units.

Similar relationships can be seen in other areas where both bedrock and older alluvium have been mapped. For example, Bartholomew and Lowry (1979) included a Quaternary unit called Terrace deposits in their geologic map of the Blacksburg, Virginia, 7 1/2-minute quadrangle. The terrace deposits are small (0.1-0.5 km across) elliptical to rounded patches of Blue Ridge-derived alluvium. They occur at elevations of 573-658 m (1880-2160 ft) and were probably deposited by the Blacksburg River. Although both clastic and carbonate bedrock lithologies are present in the quadrangle, the terrace deposits overlie only carbonate bedrock. A possible exception is the Cambrian Rome Formation which underlies a number of the terrace deposits. The Rome was described (Bartholomew and Lowry, 1979) as

". . . interbedded . . . phyllitic mudstone, fine grained sandstone and siltstone and . . . fine grained dolomite. . . . The . . . dolomite beds are up to 9.2 m thick." It is not known whether the terrace deposits are preferentially preserved above the dolomite beds of the Rome Formation. This would be an interesting test of the hypothesis that surficial materials tend to be preserved primarily over carbonate bedrock.

The preceding examples show that the absence of alluvium on clastic bedrock can be attributed to mechanical weathering and surface runoff, and that the preservation of alluvium on carbonate bedrock can be attributed to the relatively larger role of chemical weathering, and to the predominance of subsurface drainage. The erosion of carbonate rock is accomplished by a large component of solution, resulting in high secondary porosity and permeability, which in turn results in subsurface drainage. The relative effects of surface and subsurface drainage were seen in Spruce Run valley following a cloudburst in June 1973. The southeast slope of Spruce Run Mountain, underlain by the Martinsburg Formation, had been almost completely stripped of organic debris and soil by sheet wash. However, there was no evidence of sheet wash or of even very much erosion farther down the slope on carbonate bedrock. The evidences of erosion on carbonate bedrock, although fairly impressive, were confined to small valleys normally occupied by intermittent streams. Interfluves covered by alluvium and residuum were not eroded by the storm because the water was able to enter the subsurface drainage system.

A final consideration in the relative degree of preservation of alluvium overlying clastic and carbonate bedrock is the effect of slope. In general, the slopes on clastic rock are steeper than those on carbonate rock. Distribution of slopes exceeding 33 percent (18.4°) in the map area is shown in figure 23 relative to the outcrop areas of clastic and carbonate rock. It is apparent from this sketch that most of the areas having steep slopes are confined to the outcrop belts of clastic rock, although some steep slopes are also present in the carbonate terrain. Figure 23 also shows the distribution of alluvium. A previous sketch (fig. 20) shows that alluvium and clastic bedrock were essentially mutually exclusive, but figure 23 shows that alluvium and slopes greater than 33 percent are not mutually exclusive. This is a strong indication that the preservation of alluvium is more a function of bedrock lithology than of slope.

Alluvium in the Subsurface

Thus far the discussion of alluvium has dealt only with surface deposits. However, the solubility of carbonate rock and the presence of subsurface drainage through sizable

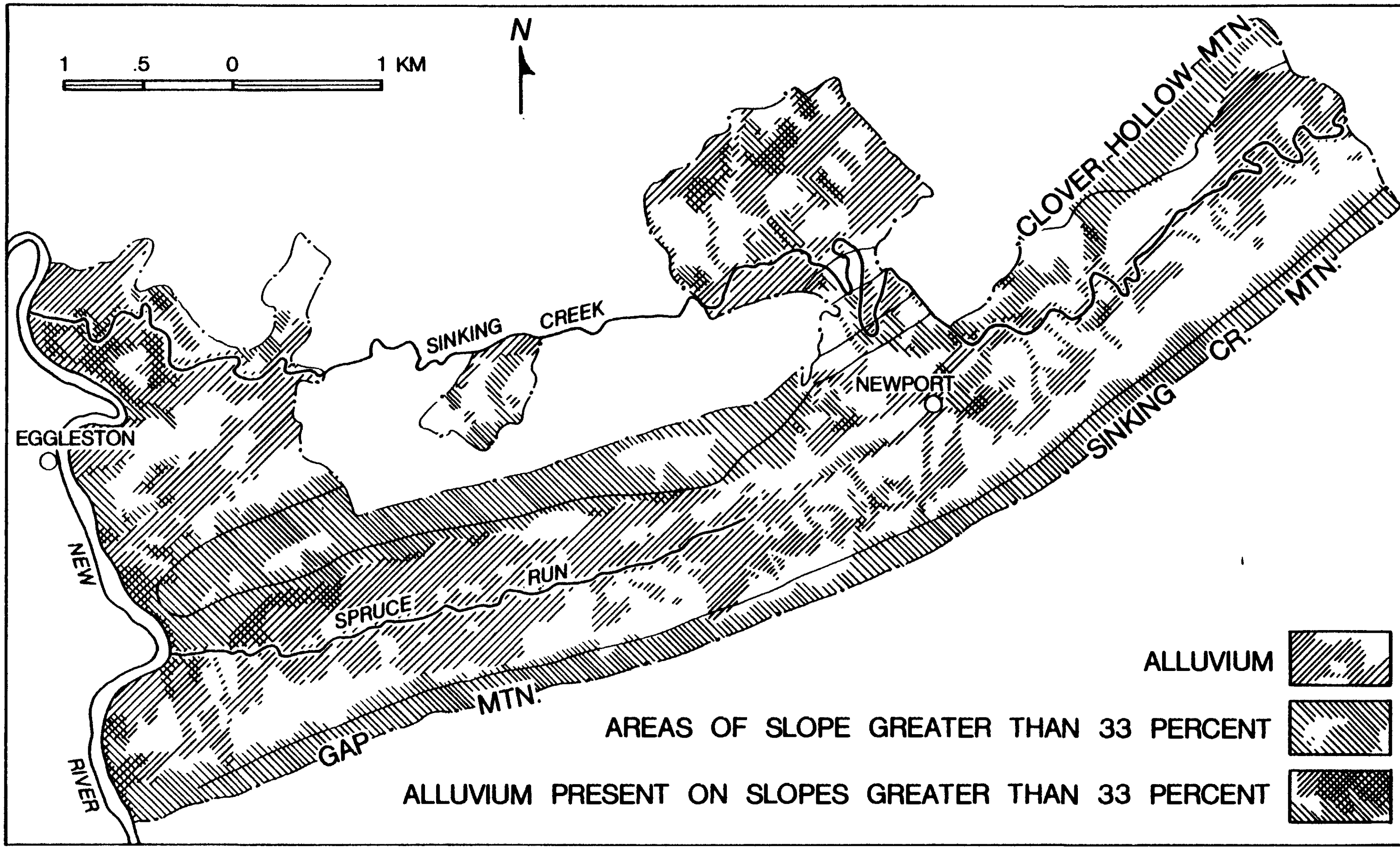


Figure 23.--Areal distribution of alluvial deposits in the study area in relation to slopes of greater than 33 percent. The boundaries between areas of clastic and carbonate bedrock are the same as in figure 20 and are indicated by solid lines. Alluvial deposits include Blue Ridge- and Valley and Ridge-derived alluvium and second-stage alluvium.

solution networks assure that there will be appreciable amounts of alluvium underground as well as at the surface. Cooper (1961, p. 9) mentioned the presence of colluvium and alluvium in a fissure about 245 m (800 ft) below the land surface in a limestone mine near Kimballton, 6 km northeast of Pearisburg. Within the study area, vein quartz and metaquartzite cobbles are present in a travertine-cemented fissure fill exposed in the abandoned Ripplemead Limestone Company quarry on the west side of the New River next to the old U.S. 460 bridge east of Pearisburg. The source of the quartzose cobbles is a New River alluvial deposit above the quarry. The cobbles are present from the top of the fissure to the quarry floor (a depth of about 15 m (50 ft)) and probably deeper.

In addition to being washed into fissures, alluvium is also transported underground in subhorizontal caverns. An alluvial deposit in a horizontal passage in Pig Hole, about 1.0 km south of Giles County road 700, south of Salt Pond Mountain, consists of imbricately bedded layers of discoidal Rose Hill cobbles and ovoid Tuscarora-Keefer-Juniata cobbles separated by beds of poorly sorted pebbly sand, silt, and clay.

Subsurface alluvial deposits have a history of accumulation and preservation similar to that of surface deposits. The alluvium is transported and deposited primarily during periods of greater than average flow velocity. Remnants of the alluvial deposits are left behind as a result of subsurface and surface stream capture and continual lowering of the water table in response to surface erosion. The principal difference in the two depositional environments is the retention of a much higher percentage of clay-size sediment in the subsurface drainage system. Clay is winnowed out in surface streams, but it tends to be trapped in the restricted solution passages occupied by subsurface streams. Another related difference is the absence of abundant boulders in subsurface alluvium. Most of the conduits into the subsurface drainage system are too small to admit boulder-size material.

Much of the alluvium in the subsurface probably eventually re-enters the surface drainage system in either of two ways: by the intersection, through erosion, of abandoned subsurface channels with the land surface or by transportation underground to springs. Alluvial deposits which can be related to each of these mechanisms are present in the study area.

A Valley and Ridge-derived alluvial deposit on the north side of U.S. 460, 0.8 km west of Maybrook (sample loc. 17) is interpreted to be a cave deposit that has been exposed by lowering of the surrounding land surface. This interpretation is based on the occurrence of abundant, highly polished chert pebbles in the deposit, which is taken to be an indication of deposition in a cave environment. A comparison of the chert clasts in Tawneys Cave (north of Giles County road 604, 0.3 km east of the junction with road 700, sample locality 81) with clasts in modern surface streams showed that much of the chert in the cave is highly polished. In contrast, chert in surface streams is often smooth and rounded, but no highly polished chert pebbles have been found.[1] The high polish on chert in caves may develop from abrasion with clay and silt-size particles. During flood conditions many constricted cave passages are completely filled with water, and, in conjunction with the high percentage of clay and silt in caves, it seems likely that parts of cave systems may act as large polishing tumblers.

The interpretation that this alluvium was deposited in a cave is significant in regard to the age of the deposit. Although the lithology of the deposit is megascopically identical to that of surrounding alluvial deposits (with the exception of the occurrence of polished chert pebbles), the cave deposit may be considerably older than the surrounding

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[1]This comparison was suggested by G. Grender (oral commun., 1973).

alluvial deposits. Estimates of the relative ages of alluvium based on the weathering of zircon as discussed in Chapter 5 indicate that this cave deposit may be on the order of 3 m.y. older than other Valley and Ridge-derived alluvium at similar heights above Sinking Creek.

A second example involves the resurgence of subsurface alluvium into Sinking Creek. The alluvium in the channel of this stream has been sampled at a dozen localities along its course, over a distance of 25 km (pl. 2, table 4, appendix. The gross lithology of the alluvium is typical of Valley and Ridge-derived alluvium along the entire course, but where Sinking Creek passes Tawneys-Smoke Hole cave and receives discharge from springs, the heavy-mineral assemblage changes. Figure 24 shows the heavy-mineral percentages of twelve samples of modern Sinking Creek alluvium and of a sample collected from the stream in Tawneys cave (sample 81). The samples are arranged in order from upstream, at the top of figure 24, to downstream, at the bottom, and locations of the springs which enter Sinking Creek from the Tawneys-Smoke Hole cave system are indicated.

The amount of discharge from the springs is difficult to estimate because the spring from Tawneys cave enters Sinking Creek below the water level of the creek. There is surface-water flow from Smoke Hole cave, but there may also be some subsurface discharge--as there is from Tawneys cave.

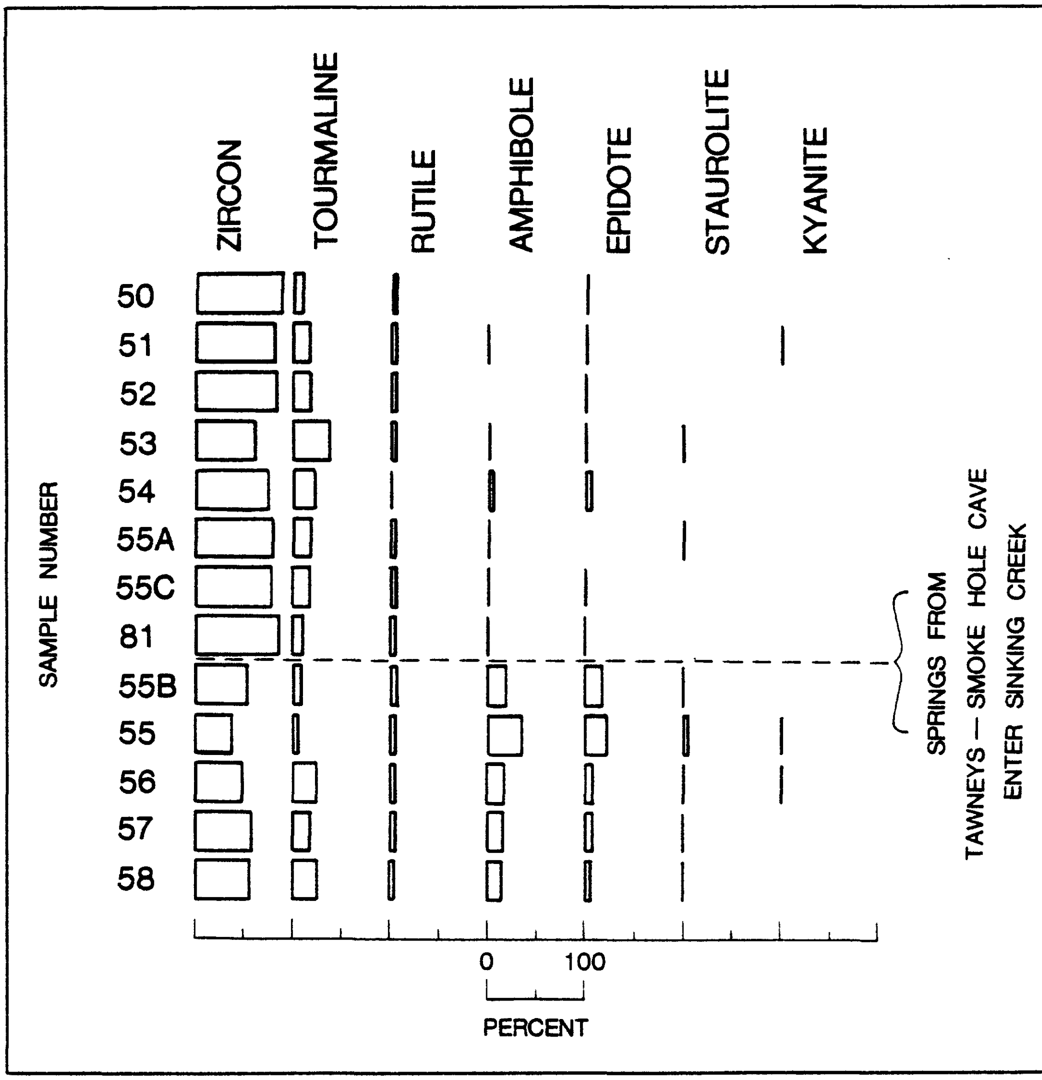


Figure 24.--Percentages of heavy-mineral species present in modern Sinking Creek alluvium arranged in order from upstream (sample No. 50) to downstream (sample No. 58). For sample locations, see plate 2.

A very rough estimate is that the nonflood-stage discharge from the springs is equal to perhaps 10 percent of the discharge of Sinking Creek.

Upstream from the cave system (and in the upper levels of Tawneys Cave) the heavy-mineral assemblages are very mature and consist of an average of 78 percent zircon, 18 percent tourmaline, 3 percent rutile, and 1 percent or less amphibole, epidote, staurolite, and kyanite. Immediately downstream from the area in which the springs from the cave system enter Sinking Creek, the percentages of amphibole and epidote increase from 1 percent or less to about 25 percent amphibole and 20 percent epidote. Downstream from the springs to near the mouth of Sinking Creek, the amounts of amphibole and epidote remain fairly constant at about 15 percent amphibole and 7 percent epidote.

The spatial coincidence of the increase in the amounts of amphibole and epidote in the alluvium with the locations of springs leads to the conclusion that these minerals enter surface drainage from the Tawneys-Smoke Hole cave system. The source of the amphibole and epidote was probably the Blacksburg River with headwaters in the Blue Ridge, which flowed to the New River through the gap between Clover Hollow Mountain and Spruce Run Mountain (Chap. 6). Some of the alluvium transported by this river entered the subsurface drainage system, has remained in place, and is periodically flushed out of the Tawneys-Smoke Hole cave system during floods. The abundance of amphibole and epidote in the sediment from the springs as compared to their small percentage in the alluvium of the stream which flows through the upper levels of Tawneys Cave suggests that the relatively unstable amphibole and epidote are preserved in impermeable clays and silts in the lower parts of the cave system--probably below the water table. Blatt and Sutherland (1969), in a study of contemporaneous shale and sandstone beds of the Texas Gulf Coast, found that a greater percentage of unstable heavy-mineral species was preserved in the shale. They interpreted this to be the result of the lower permeability of shale and of less interstratal solution. The large amount of clay in caves, therefore, provides an excellent environment for the preservation of heavy minerals.

In addition to the probability that large percentages of amphibole and epidote indicate the presence of alluvium derived from the Blue Ridge, the relative percentages of these two minerals give an indication of the depositional history of the alluvium. The greater amount of amphibole (25 percent) as compared to epidote (20 percent) suggests that much of the original alluvium deposited in the caves was derived directly from the Blacksburg River--not from smaller streams which were reworking older alluvial deposits.

Analysis of heavy-mineral assemblages in New River alluvium (Chap. 5, table 4, figs. 25, 26) shows that both amphibole and epidote are unstable in the subaerial environment but that amphibole is considerably less stable than epidote. Alluvium of the modern New River contains about 60 percent amphibole and 30 percent epidote. In older alluvial deposits of the New River (samples 61, 74, 75, 77), however, the relative abundance of amphibole versus epidote is reversed (about 25 percent epidote and 10 percent amphibole). The oldest alluvial deposits, which include all the deposits of the Blacksburg River and two sampled deposits of the New River (19 and 21), contain less than 10 percent combined amphibole and epidote.

Thus, both the combined abundance of amphibole and epidote and the greater abundance of amphibole as compared to epidote suggest that most of the alluvium in the caves was derived directly from the Blacksburg River and did not undergo any intermediate subaerial weathering.

Estimates of the relative ages of alluvium (Chap. 5) indicate that the Blacksburg River was captured and that its channel in the area of Tawneys-Smoke Hole cave was abandoned about 6 m.y. ago. Preservation in the subsurface drainage system for 6 m.y. of unstable heavy minerals suggests that studies of the heavy minerals in caves may provide important clues to former drainage patterns in other parts of the Appalachians.

CHAPTER 5

HEAVY MINERALS

The nonopaque heavy minerals present in alluvium of the modern streams, in older alluvial deposits, and in colluvium and residuum were identified and studied to determine the effects of provenance, transport distance, and age on the heavy-mineral assemblages. A total of 57 samples were analyzed. Sample locations are shown in figures 2 and 4 and on plate 2. The percentages of heavy-mineral species present in each sample are given in table 4.

Sampling and Preparation

Samples of smaller than cobble size materials weighing 3-5 kg were collected. Most of the samples of older alluvial deposits, colluvium, and residuum were taken from road cuts at least 1 m high. Beds of silt to pebble-size material were sampled by means of several randomly located short channel samples at each location. This was done to homogenize the variability produced by fluviatile bedding and sorting. Some of the alluvial deposits have no vertical exposure. These deposits were sampled by digging several shallow holes over an area of about 4000 m^2 and collecting the sediment about 0.5 m below the surface.

Samples from the smaller of the modern streams were collected from the stream bed at several points across and

Table 4.--Heavy-mineral assemblages of samples of surficial materials and modern alluvium, New River drainage basin, North Carolina and Virginia. Specific locations given in appendix

[Leaders (--) indicate 0 percent; tr, 0 to 1 percent.]

Type of surficial material	Sample number	Percentages of heavy-mineral species: Zircon	Tourmaline	Rutile	Amphibole	Epidote	Staurolite	Kyanite	Garnet	Chlorite	Monazite	Other (tr to 1)	Z/T [1]	Percent metamict zircon	mZ/nZ [2]	Number grains counted
Older alluvium-	10	49	44	2	1	1	2	--	--	--	--	--	1.1			126
Do----------	11	62	32	5	--	tr	tr	--	--	tr	--	--	2.0	57	1.3	238
Colluvium------	12	73	24	3	tr	1	--	--	--	--	--	--	3.1	40	0.7	359
Residuum-------	13	81	11	2	--	--	4	--	--	2	--	--	7.6	68	2.1	47
Older alluvium-	14	45	52	1	1	--	1	--	--	--	--	--	0.9	41	0.7	113
Older alluvium-	15	38	61	1	--	--	1	--	--	--	--	--	0.6	38	0.6	224
Do----------	16	39	59	2	--	tr	tr	--	--	--	--	--	0.7	34	0.5	246
Do----------	17	39	59	1	--	--	--	--	--	--	--	--	0.7	47	0.9	76
Residuum-------	18	71	29	--	--	--	--	--	--	--	--	--	2.5			7
Older alluvium-	19	35	20	26	3	2	10	4	--	--	--	--	1.7	51	1.0	252
Older alluvium-	20	47	35	12	--	2	4	tr	--	--	tr	--	1.4	45	0.8	205
Do----------	21	32	40	16	4	3	5	tr	tr	--	--	--	0.8	38	0.6	814
Do----------	22	30	65	2	1	1	1	--	--	--	--	--	0.5	38	0.6	145
Do----------	24	41	51	5	1	2	1	--	--	--	--	--	0.8	27	0.4	297
Residuum-------	25	66	30	3	--	1	--	--	--	--	--	--	2.2	43	0.8	71
Older alluvium-	26	35	57	2	2	3	--	--	--	--	--	--	0.6			88
Do----------	27	22	78	--	--	--	--	--	--	--	--	--	0.3	22	0.3	37
Do----------	28	26	68	2	1	2	1	--	--	tr	--	--	0.4	36	0.6	231
Modern alluvium	30	9	tr	6	53	30	1	--	tr	--	tr	sphene	27.0	67	2.0	293
Do----------	31	15	tr	6	52	24	--	--	2	--	--	apatite	38.0	71	2.5	251
Modern alluvium	32	11	1	9	48	28	tr	tr	1	1	tr	pyroxene	8.7			234
Do----------	33	tr	1	1	68	23	1	--	3	1	1	apatite	0.3			243
Do----------	34	1	1	2	68	25	tr	--	2	tr	--	--	1.0	76	3.2	195
Do----------	35	8	1	2	43	45	1	--	--	--	--	--	6.7	79	3.7	244
Do----------	36	4	1	2	66	24	1	1	tr	--	tr	sillimanite	2.8	68	2.1	307
Modern alluvium	37	1	tr	tr	73	23	1	--	1	tr	--	--	4.0	58	1.4	268
Older alluvium-	38	49	6	31	2	7	4	1	--	tr	--	--	8.3	63	1.7	800
Modern alluvium	39	7	1	3	61	25	--	2	2	tr	--	--	6.5	70	2.3	195
Do----------	40	73	18	5	tr	3	--	--	--	--	--	--	4.0	45	0.8	191
Do----------	41	81	13	4	1	tr	--	--	--	--	--	--	6.3	47	0.9	216

1 Z/T (ratio of zircon to tourmaline) calculated from numbers of grains, not from percentages.
2 mZ/nZ, ratio of percentage intermediate and metamict zircon to percentage normal zircon.

Table 4.-- Heavy-mineral assemblages of samples of surficial materials and modern alluvium, New River drainage basin, North carolina and Virginia. Specific locations given in appendix--Continued

Type of surficial material	Sample number	Percentages of heavy-mineral species											Z/T [1]	Percent metamict zircon	mZ/nZ [2]	Number grains counted
		Zircon	Tour-maline	Rutile	Amphi-bole	Epidote	Stau-rolite	Kyanite	Garnet	Chlorite	Mona-zite	Other (tr to 1)				
Modern alluvium	42	66	28	4	1	1	--	--	--	--	--	--	2.4	53	1.1	372
Do----------	43	70	21	3	3	2	tr	--	--	--	--	--	3.4	56	1.3	343
Do----------	44	89	5	5	--	1	--	--	--	--	--	--	16.4	51	1.0	777
Do----------	45	85	8	4	--	2	tr	--	--	--	--	--	10.1	54	1.2	832
Do----------	50	87	9	2	--	1	--	--	--	--	--	--	9.4	41	0.7	300
Modern alluvium	51	80	16	3	tr	tr	--	tr	--	--	--	--	4.9	42	0.7	616
Do----------	52	82	16	2	--	tr	--	--	--	--	--	--	5.2	47	0.9	446
Do----------	53	60	36	2	1	tr	tr	--	--	tr	--	--	1.7	41	0.7	474
Do----------	54	73	22	1	2	2	--	--	--	--	--	--	3.3	44	0.8	335
Do----------	55	36	3	4	33	22	2	1	--	--	--	--	11.4	45	0.8	223
Modern alluvium	55A	79	18	2	1	--	tr	--	--	--	--	--	4.5	53	1.1	566
Do----------	55B	52	7	4	19	18	tr	--	--	--	--	--	7.4			526
Do----------	55C	78	16	5	1	1	--	--	--	--	--	--	5.0			403
Do----------	56	49	24	2	16	7	tr	1	tr	--	--	--	2.0	51	1.0	865
Do----------	57	58	19	3	15	6	tr	--	--	--	--	--	3.1	45	0.8	809
Modern alluvium	58	54	26	2	13	5	1	--	--	--	--	--	2.1	55	1.2	471
Do----------	60	9	1	3	60	22	2	tr	3	tr	--	--	6.7	67	2.0	230
Older alluvium-	61	28	7	19	14	23	6	2	--	--	tr	*	4.0	57	1.3	341
Do----------	65A	60	34	5	tr	1	tr	--	--	--	--	--	1.8	49	1.0	509
Do----------	66	62	32	3	tr	2	tr	tr	--	--	--	--	1.9	36	0.6	859
Older alluvium-	74	23	4	21	11	34	5	2	--	--	--	--	5.7	61	1.6	342
Do----------	75	23	5	19	9	36	5	2	--	tr	--	--	4.4	61	1.6	520
Do----------	77	38	8	30	5	9	8	2	--	--	--	--	4.7	59	1.4	929
Do----------	78	68	21	7	--	2	2	tr	--	tr	--	--	3.3			595
Do----------	79	75	22	2	tr	tr	tr	--	--	--	--	--	3.4	34	0.5	926
Older alluvium-	80	74	24	2	--	--	--	--	--	--	--	--	3.1	34	0.5	679
Modern alluvium	81	84	10	4	tr	1	--	--	--	--	--	--	8.2			495

1 Z/T (ratio of zircon to tourmaline) calculated from numbers of grains, not from percentages.
2 mZ/nZ, ratio of percentage intermediate and metamict zircon to percentage normal zircon.
* chlorotoid, andalusite.

along the channel over a 5- to 10-m^2 area. Samples from deeper streams were collected from sandy banks adjacent to the streams.

Heavy minerals were separated from the 64- to 125-μ-size fraction of the samples using tetrabromoethane or bromoform adjusted to a specific gravity of about 2.8. After removal of the magnetic minerals with a hand-held magnet, grain mounts of the remaining heavy minerals were prepared.

The nonopaque heavy minerals were point counted by variations of the traverse method, depending on the number of grains present on a slide. If there was a large number of grains, only the grains intersected by the crosshair were counted in each traverse. On slides with fewer grains, every grain within the field of view in each traverse was counted. The methods were determined to be statistically equivalent by point counting a number of samples twice, using both methods. In each case, the percentages of mineral species counted by the two methods were within 5 percent of each other. The traverses were adjusted to give uniform coverage of each slide and to give a total count of at least 150 grains. Some samples contained very few heavy minerals, and in these samples every transparent grain on the slide was counted. Muscovite, biotite, soil chlorite, and opaque minerals were not counted.

Heavy-Mineral Assemblages

The total amount of transparent heavy minerals in each sample varies considerably among samples, depending on the type of surficial material. The percentages by weight of the heavy-mineral fractions were not calculated because the samples are not representative of the complete range of particle sizes present in the deposits. In broad terms of relative abundance of heavy minerals, however, the various types of surficial materials can be ranked as follows, from greatest amount of heavy minerals to least: (1) modern New River alluvium; (2) older alluvium of the New and Blacksburg Rivers; (3) modern Valley and Ridge tributary alluvium, and colluvium derived from sandstone units; (4) older alluvium of the Valley and Ridge tributaries; and (5) residuum overlying shale and carbonate units.

This ranking of surficial materials, based on the relative abundance of transparent heavy minerals, is approximately the same ranking which can be obtained from analysis of the degree of maturity of the heavy-mineral assemblages. Both reflect the amount of amphibole and epidote present in the samples.

The amount of transparent heavy minerals in surficial materials and the maturity of heavy-mineral assemblages in the subaerial environment depend on three factors: time, climate, and source. For the New River alluvium, a change in the source area as an explanation of the greater maturity of the heavy minerals in the older alluvium relative to the modern alluvium does not seem likely. The remaining two factors--time and climate--are both important in the weathering of heavy minerals. It is the general consensus of opinion among geologists that time is an important factor in all weathering processes, including the degradation of unstable heavy minerals such as ferromagnesian silicate minerals. Therefore, in terms of time alone, it is reasonable that the older New River alluvium contains a smaller and more mature heavy-mineral assemblage than does the modern alluvium.

For a number of reasons, it is harder to assess the effects that previous climates have had on the maturity of heavy minerals in the older alluvial deposits, although the Cenozoic climate of eastern North America is known in broad outline. Most evidence points to a thermal maximum in the late Eocene or early Oligocene, followed by a more or less steady decrease of mean annual temperature and culminating in the Pleistocene glacial stages (Berry, 1937; Dorf, 1960). In a series of sketches of climatic zones drawn for different time periods in the Cenozoic, Dorf showed the following climates for the study area: tropical to subtropical in the late Eocene-early Oligocene, subtropical to warm temperate in the late Oligocene-late Pliocene, tundra to subarctic in Pleistocene glacial stages, and subtropical in interglacial stages. The appearance of extensive grasslands in the central plains region during the Pliocene is evidence for drier conditions beginning at that time (Berry, 1937).

The main difficulty in deducing the effect of climate on heavy-mineral assemblages (or in deducing past climates from heavy-mineral assemblages) is separating climatic effects from other effects, such as time, history of the alluvium following deposition, climatic differences between the source area and the deposition area, tectonic movements in the source area, and numerous hydrologic factors.

The sampling program of the present study was inadequate to separate these conflicting effects. Therefore, lacking clear evidence to the contrary, it is assumed that the greater maturity of the heavy-mineral assemblages of the older alluvial deposits is mainly a function of time.

New River

The headwaters of the New River are in the Southern Blue Ridge Province of North Carolina and Virginia (fig. 2). This area consists of Precambrian metasedimentary, plutonic, and volcanic rocks in the greenschist and amphibolite facies (through kyanite grade) and the relatively unmetamorphosed sandstone and shale of the Chilhowee Group of late Precambrian and Early Cambrian age (Rankin and others, 1972; Espenshade and others, 1975). The river leaves the Blue Ridge near Austinville, Virginia, and flows northwestward across Paleozoic sedimentary rocks of the Valley and Ridge and Appalachian Plateau Provinces.

The heavy-mineral assemblages contained in the samples of New River alluvium are shown in figure 25. The modern alluvium contains an average of 85 percent amphibole and epidote-group minerals. Zircon and rutile are present in minor amounts. The rest of the assemblage consists of rare to trace amounts of tourmaline, staurolite, kyanite, garnet, chlorite, sillimanite, apatite, monazite, pyroxene, and sphene. Figure 25 shows that there is no apparent dilution or other systematic variation of this assemblage after the New River leaves the Blue Ridge and flows across the relatively mature sedimentary rocks of the Valley and Ridge Province.

The heavy-mineral assemblages of older New River alluvial deposits, also shown in figure 25, are predictably more mature than the modern alluvium. The older alluvium contains an average of 23 percent amphibole and epidote, 33 percent zircon, 23 percent rutile, 13 percent tourmaline, 6 percent staurolite, 2 percent kyanite, and less than 1 percent chlorite, chloritoid, andalusite, monazite, and garnet.

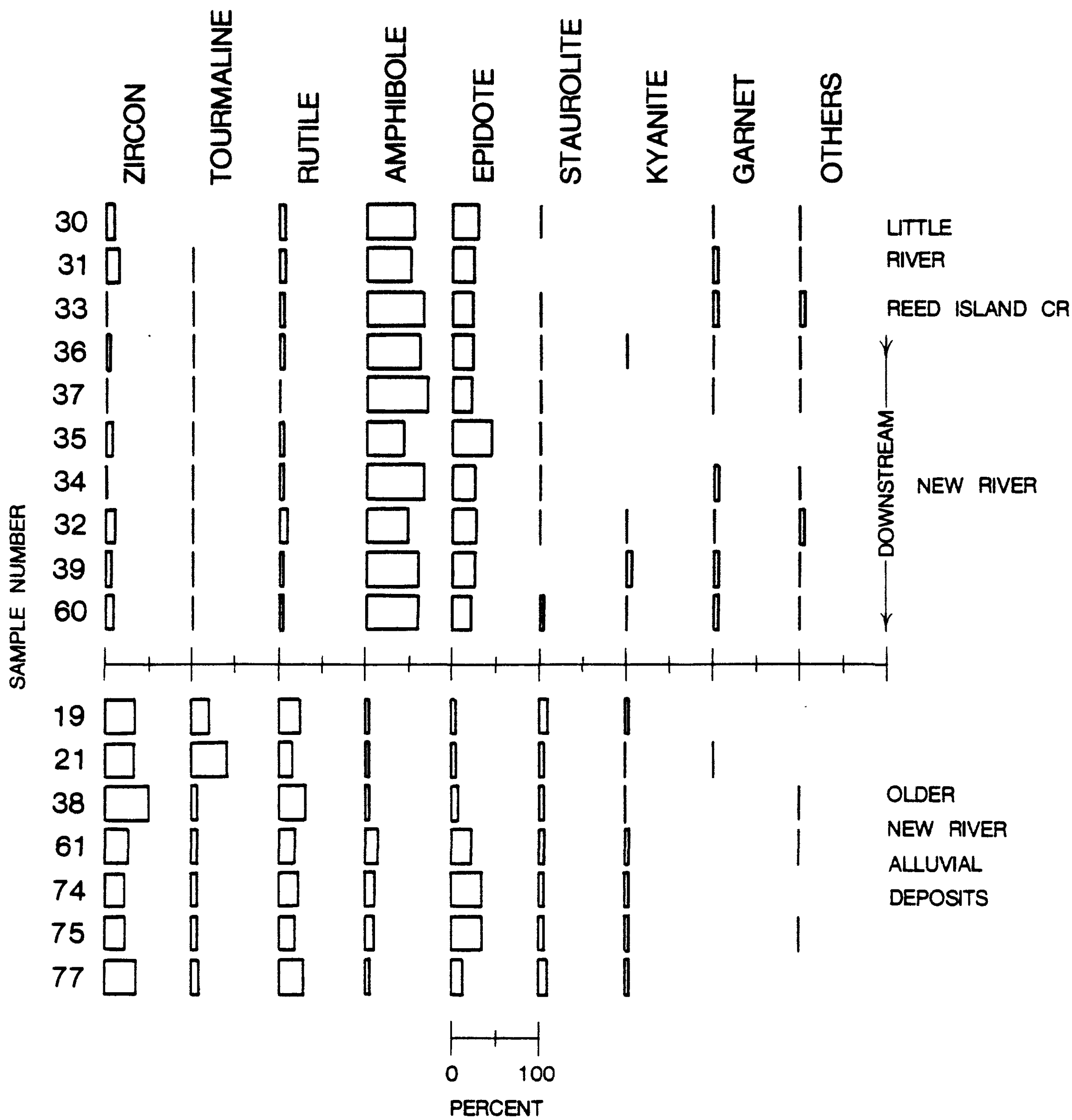


Figure 25.--Heavy-mineral assemblages of modern New River alluvium and older New River alluvial deposits.

These same data are shown in figure 26, where they are plotted against the height of the alluvial deposits above the New River. The points at zero meters are the averages of the modern New River alluvium samples for each mineral species. The points on the graphs show a considerable amount of scatter, as is normal with heavy-mineral analyses, but there is a general trend toward increasing maturity of the heavy-mineral assemblages with increasing height (and presumably increasing age) above the New River.

The sharp increases in the amounts of zircon and rutile in the older alluvium as compared to the modern alluvium are probably artifacts of the sharp drop in the amount of amphibole present in the older alluvium. Amphibole apparently weathers very rapidly. Similarly, the increase in the amount of tourmaline above 150 m could be, in part, an artifact of the decrease in the amount of epidote. The last graph in figure 26 shows the ZTR maturity index of Hubert (1962). As in the other graphs, there is considerable scatter of the points, but there appears to be a general increase in the maturity of the assemblages with no obvious breaks in the slope of the trend.

Blacksburg River

Because the former Blacksburg River was captured by the Roanoke River, the original location and extent of its drainage basin are not known. However, the common presence

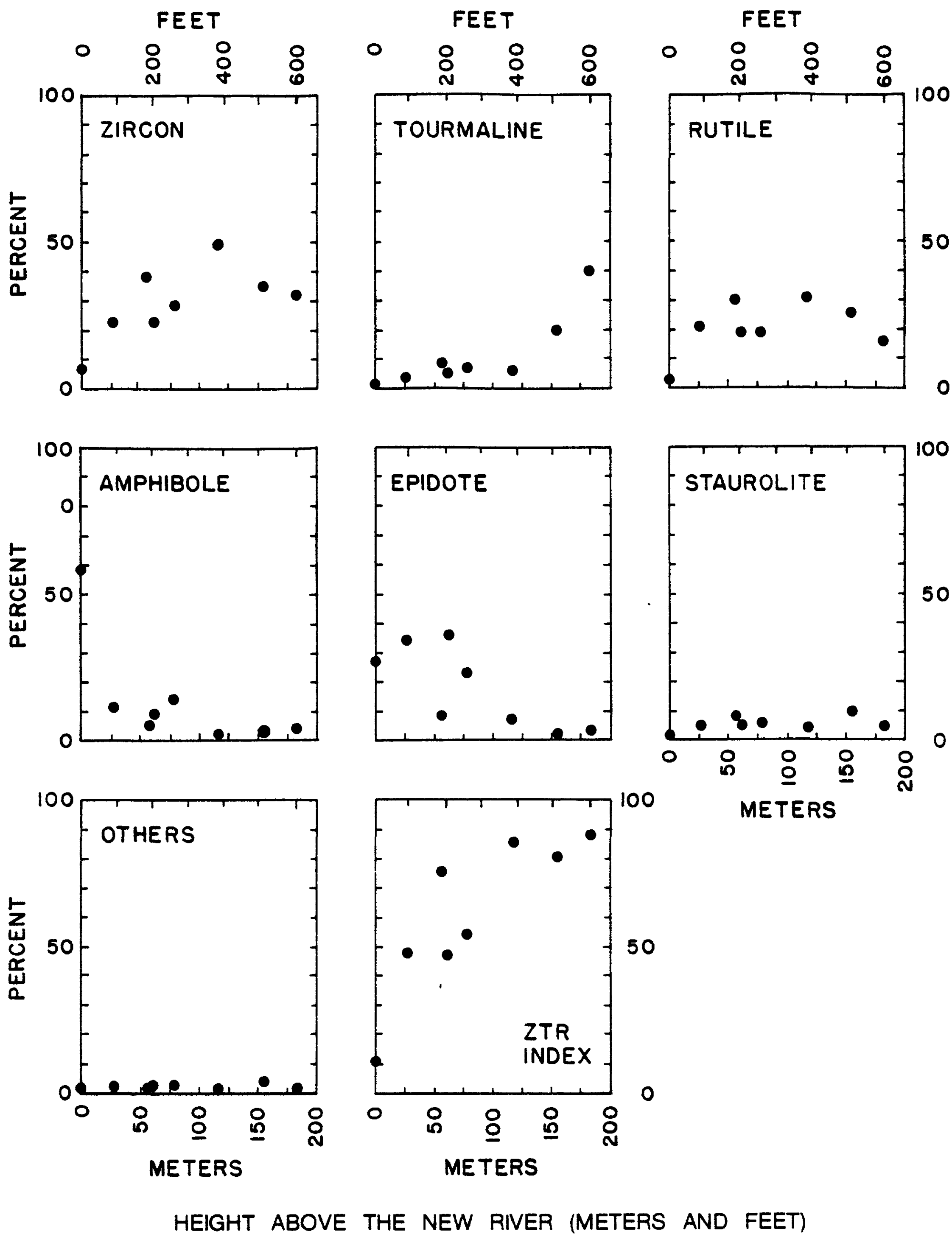


Figure 26.--Percentages of heavy-mineral species present in older New River alluvium relative to the height of the alluvial deposits above the modern New River. ZTR index is the sum of zircon, rutile, and tourmaline percentages.

of vein quartz and metaquartzite cobbles in alluvium deposited by the Blacksburg River indicates that at least part of its headwaters were in the Blue Ridge. It is likely that it drained all the area west of the crest of the Blue Ridge presently drained by the Roanoke River (fig. 1). No samples of modern alluvium were collected from streams in this area. However, the heavy-mineral species contained in the alluvium are probably approximately the same as those in modern alluvium of the New River because the rocks of this part of the Blue Ridge (the south end of the Central Blue Ridge and the transition area between the Central and Southern Blue Ridge) are broadly similar in age, metamorphic grade, and lithology to the rocks in the area drained by the New River (Rodgers, 1970, p. 167). An exception is that hypersthene may be contained in streams which drain the Central Blue Ridge because of the presence of charnokitic rock in that area (Espenshade, 1970).

The heavy minerals contained in the older alluvium of the Blacksburg River are a mature assemblage (fig. 27) consisting of an average of 95 percent zircon and tourmaline and only 2 percent amphibole and epidote. This relatively more mature assemblage as compared to the average assemblage of New River alluvial deposits (46 percent zircon and tourmaline, 23 percent amphibole and epidote) is, in part, a result of the greater average age of the Blacksburg River

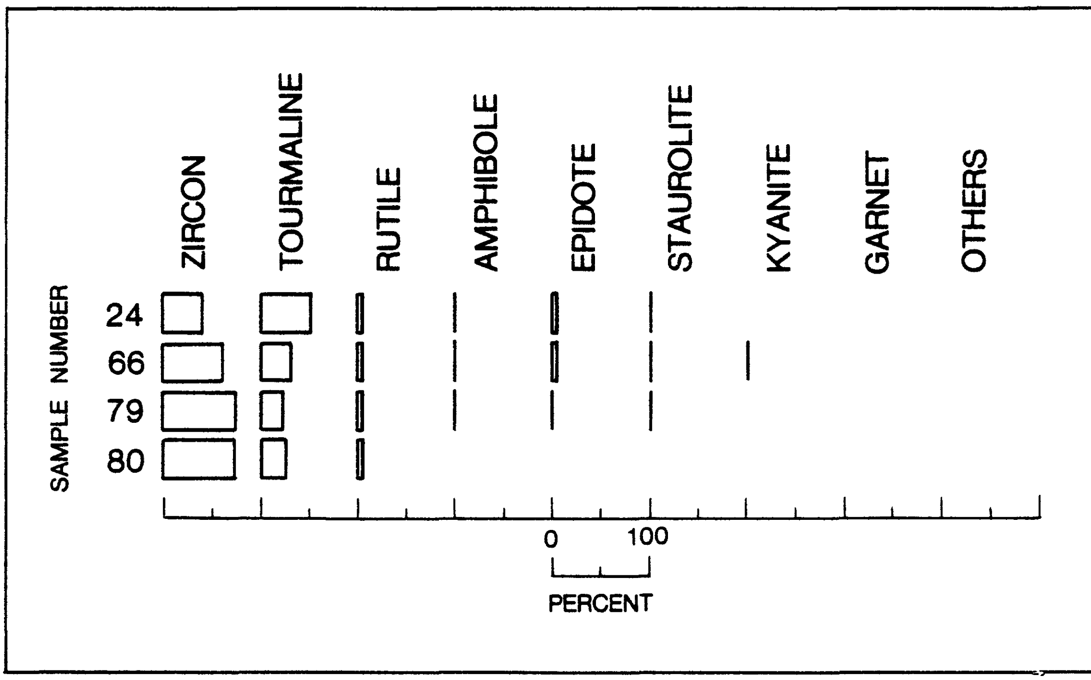


Figure 27.--Heavy-mineral assemblages of Blacksburg River alluvial deposits.

alluvium rather than of major differences in mineralogy of the source areas.

However, the difference in the amount of rutile in Blacksburg River alluvium as compared to that in New River alluvium (3 percent as compared to 23 percent) may reflect a significant difference in mineralogy between the Central and the Southern Blue Ridge. Another possibility (and the preferred one) is that the drainage basin of the Blacksburg River included a relatively greater area within the Valley and Ridge Province than did the New River. This would account for both the more mature aspect of the Blacksburg River heavy minerals and the lesser amount of rutile. Modern Valley and Ridge alluvium contains an average of only 2 percent rutile. This is also a reasonable possibility, because the Central Blue Ridge is considerably narrower than the Southern Blue Ridge.

Valley and Ridge tributaries

The heavy-mineral assemblages of modern alluvium of Valley and Ridge tributaries are very mature, containing an average of 94 percent zircon and tourmaline and less than 2 percent amphibole and epidote (fig. 28). The anomalously high percentages of amphibole and epidote in modern alluvium from the lower part of Sinking Creek are probably caused by an influx of unweathered alluvium of the Blacksburg River, as discussed previously (p. 119).

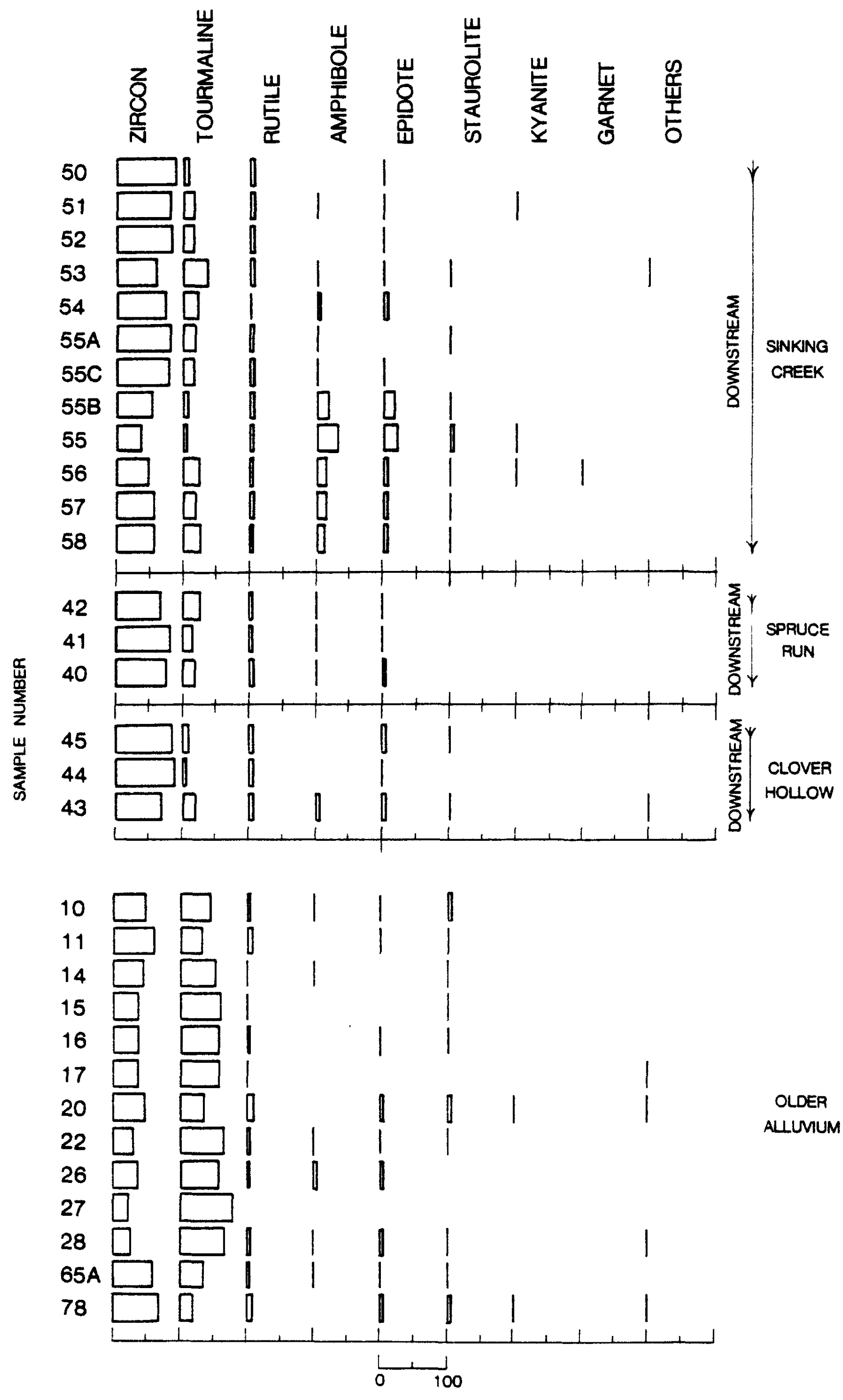


Figure 28.--Heavy-mineral assemblages of modern alluvium and older alluvial deposits of the Valley and Ridge tributaries, Virginia.

The heavy minerals contained in the older alluvial deposits of the Valley and Ridge tributaries are about the same as those in the modern alluvium in terms of maturity (93 percent zircon and tourmaline, 2 percent amphibole and epidote). Nearly all the deposits contain small amounts of alluvium reworked from alluvial deposits of the Blacksburg River, as evidenced by the rare presence of Blue Ridge-derived quartzose cobbles in outcrops. However, this admixture is not evident in the heavy-mineral assemblages because these two types of older alluvium have nearly the same composition, and the quantity of Blacksburg River alluvium present is so small.

Two of the samples shown in figure 28 (samples 20 and 78) are from alluvial deposits that contain reworked alluvium of the New River. These samples are differentiated by their relatively greater amounts of rutile (12 and 7 percent, respectively) as compared to those in the other samples. Also, in outcrop these two deposits contain greater than average percentages of vein quartz and metaquartzite cobbles, although still probably less than 10 percent.

Colluvium and residuum

One sample of colluvium and three samples of residuum were collected. All four contain very mature heavy-mineral assemblages (fig. 29), although only the colluvium sample contained enough grains for the point count to be

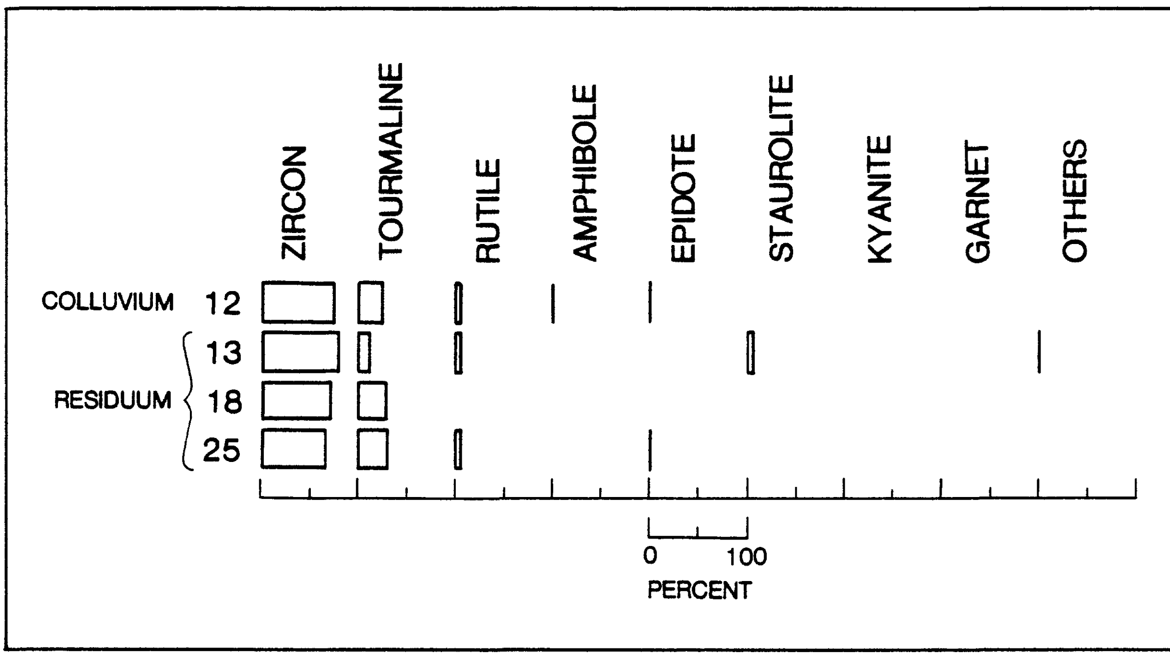


Figure 29.--Heavy-mineral assemblages of colluvium and residuum in and near the study area. Sample locations shown on plate 2.

statistically significant. The colluvium sample, No. 12, is from near Rocky Gap at the head of Clover Hollow, and consists of detritus from the Juniata Formation and Tuscarora Sandstone. Sample 13 is from residuum overlying the lower part of the Martinsburg Formation; samples 18 and 25 are from residuum overlying the Knox Group; sample 25 is from a location near the bottom of the Knox, and sample 18 is from near the top.

Ratio of Zircon to Tourmaline

In figures 25, 27, and 28 in the preceding general description of the heavy-mineral assemblages, the older alluvial deposits are arranged according to sample numbers. In figure 30, the averaged assemblage of modern alluvium of the Valley and Ridge tributaries, and assemblages of certain of the older alluvial deposits of the Valley and Ridge tributaries, are arranged according to the height of each deposit above the modern drainage. The deposits not included in figure 30 are those which were not mapped (thus, the heights of these deposits above the modern drainage are not known) and those which contain reworked New River alluvium. Clearly, figure 30 shows that the percentage of zircon decreases with increasing height of each deposit and that the percentage of tourmaline increases. This relationship also holds for alluvial deposits of the New River and the Blacksburg River, but it is not obvious on this type of

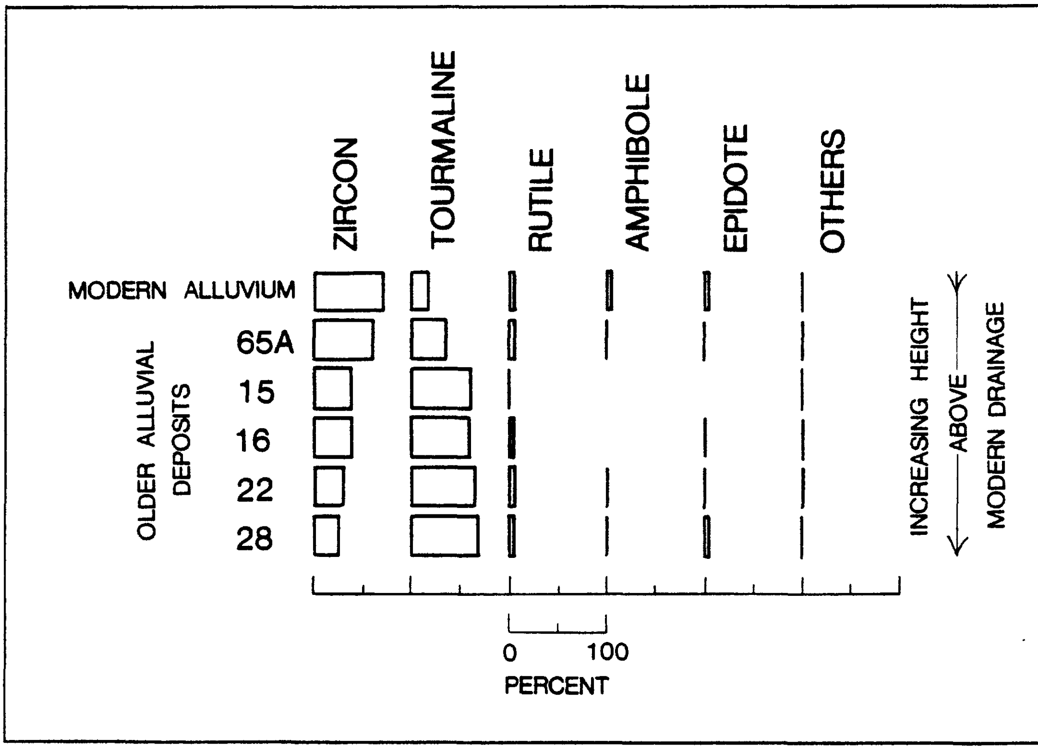


Figure 30.--Heavy-mineral assemblages of Valley and Ridge tributary alluvium showing the decrease in percentage of zircon and the corresponding increase in percentage of tourmaline with increasing height above the modern drainage. Sample locations shown on plate 2.

illustration. For the New River alluvial deposits, the relationship is masked by the degradation of less stable heavy minerals. For the Blacksburg River, the deposits are out of chronological order because some overlie clastic bedrock and have not been lowered by solution, whereas the deposits overlying carbonate bedrock have been lowered.

If the data are presented in the form of the ratio of zircon to tourmaline, Z/T, and the resulting ratios are plotted against the height of each deposit above the modern drainage, the relationship is apparent for the alluvium of all three stream systems (fig. 31). The elevation of the New River was used to calculate heights above the modern drainage of alluvium deposited by the Blacksburg River. Because the Blacksburg River was a major tributary of the New River, the two rivers were probably in equilibrium with each other and eroded at about the same rate. It is assumed that, had the Blacksburg River not been captured, this state of equilibrium would have continued and its modern elevation would be similar to that of the New River.

The points in figure 31 define straight lines, indicating that the value of Z/T decreases as a linear function of age, assuming a constant erosion rate for the period of time represented. Two lines with similar y-axis intercepts are drawn through the four data points of the Blacksburg

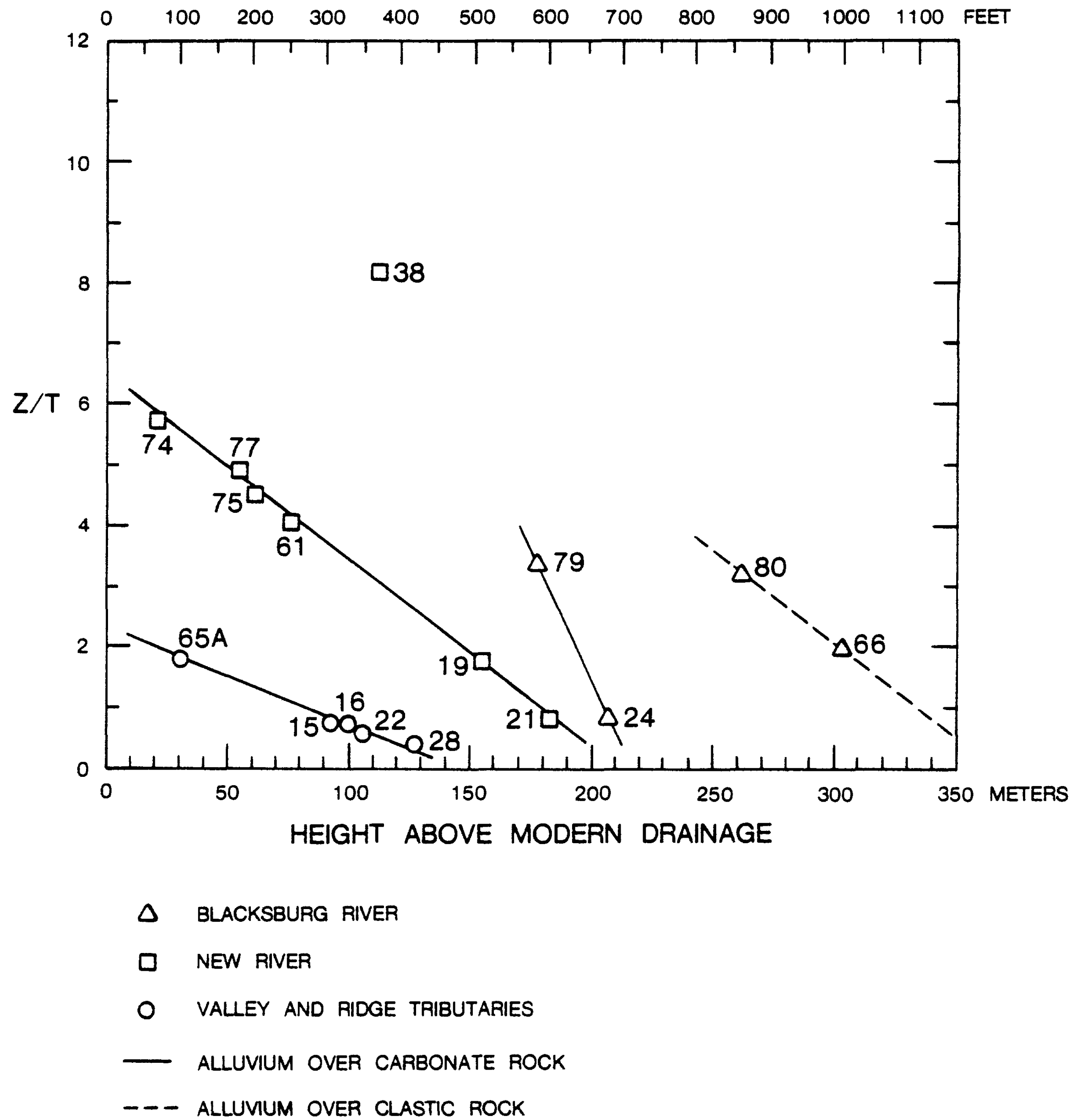


Figure 31.--Ratio of zircon to tourmaline in relation to height of alluvial deposits above the modern drainage. Sample locations given in appendix.

River. The line with the steeper slope is drawn through points which correspond to samples of alluvium overlying carbonate bedrock (samples 79, 24). The second line is drawn through points corresponding to samples from deposits overlying clastic bedrock (samples 80, 66).

Of the sixteen points plotted in figure 31, only the position of the point representing sample locality 38 (southeast of Brush Mountain in Montgomery County) is anomalous. On the basis of its Z/T ratio and its height above the modern drainage, it plots with the Blacksburg River alluvium. However, the rutile content (31 percent) and the proximity of the deposit to the New River (figs. 4, 22) indicate that this alluvium was probably deposited by the New River.

The alluvium at this particular sample locality is unusual in other respects. It contains clasts of highly weathered gneiss and rhyolite(?) in which all the original minerals have been altered to quartz, clay minerals, and hematite. The gneiss is identifiable by alternating light and dark color bands. The rhyolite(?), which may have come from the Mount Rogers area (Rankin, 1970), was tentatively identified on the basis of its homogeneous appearance (lack of metamorphic fabric) and the rare presence of quartz grains with square outlines which may be pseudomorphs of sanidine. This is the only exposure where these clasts were seen. All the other alluvial deposits contained only Blue Ridge-derived quartzose clasts and (or) clasts of Paleozoic sedimentary rocks.

Another unusual aspect of the alluvium at sample locality 38, perhaps related to the presence of weathered metamorphic and igneous clasts, is the appearance of the tourmaline and rutile in the heavy-mineral fraction. Some of the tourmaline grains are greatly elongated, colorless crystals (about 10:1, length to diameter). Tourmaline of this color and form was not seen in any other samples. Knee-shaped rutile twins are common, and the rutile is, in general, clearer, with fewer fractures than the rutile in other samples. Neither the elongate tourmaline crystals nor the knee-shaped rutile crystals could have been transported very far without breaking. They probably are derived from in situ disintegration of metamorphic and igneous clasts. The incorporation of the heavy minerals from the metamorphic and igneous rocks into the normally transported assemblage probably accounts for the anomalous position of point 38 in figure 31.

The alluvium at sample locality 38 may have been deposited by an exceptionally large flood with enough energy to transport metamorphic and igneous rocks from the Blue Ridge during a single event. It may be more than a coincidence that this alluvial deposit is only 3.3 km west of the deposit that was interpreted to be an expansion bar formed during a large flood (p. 62).

The relationship between tourmaline and zircon shown in figure 31 suggests that tourmaline is more stable than zircon under conditions of weathering. Alternate explanations seem less likely. First, the decrease in the value of Z/T must be caused by a decrease in the amount of zircon. The only other possibility is that the amount of tourmaline increases. This could actually happen if tourmaline grains broke up into smaller grains in situ after being deposited. The evidence is that this is not a cause for higher tourmaline counts because the majority of tourmaline grains in all the alluvium samples are rounded and do not appear to have been broken after transport.

Second, is the decrease in the amount of zircon in alluvial deposits really time dependent, and is weathering the factor which causes the decrease? The basis of the hypothesis that the amount of zircon in alluvium is time dependent is the assumption that the height of alluvial deposits above the modern drainage is a function of time. In general, this is true; however, several exceptions to the underlying assumption come to mind.

Tectonic movements can displace the elevation of alluvial deposits relative to one another and to modern streams, but tectonic movements of this type (faults) are uncommon in the Central and Southern Appalachians (Howard and others, 1978). Vertical movements from leveling data in the Appalachians, described by Brown and Oliver (1976) and perhaps attributable to crustal unloading by erosion, probably affect broad areas of the crust and would not displace individual alluvial deposits within an area of a few square kilometers. A fault that displaces alluvium downward against the shale of the Devonian Millboro Formation near Clifton Forge, Virginia (in the Valley and Ridge Province, 80 km northeast of the study area), has been described by White (1952) and is shown in Howard and others (1978) as a fault. However, after examining the fault and the surrounding area, I interpret the vertical contact of the alluvium against the shale to be the result of a slide in the underlying shale. The Millboro Formation in this area is intensely deformed (mascerated in places), and modern sliding is a serious problem along the highway below the "fault."

Landsliding is another way whereby vertical displacement of alluvial deposits can occur. No landslide deposits have been identified within the study area, though, so it is doubtful that any of the alluvial deposits have been lowered by this mechanism.

The problem posed by differential lowering of alluvial deposits that overlie carbonate bedrock as compared to those that overlie clastic bedrock is recognized and has been discussed in the previous chapter. All the alluvial deposits overlying carbonate bedrock are being and have been lowered by solution at approximately the same rate relative to each other (assuming that erosional equilibrium prevails). The alluvial deposits overlying clastic bedrock are either being removed (as the deposit southeast of Brush Mountain, p. 109) or have been preserved at their original elevation of deposition (sample 80, from the wind gap on Gap Mountain). It is quite likely that two alluvial deposits at the same elevation could be of different ages if one overlies carbonate bedrock and the other overlies clastic bedrock. Similarly, an alluvial deposit on carbonate bedrock could be of the same age as a deposit at a higher elevation that is preserved on clastic bedrock.

Thus, it is probably a reasonable assumption that the height of an alluvial deposit above the modern drainage is a direct function of the age of the deposit. However, in the study area this function has two values--one for alluvium overlying carbonate bedrock and one for alluvium overlying clastic bedrock, as shown in figure 31.

Subaerial stability of zircon

The second part of the question posed in the preceding section, ". . . is weathering the factor which causes the decrease [of zircon]?", is considered in this section. Although zircon and tourmaline have been thought by many workers to be the most stable of all the heavy minerals (for example, Dryden and Dryden, 1946), there have been a few references to the apparent solubility of zircon.

In an investigation of a drill core of Arkansas bauxite, Frederickson (1948) noted that:

> ". . . the only places in the core where zirconium is found in the form of zircon crystals is in the pisolites. Well formed zircon crystals are found in red, unleached pisolites containing gibbsitized feldspar remnants. In the pisolites that have been leached by later solutions the remaining zircons show corroded, irregular outlines indicating that they are gradually going into solution."

Carroll (1953) observed that zircon grains in soils tended to be corroded if they contained numerous inclusions or were zoned, and concluded that:

> "In weathering processes with normal and hyacinth types of zircon the grains are reduced by the slow corrosion of the mineral substance which is removed in solution; . . ."

Carroll thought that laterizing conditions promoted the solution of zircon.

Grimm (1973) described the effects of weathering on heavy minerals contained in upper Miocene alluvial fans in Germany. The fan sediments are 20-40 m thick and are divisible into lower, middle, and upper units on the basis of a well-developed weathering profile. Thus, Grimm was able to compare the abundance and appearance of the various heavy minerals with location in the weathering profile. He described the progressive weathering of zircon as beginning with alined small etch pits which can merge into larger etching fields or grooves. The next effects are ". . . a flaky texture of the surface and corrosion of the borders, forming serrated and lobate contours. Finally, some individuals were transformed into deeply corroded skeletons." Grimm interpreted the weathering effects to result from "humic solutions" and "kaolin weathering conditions."

On the basis of these three investigations, it appears that zircon can be dissolved during the weathering process and that the probable effective agent of the process is acidic ground water.

It is likely that not all zircon is equally soluble. It has long been recognized that zircon can be separated into three gradational types on the basis of varying optical properties and density. The three types are normal, intermediate (hyacinth), and metamict (malacon). Hutton (1950) briefly reviewed the development of the three-fold subdivision of zircon. The differences in the physical properties (some of which are listed in table 5) are the result of radiation damage to the crystal structure from small amounts of uranium and thorium, which are nearly always present in zircon. Holland and Gottfried (1955) in a study of structural damage to zircon concluded that most of the damage is probably due to displacement of atoms caused by recoil nuclei.

The importance of structural radiation damage in zircon is that the damage apparently enhances the solubility of the mineral. Frederickson (1948) and Grimm (1973)

Table 5.--Optical and physical properties of zircon

[Density, refractive indices, and radioactivity from Deer and others, 1966]

	D	ω	ε	δ	Radio-activity
Normal zircon	4.6-4.7	1.924-1.934	1.970-1.977	0.036-0.053	Low
Intermediate	4.2-4.6	1.903-1.927	1.921-1.970	0.017-0.043	Medium
Metamict zircon	3.9-4.2	1.782-1.864	1.827-1.872	0-0.008	High

[Color, alpha dose, and density of Ceylon zircons modified from Vaz and Senftle, 1971]

	Alpha dose[1] $\times 10^{16}$ α/mg	Density g/cm^3
Pink	0.0078	4.68
Light yellow	.046	4.71
Yellow brown	.010	4.63
Yellow	.18	4.60
Yellow	.19	4.63
Green	.197	4.58
Light green	.256	4.51
Green	.36	4.38
Green	.43	4.50
Green	.498	4.38
Green	.67	4.17
Green	.698	4.19
Green	.75	4.19
Green	.76	4.21
Green	.79	4.15
Green	.97	4.13
Dark green	1.13	4.01
Dark green	1.17	3.99
Dark green	1.26	4.04

[1]Proportional to degree of metamictization.

did not mention zircon type in their studies, but Carroll (1953) noted that grains which were zoned or contained inclusions (hyacinth) were more likely to be corroded than was normal zircon. This observation is also considered true in the present study.

It seems reasonable (intuitively, at least) that a damaged crystal lattice would render a mineral more susceptible to chemical attack--and that the more damaged the lattice, the greater the susceptibility. Metamict zircon, which is isotropic and possesses only the short-range order of the glassy state, should certainly alter or corrode readily. In addition, the solubility of intermediate and metamict zircon is surely enhanced by the presence of numerous fine cracks in many grains observed in this study and by others (Hutton, 1950; Carroll, 1953). The effect of the cracks is to increase the surface area available to chemical attack.

Tourmaline is used in this study as the standard against which zircon loss is measured because these two minerals are essentially the only nonopaque heavy minerals remaining in the majority of the older Blue Ridge-derived alluvium samples and in all of the alluvium derived from the Valley and Ridge Province. However, there are three obvious problems associated with using tourmaline as the standard. First, tourmaline is apparently more stable than zircon but is undoubtedly also subject to weathering.

Little is known of the effect of different variables (chemical composition, climate) on the weathering of tourmaline, although there is a tendency, with increasing age, for alluvium to contain greater percentages of nearly opaque, very dark brown or green tourmaline. It is possible that these dark grains have been altered by weathering.

Second, tourmaline is not necessarily present in all source-rock lithologies in a statistically significant quantity. Finally, the densities and hence the behavior of zircon and tourmaline in hydraulic systems are quite different (zircon = 4.6-4.7, tourmaline = 3.03-3.25). Thus, the Z/T value of a sand lens could be as much or more a function of the flow conditions under which the sand was deposited as it is a function of the age of the deposit. In the present study, this particular bias was avoided in the case of the older but not the modern alluvium.

The method of sampling the older alluvium was three dimensional and therefore presumably is representative of several flow conditions. This has the effect of producing a population of zircon and tourmaline which closely represents the total population of these minerals as supplied by the source area. The sampling of modern alluvium was two dimensional (horizontal). The samples were collected from the sediment-water interface (or sandy banks); thus, each sample probably represents a single flow condition and contains an amount of zircon and tourmaline prescribed, in part, by that flow condition.

A potentially better standard than tourmaline for measuring zircon loss is normal (nonmetamict) zircon. Normal zircon can be thought of as an internal standard--that is, if intermediate and metamict zircon are present in an alluvial deposit then normal zircon will also be present. In addition, the difference in density between normal zircon (D = 4.6-4.7) and intermediate and metamict zircon (D = 3.9-4.6) is not as great as that between zircon and tourmaline. Thus, hydraulic sorting is not as much of a problem.

Figure 32 shows the same data points as figure 31, with the exception that the y-axis of figure 32 is the ratio of intermediate and metamict zircon to normal zircon (mZ/nZ). The lines in both figures have similar slopes. This indicates that normal zircon is approximately as stable as tourmaline in the weathering environment and that intermediate and metamict zircon are indeed removed from alluvium as a function of time.

The principal differences between figures 31 and 32 are the greater amount of scatter of data points on figure 32 and the displacement of the lines for the Valley and Ridge tributaries and the New River to the right relative to those for the Blacksburg River. Both of these differences can probably be attributed to subjective error

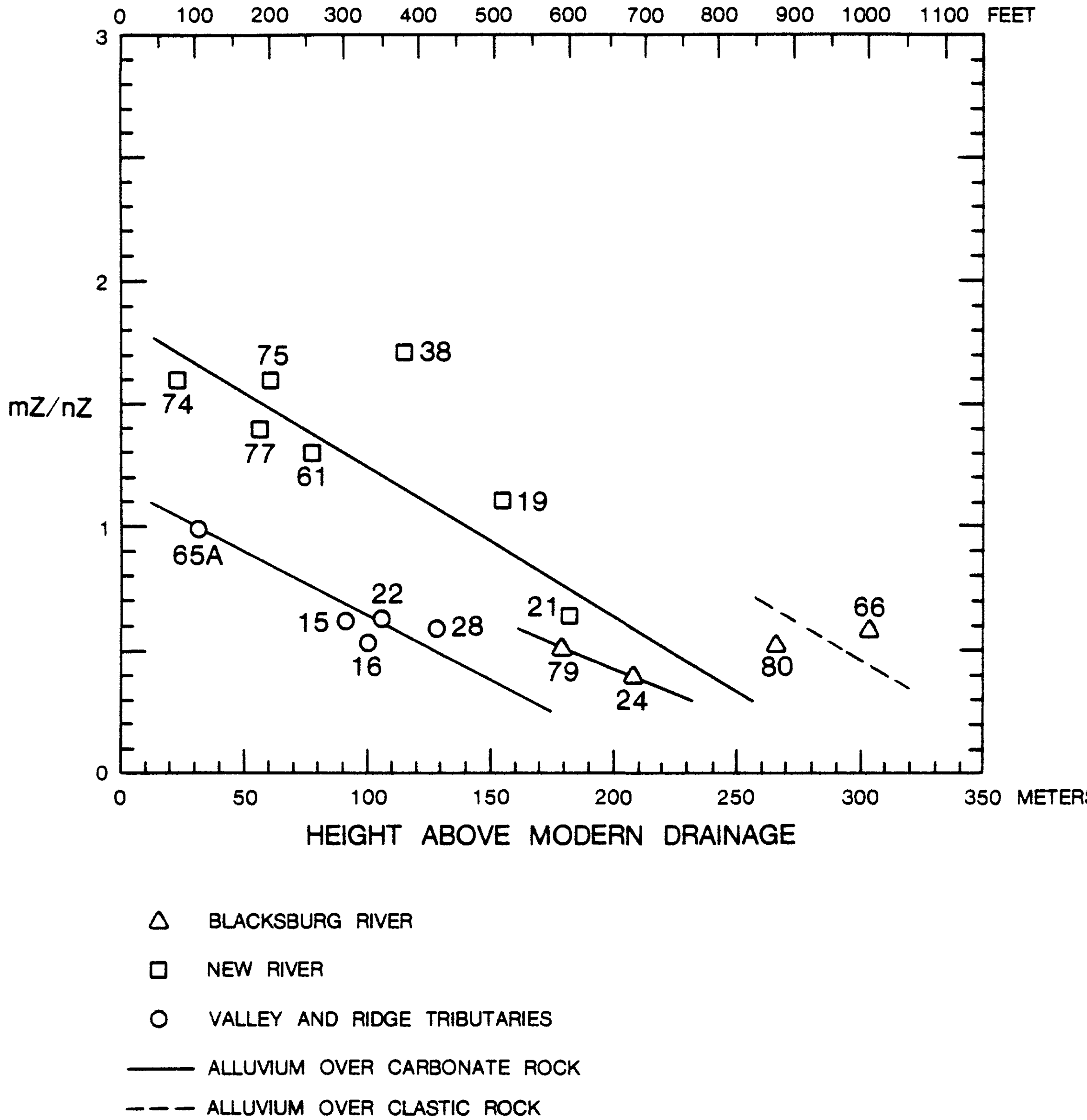


Figure 32.--Ratio of intermediate and metamict zircon to normal zircon in relation to height of alluvial deposits above the modern drainage.

inherent in the optical (point-count) method used to determine the amount of intermediate and metamict zircon. Zircon grains were considered to show radiation damage if they had any or all of the following characteristics: lower than normal birefringence and relief, abundant cracks, brown or yellow coloring, cloudy gray appearance, and (or) zonation accompanied by cracks. There is no difficulty in optically identifying the end members in the normal-intermediate-metamict zircon sequence (fig. 33). However, because the sequence is gradational and because of the different sizes, shapes, and orientations of the grains, it is impossible to establish any consistent criteria for distinguishing normal from intermediate zircon.

If a technique could be developed to determine more accurately the amount of normal versus intermediate and metamict zircon in a sample, then the ratio mZ/nZ might have application as an indicator of the age of alluvial deposits. It has already been suggested that the metamict properties of minerals could be used for age determination. For example, Kulp and others (1952) noted that the area under the peak of a differential thermal analysis curve is proportional to lattice disorganization in radiation-damaged minerals, and demonstrated that the ratio of this area to the measured alpha activity increased with age of the mineral.

A

B

The age of the zircons in the present study is known to be Precambrian because their source area is in the Blue Ridge, although a statistically insignificant amount of zircon of Ordovician age is contributed from bentonite beds present in the middle and upper part of the Ordovician section. Zircon ages of 820 m.y. for felsic volcanic rocks and 1050 m.y. for the granitic basement have been obtained in the Blue Ridge (Rankin and others, 1969). Thus, rather than using the metamict properties to determine the age of the zircon, it is proposed that the solubility of zircon, which is the result of the metamict properties and is linear (in this study) and predictable with respect to time, can be used to determine the length of time a zircon population has been subjected to subaerial weathering. If datable materials (airfall tuffs, fossils) were intercalated in the alluvial deposits of a drainage basin, then the rate of zircon solution could be calibrated and tested in other areas.

Another implication of the Z/T and mZ/nZ curves of figures 31 and 32 is that different source areas supply different zircon populations and that the areas can be distinguished from one another on the basis of the percentage of radiation-damaged individuals contained in the population. Thus, the curves for alluvium from the Valley and Ridge are lower (the population contains less radiation-damaged zircon) than the New River curves because the

Valley and Ridge (Paleozoic) zircon population has undergone one to two additional weathering cycles as compared to the Blue Ridge zircons. The damaged zircon was probably dissolved during the weathering and transport cycle, but some could have been removed by intrastratal solution after deposition.

The mZ/nZ line of the two alluvial deposits of the Blacksburg River which overlie carbonate bedrock (sample locs. 79 and 24) lies between the lines of the New River and the Valley and Ridge tributaries. This lends credence to a previous suggestion (p. 137) that most of the drainage basin of the Blacksburg River might have been in the Valley and Ridge Province. Thus, the zircon population of the Blacksburg River could be expected to contain a large component of multicycle zircons from Paleozoic rocks of the Valley and Ridge Province.

Solution Rate of Carbonate Bedrock

The principal use of Z/T values in this study is as an aid to estimating the percentage of the average erosion rate that can be attributed to the solution of carbonate rock. The distance which the alluvial deposits overlying carbonate bedrock have been lowered by solution can then be added to their present elevation to determine their original depositional elevation and thus their approximate age, relative to other alluvial deposits, based on the total erosion rate.

The solution rate can be obtained from the two Z/T curves for the Blacksburg River shown in figure 31. The upper line corresponds to alluvial deposits that overlie clastic bedrock; the lower curve corresponds to alluvial deposits that overlie carbonate bedrock. Therefore, it is assumed that the difference in height above the modern drainage, between the two curves, indicated at any point on the curves, is due to lowering by solution of the carbonate bedrock. The slope of the lower curve is about one-third greater than that of the upper curve, indicating a solution rate of about 13.5 m/m.y. (assuming a total erosion rate of 40 m/m.y.).

Three assumptions are involved in these calculations. It is assumed, first, that none of the alluvial deposits plotted in figure 31 have been reworked; second, that the deposits overlying carbonate bedrock have been lowered by solution only; and third, that the deposits overlying clastic bedrock have not been lowered at all.

These assumptions are probably approximately valid. Reworked alluvial deposits are present in the area and have been identified in this study. However, none of the deposits used in the Z/T analysis have the characteristics of reworked alluvium.

The validity of the second and third assumptions is, in part, verified by the very existence of the alluvial deposits. If the alluvium had been lowered or otherwise modified by a large component of mechanical erosion, the deposits would probably have been removed. It is likely that many older alluvial deposits are accidental remnants of more extensive deposits and that they have escaped mechanical erosion by virtue of being located on saddles and knobs over carbonate bedrock, or, in the case of sample locality 80, in an abandoned water gap over clastic bedrock.

Finally, the figure used in the calculations is the maximum elevation of each deposit. This is important, because on some deposits as much as 100 m (300 ft) of relief has developed. The maximum elevation is used primarily in order to be consistent, but it has the effect of giving a minimum value for the solution component of the erosion rate.

Figure 34 shows two lines for each of the stream systems. The additional lines represent the total amount of erosion that has occurred since the alluvium was deposited; the lines were obtained by adding the solution factor of 13.5 m/m.y. to the lines of the Valley and Ridge tributary alluvium and the New River alluvium. If the Z/T values of the alluvial deposits are relocated on the calculated curves representing the total erosion rate, the approximate age of the alluvium can be estimated from the time scale at the top of the figure. The time scale is

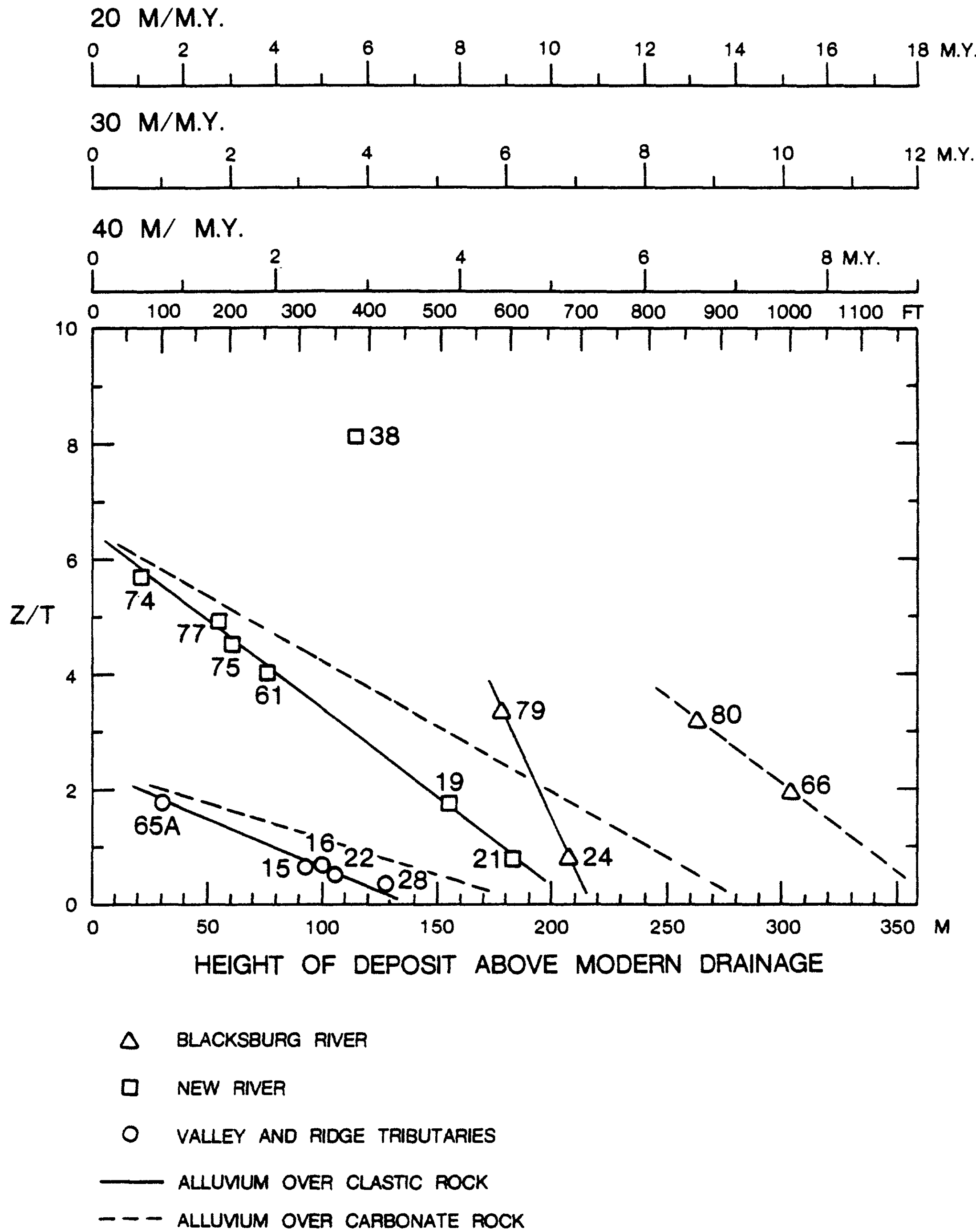


Figure 34.--Plot of Z/T lines (1) determined by the present elevation of the alluvial deposits (from fig. 31) and (2) calculated Z/T lines (dashed) which include the estimated solution factor of 13.5 m/m.y. Time scales based on three different calculated erosion rates are shown at the top of the figure.

based on a total average erosion rate of 40 m/m.y. This is the rate estimated by King (1959), Judson and Ritter (1964), and Hack (1965). Time scales based on erosion rates determined by Gilluly (1964), 20 m/m.y., and Doherty and Lyons (1980), 30 m/m.y., are also included in figure 34. Figure 34 indicates that the oldest alluvial deposit sampled is represented by sample 24 and that it ranges in age from 8.5 to 17 m.y. old, depending on which time scale is used.

CHAPTER 6

EVOLUTION OF A PART OF THE NEW RIVER DRAINAGE SYSTEM

Drainage of the study area consists of the New River within the Valley and Ridge Province and its subsequent tributaries from the northeast. This part of the New River drainage basin is bounded on the northeast by the drainage basins of the James and Roanoke Rivers (fig. 1). Through time, the courses of the New River and its tributaries have been modified by stream capture and by response to structural and lithologic variations as the streams have eroded through the stratigraphic section. Figures 36, 38, and 40 show, schematically, the probable configuration of the drainage at three stages of drainage modification during the latter half of the Neogene. The evolution of the drainage configurations is discussed in the following sections in terms of structural and lithologic parameters which controlled geomorphic processes and in terms of evidence provided by alluvial deposits.

Paleozoic Through Early Cenozoic Drainage

Westward drainage of a landmass in the region of the present Blue Ridge and Piedmont Provinces was initiated during the Taconic orogeny in late Middle Ordovician time (Blountian), as evidenced by facies relationships of

Paleozoic sediments of the Valley and Ridge Province (Pettijohn, 1970, p. 2). In the Southern Appalachians, westward drainage has continued to the present time. Lowry (1979, p. 4) has suggested that the present course of the New River was established as early as Mississippian time, based on his interpretation of lithologic facies changes in the Cloyd Conglomerate at the New River gap between Cloyds and Brush Mountains.

Late Cenozoic Drainage

Within the map area the distribution and lithology of the alluvial deposits can be used to document the drainage configurations shown in figures 36, 38, and 40. These configurations show progressive stream capture by the James and Roanoke Rivers of the tributaries to the New River from the northeast. The times of capture range from about 6 m.y. B.P. to more than 10 m.y. B.P.
This time range is calculated from the erosion rate of 40 m/m.y. (130 ft/m.y.), and specific ages are used only for ease of comparison in the discussion of drainage evolution.

An upper age limit of somewhat more than 10 m.y. for evidence of former drainage patterns, as provided by alluvial deposits, applies to the area of the Narrows fault block (pl. 1). This approximate age limit corresponds to a former elevation of about 900 m (3000 ft). At this elevation the outcrop area of carbonate bedrock was restricted to the crest of the Bane anticline and, as discussed in Chapter 4, surficial materials tend to be preserved only on carbonate bedrock. Beginning at about 10 m.y. B.P. and continuing to the present, the outcrop area of carbonate bedrock in the New River Valley in Giles County has constantly increased as erosion has progressed downward through the stratigraphic section.

The record of previous drainages which can be supplied by alluvium in the strike valley between Spruce Run-Clover Hollow Mountain and Gap-Sinking Creek Mountain is considerably longer. Figure 35 illustrates that carbonate rock could have been present above the location of the modern valley for a vertical distance of as much as 3000 m (about 9700 ft), or 75 m.y. This maximum estimate is based on a constant dip of about 60° for both the rock units and the Saltville fault, and on the assumption that the Saltville fault is not the ramp part of a low-angle thrust fault which has since been removed by erosion.

The Pulaski thrust sheet (fig. 5), where carbonate bedrock has been exposed continuously from about 1000 m elevation (3300 ft) to the present elevation of 600 m (about 2000 ft), has a cover of alluvial deposits which probably contains considerable information regarding

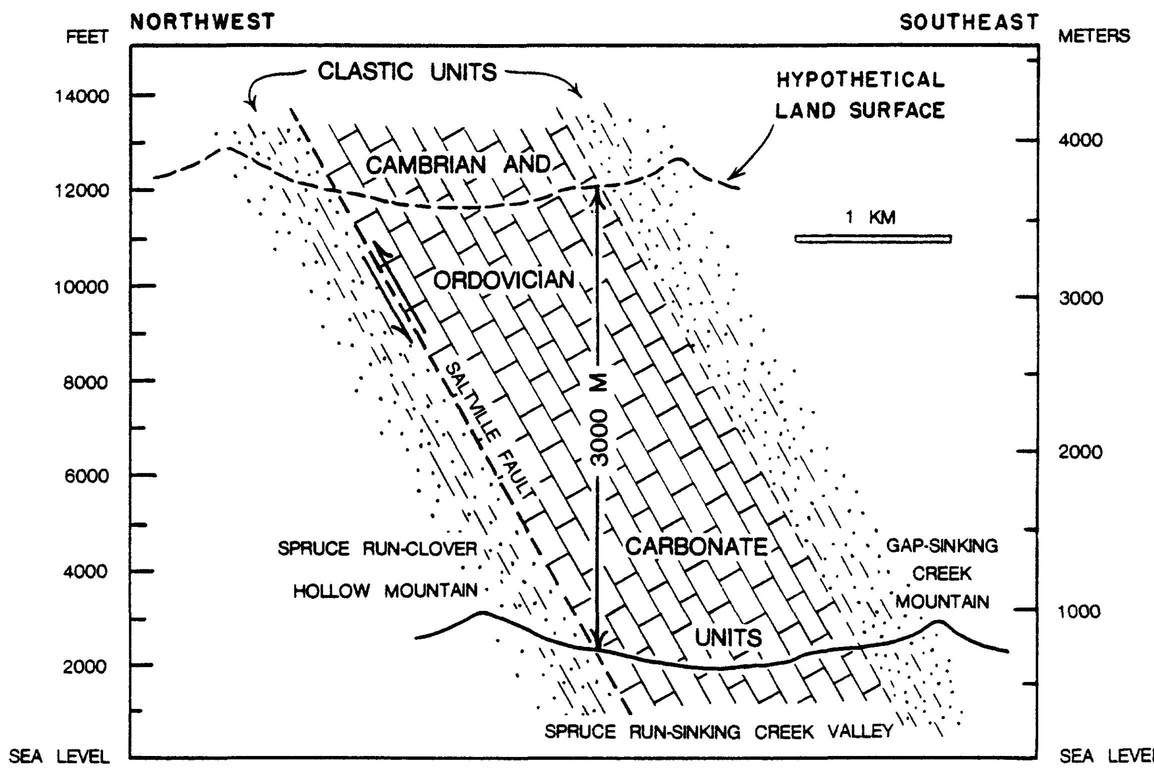


Figure 35.--Cross-sectional reconstruction of the maximum thickness of carbonate rock which could have been eroded from above the present location of Spruce Run-Sinking Creek valley.

previous drainages. However, only a small part of the Pulaski thrust sheet was mapped in this study.

Throughout the time interval for which there is evidence for drainage configurations (about 10 m.y. B.P. to the present, over the Narrows fault block), the New River apparently has not deviated from its present course by more than 5 km--deviations explainable as meander migrations, extensions, and cutoffs. The Blue Ridge-derived alluvium outside this 5-km-wide band was deposited by the Blacksburg River and the County Line River.

Drainage adjustments >10-8 m.y. B.P.

The earliest drainage configuration evidenced by alluvial deposits is shown in figure 36. Three of the rivers shown in this figure and in subsequent figures--the County Line, Clover Hollow, and Blacksburg Rivers--no longer exist and have been designated by informal names for the sake of convenience. The headwaters of the County Line River were the first to be captured--presumably by the Roanoke River drainage, but possibly by the Blacksburg River.

Evidence for the existence and course of the County Line River is:

1. Two alluvial deposits in Sinking Creek valley between Newport and the Giles-Craig County line (pl. 2) contain abundant Blue Ridge-derived quartzose pebbles and cobbles.

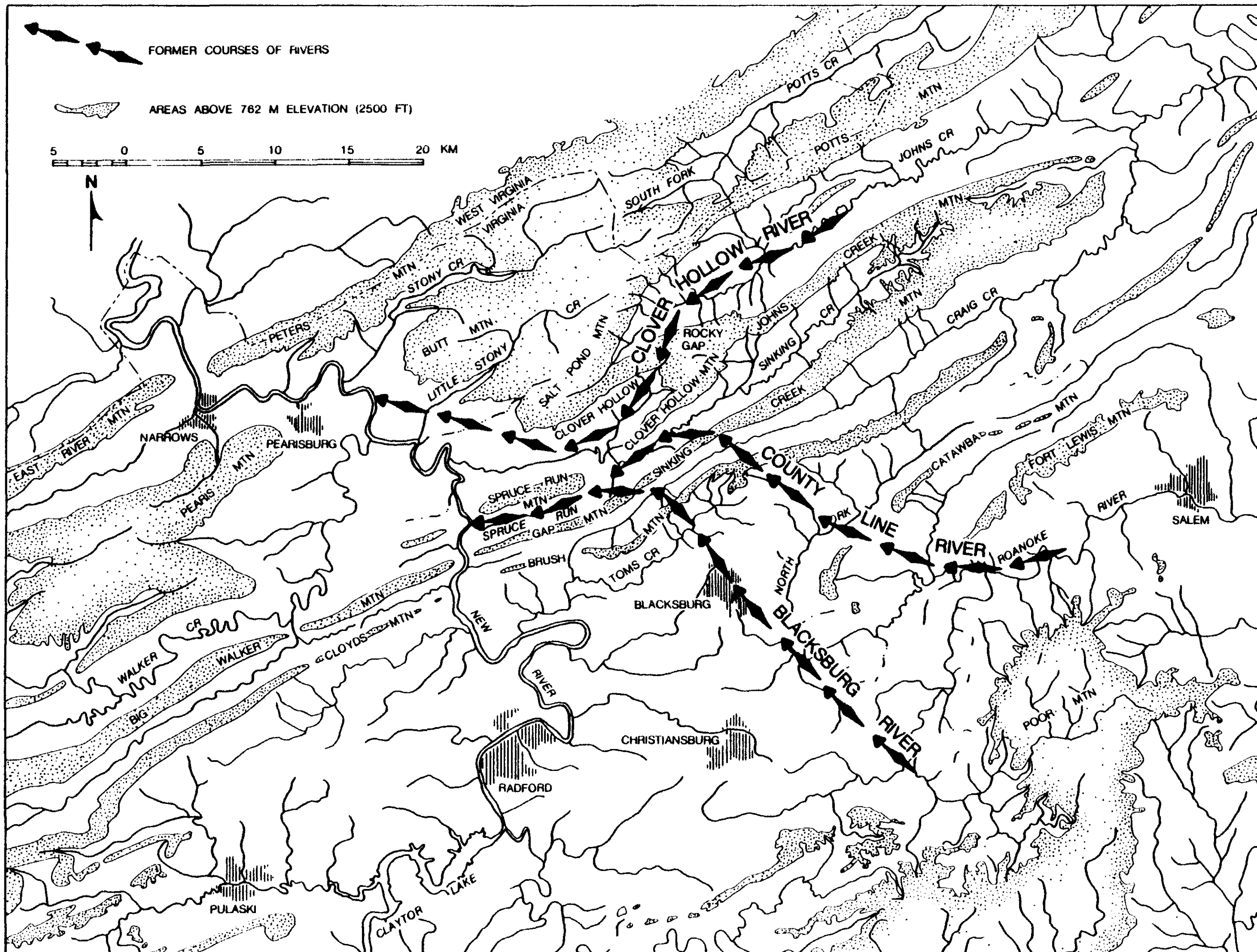


Figure 36.--Locations of the Blacksburg, County Line, and Clover Hollow Rivers at some time prior to 10 m.y. B.P.

2. The rare presence of vein quartz and metaquartzite clasts in Sinking Creek alluvium southwest of the Giles-Craig County line.
3. The absence of vein quartz and metaquartzite clasts northeast of the county line.

The vein quartz and metaquartzite clasts indicate that the County Line River drained the Blue Ridge. Lack of these clasts in Sinking Creek alluvium northeast of the county line suggests that the river crossed Sinking Creek Mountain from the east between the county line and the most northeasterly of the two alluvial deposits which contain abundant Blue Ridge-derived clasts. No significant wind gaps occur in this area, so the elevation of Sinking Creek Mountain in this interval, 884-914 m (386-416 m above the modern drainage) (2900-3000 ft (1265-1365 ft above the modern drainage)), restricts the time of capture of the County Line River to a minimum of 10 m.y. B.P. Poor preservation of the two alluvial deposits of the river, consisting of small, very thin patches of gravel and sand, is a further indication that the County Line River was captured a relatively long time ago.

The headwaters of the Clover Hollow River are shown in figure 36 to have been in the Devonian shale valley of the Johns Creek syncline which is now drained to the northeast by Johns Creek. The river flowed southwestward from the

Johns Creek syncline to the Clover Hollow anticline, crossing the outcrop belt of Ordovician and Silurian sandstone in the vicinity of Rocky Gap. The presence of alluvial deposits indicates that the river flowed southwestward through Clover Hollow and then west-northwestward along the base of Salt Pond, Doe, and Butt Mountains. Clover Hollow River probably entered the New River between Hoges Chapel and Klotz (Eggleston and Pearisburg 7 1/2-minute quadrangle maps). The type of alluvium deposited by the Clover Hollow River and the physiography of its proposed drainage basin suggest that it was similar to the modern Stony Creek and Little Stony Creek (fig. 36). These streams drain the high and moderately rugged mountainous area of Salt Pond, Doe, Butt, and Peters Mountains. Thus, the Clover Hollow River was probably a high-energy, high-gradient stream which transported abundant large sandstone clasts.

The principal evidence for former existence of a sizable high-gradient stream in Clover Hollow is a veneer of alluvium containing many rounded and (or) polished clasts which blankets the valley. Much of this alluvium has been interpreted previously to be colluvium (Gambill, 1974), in part because of the very large size (as much as 2 m) of some of the clasts. Some of the larger boulders, however, have been stream polished on one surface, and many of the smaller boulders and cobbles are polished on all surfaces. A few of the cobble-size clasts are very well rounded, but most of them are subrounded to subangular. The most conspicuous alluvial deposits of the Clover Hollow River are on Big Ridge, a medial carbonate ridge in Clover Hollow. The appearance of this alluvium is the same as that of Stony and Little Stony Creeks; that is, poorly sorted, with a considerable range in clast size and amount of stream polish.

Clover Hollow River was probably captured by gradual headward erosion of Johns Creek. In this respect also it is similar to Stony Creek, which has the appearance of being in the process of being captured by headward erosion of the South Fork of Potts Creek (figs. 36, 37).

In general, the alluvium in Clover Hollow appears to be a mixture of second-stage and Valley and Ridge-derived alluvium. This mixture is particularly evident in the exposure of Clover Hollow River alluvium at sample locality 11 (fig. A1). The clasts in this deposit consist primarily of subangular to subrounded sandstone boulders and cobbles which a stream the size of the modern creek in Clover Hollow might carry. However, the deposit also contains very well rounded and polished sandstone cobbles which could not possibly be the work of the modern stream.

The mixture may be, in part, the result of reworking of the alluvium by smaller streams after Clover Hollow

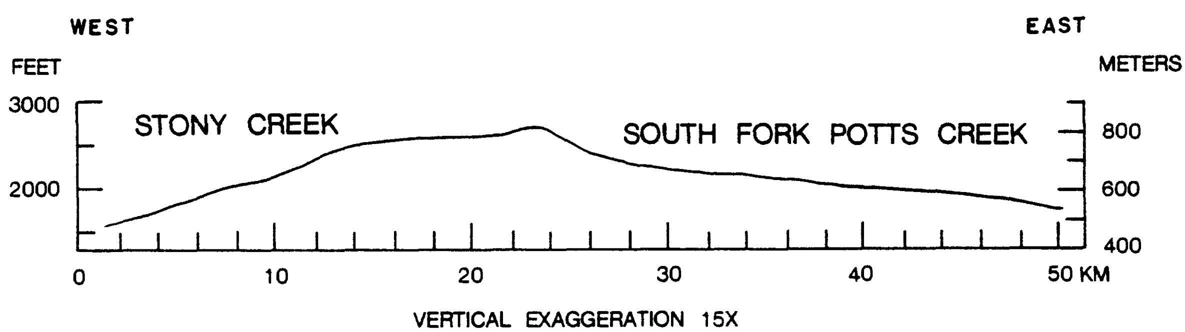


Figure 37.--Longitudinal profiles of Stony Creek and the South Fork of Potts Creek. The lower overall gradient and the steep gradient at its head suggest that Potts Creek is eroding headward relative to Stony Creek.

River was captured. However, it is likely that this was the type of material transported by the river. The river probably had a very steep gradient, perhaps on the order of 40 m/km (about 200 ft/mi) for a few kilometers downstream from Rocky Gap, which enabled it to transport the sandstone eroded from the Ordovician and Silurian sandstone outcrop belt in the area of Rocky Gap. The steep gradient also would have had the effect of increasing the slope angle of adjacent ridges and causing rapid transport of first-stage alluvium to Clover Hollow River from the flanks of Johns Creek Mountain, Kelly Knob, and Clover Hollow Mountain. Thus, the alluvium in Clover Hollow is probably a mixture of clasts that have been transported by the Clover Hollow River from a considerable distance northeast of Rocky Gap and abundant detritus, transported only a few kilometers and introduced to the river southwest of Rocky Gap.

Many of the clasts are highly weathered, suggesting that the Clover Hollow River was captured quite some time ago. Clasts that are polished on all surfaces but are not well rounded generally disintegrate into a pile of sand when hit with a hammer (fig. A1). The few clasts that are both polished and well rounded are cobble size and are usually hard throughout. Rounding of these clasts indicates that they probably were transported farther than the more weathered clasts and therefore represent the most resistant lithologies.

Capture of the Clover Hollow River was a gradual process of headward erosion by Johns Creek, resulting in gradually decreased discharge. The time of nearly completed capture can be estimated by using the present elevation of Rocky Gap, 995 m (3265 ft), and the average gradient of the lower 10 km of Stony Creek, 23 m/km (120 ft/mi). At a distance of 6.4 km southwest of Rocky Gap, the calculated elevation of the Clover Hollow River would have been 850 m (2790 ft). Elevation of the modern drainage at this point (junction of Giles County roads 601 and 685) is 597 m (1960 ft). Using the erosion rate of 40 m/m.y. (130 ft/m.y.), the estimated time of capture was about 6 m.y. B.P.

The Blacksburg River headwaters were in the Blue Ridge (fig. 36). It flowed northwestward across the Great Valley near Blacksburg, crossed Brush and Gap-Sinking Creek Mountains in the wind gaps presently utilized by U.S. 460, and flowed southwestward in Spruce Run valley to the New River. Evidence for this course consists of widespread alluvial deposits that contain vein quartz and metaquartzite cobbles in Spruce Run valley and a goethite-cemented alluvial deposit containing vein quartz and metaquartzite cobbles in the wind gap between Sinking Creek Mountain and Gap Mountain.

Drainage adjustments 8-6 m.y. B.P.

The next configuration (fig. 38) shows that parts of the County Line River have been captured by both the Roanoke and Blacksburg Rivers, that the headwaters of Clover Hollow River are being captured by headward erosion of the James River drainage, and that the Blacksburg River has been captured by the Clover Hollow River and diverted from Spruce Run valley northwestward across Spruce Run-Clover Hollow Mountain.

Dismemberment of the County Line River by both the Roanoke and Blacksburg Rivers is hypothetical. There may be alluvial deposits in the area between Blacksburg and Salem that would provide clues to the actual capture sequence, but the surficial materials of this area have not been mapped. The hypothetical capture sequence is based on the assumption that headward erosion by tributaries of the Roanoke River has been more rapid parallel to strike than perpendicular to strike and has proceeded from southeast to northwest. In this framework, the Blue Ridge tributaries of the County Line River would have been the first to be captured by the Roanoke drainage. This capture may have decreased the competency of the river and its ability to erode through Brush and Sinking Creek Mountains to the extent that a tributary of the Blacksburg River was able to capture the remaining part of the County Line River southeast of Brush Mountain. An additional factor which would

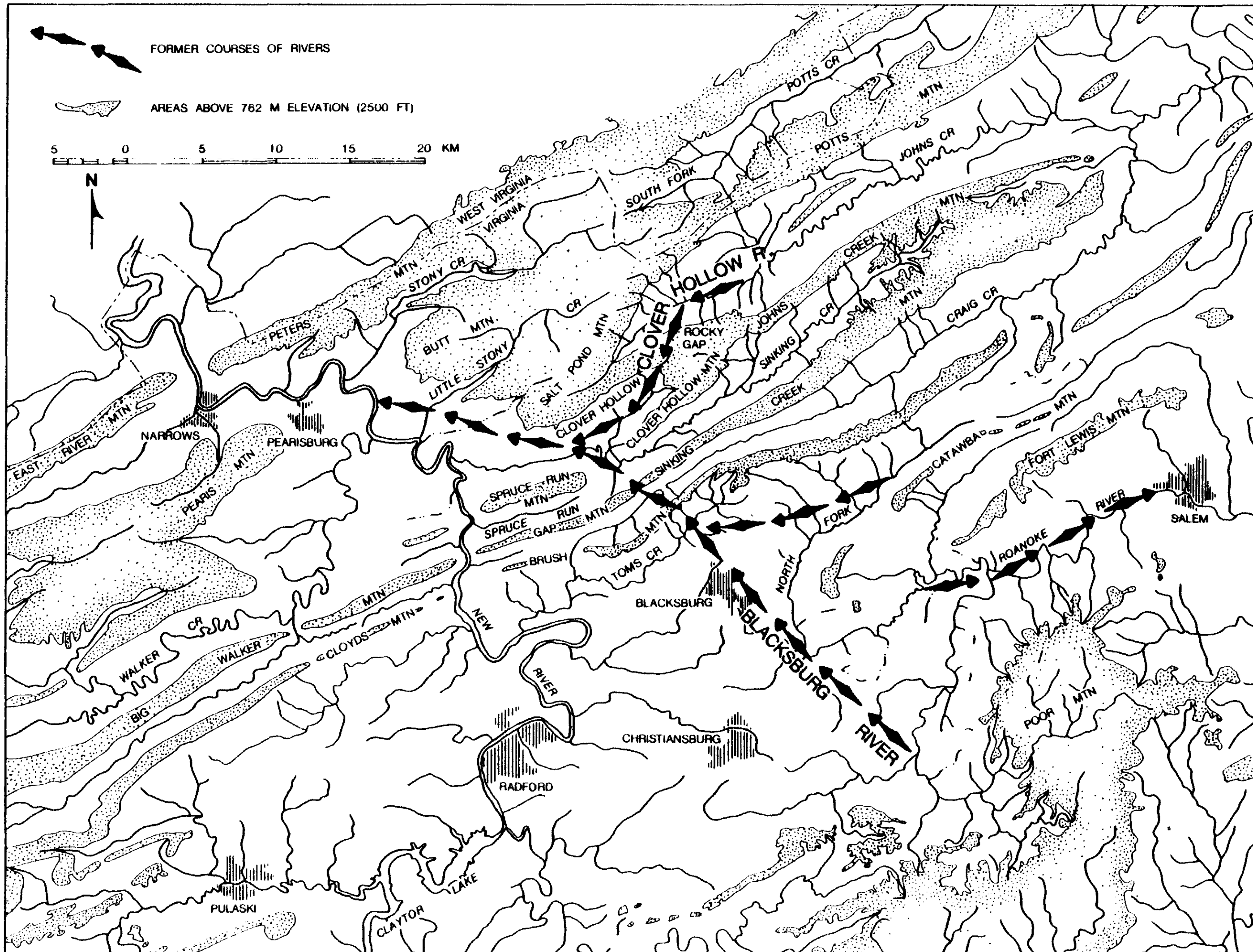


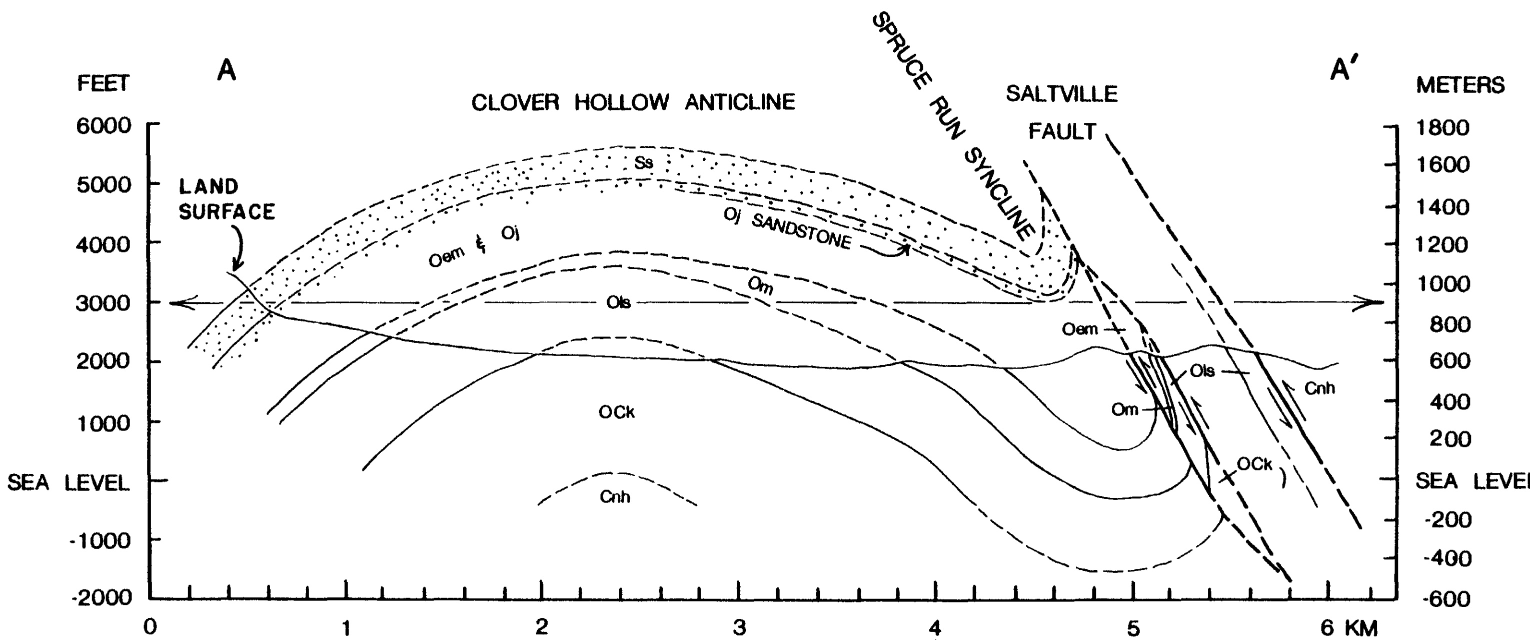
Figure 38.--Locations of the Blacksburg, and Clover Hollow Rivers during the interval 8-6 m.y. B.P.

have been an advantage in this hypothetical capture is that the Blacksburg River tributary flowed in an area of predominantly carbonate rock, which may have resulted in a gradient lower than that of the remnant of the County Line River. That the gradient of the County Line River may have been fairly high is suggested by the amount of clastic material that would have been supplied to it by Catawba, Brush, and Sinking Creek Mountains.

Evidence for the capture of the Blacksburg River by the Clover Hollow River is established by alluvial deposits near Divide Ridge at the head of Spruce Run valley and at the base of Butt Mountain north of Pembroke, and by the presence of abundant amphibole and epidote in the Tawneys-Smoke Hole cave system. The mechanism of capture was probably headward erosion by a tributary of the Clover Hollow River across an upward flexure in the Spruce Run syncline after the sandstone units had been eroded from the crest of the flexure (pl. 1). This flexure is   in the gap separating Spruce Run Mountain and Clover Hollow Mountain.

Most of the alluvium in Spruce Run valley appears to be a mixture of locally derived alluvium and reworked alluvium of the Blacksburg River. However, on Divide Ridge (sample loc. 24) and for 2.5 km to the southwest (pl. 2), the alluvial deposits contain 34 percent vein quartz and metaquartzite pebbles and cobbles and are interpreted to be unreworked deposits of the Blacksburg River. Also, the low rutile content of the heavy-mineral assemblage (5 percent) suggests that this alluvium was not deposited by the New River. Location of these deposits in the bottom of Spruce Run valley (rather than on the flanks of the valley) and on the drainage divide between the Greenbrier Branch and Spruce Run, where erosion is minimal, suggests that they may be remnants of channel and flood-plain alluvium deposited immediately prior to capture of the Blacksburg River. Analysis of the Z/T ratio (Chap. 5, fig. 34) indicates that the alluvium on Divide Ridge is about 8 m.y. old and had been deposited at an elevation of about 840 m (2750 ft) prior to letdown on the carbonate terrane.

Figure 39, which is a cross-sectional model of the Clover Hollow anticline and Spruce Run syncline drawn along the axis of the upward flexure perpendicular to the syncline (sec. A-A', pl. 1), shows that the elevation of the base of the upper sandstone unit of the Juniata Formation was about 910 m (2990 ft). The elevations of 910 m (2990 ft) for the base of the sandstone units over the upward flexure of the Spruce Run syncline and 840 m (2750 ft) for the original elevation of the youngest alluvial deposits of the Blacksburg River in Spruce Run valley are in good agreement for the proposed capture of the Blacksburg River after the sandstone had been eroded from the crest of the flexure. Taking the gradient of the



SILURIAN	Ss	SILURIAN SANDSTONE UNDIVIDED
ORDOVICIAN	Oj	JUNIATA FM.
	Oem	EGGLESTON AND MARTINSBURG FMS.
	Om	MOCCASIN FM.
	Ols	MIDDLE ORDOVICIAN LIMESTONE UNDIVIDED
CAMBRIAN	OCk	KNOX GROUP
	Cnh	NOLICHUCKY AND HONAKER DOLOMITE

Figure 39.--Structural cross section of the Clover Hollow anticline and Spruce Run syncline showing a reconstructed model of some of the rock units which have been removed by erosion. Horizontal line indicates elevation of the base of the sandstone in the Spruce Run syncline.

Blacksburg River into account, capture probably occurred at about 850 m (2790 ft) over the Spruce Run syncline, or about 8 m.y. B.P.

After being captured by the Clover Hollow River and diverted northwestward across the Spruce Run syncline, the Blacksburg River apparently flowed northwestward near the base of Johns Creek, Salt Pond, Doe, and Butt Mountains before joining the New River. Vein quartz and metaquartzite cobbles and polished, rounded sandstone cobbles were found throughout this area, reworked into all types of alluvium. The Z/T ratio and low rutile content (3 percent) of an unreworked alluvial deposit (sample loc. 66, fig. 34) at the base of Butt Mountain, 3 km north of Pembroke, indicates that the alluvium was deposited by the Blacksburg River about 7 m.y. ago at its present elevation of 783 m (2570 ft).

The elevation and age of the alluvial deposits on Divide Ridge and those north of Pembroke can be used as supporting evidence for both the postulated capture of the Blacksburg River by the Clover Hollow River and the reliability of the Z/T ratio lines. The elevation of the Blacksburg River southeast of the Spruce Run syncline at the time of capture can be calculated from the elevation of the alluvium on Divide Ridge; the elevation of the Clover Hollow River northwest of the Spruce Run syncline at the time of capture can be calculated from the age and elevation of the alluvium north of Pembroke.

Assuming a gradient of 1.7 m/km (9 ft/mi) for the Blacksburg River (the straight-line gradient of the modern New River), the elevation of the Blacksburg River at the capture point southeast of the Spruce Run syncline at about 8 m.y. is calculated by:

$$840\text{ m}+[(1.7\text{ m/km})\cdot(3.2\text{ km})]\simeq 845\text{ m}$$

$$(2750\text{ ft}+[(9\text{ ft/mi})\cdot(2\text{ mi})]\simeq 2770\text{ ft}),$$

where

840 m = the elevation of the alluvium on Divide Ridge at the time of deposition as determined by the Z/T ratio,

and

(1.7 m/km)·(3.2 km) = the elevation gain as a function of gradient and distance between Divide Ridge and the hypothetical capture point.

Elevation of the Clover Hollow River at the capture point northwest of the Spruce Run syncline at about 8 m.y. is calculated by:

$$783\text{ m}+[(8\text{ m.y.}-7\text{ m.y.})\cdot(40\text{ m/m.y.})]$$
$$+[(1.7\text{ m/km})\cdot(14\text{ km})]\simeq 850\text{ m}$$

$$(2570\text{ ft}+[(8\text{ m.y.}-7\text{ m.y.})\cdot(130\text{ ft/m.y.})]$$
$$+[(9\text{ ft/mi})\cdot(8.7\text{ mi})]\simeq 2785\text{ ft}),$$

where

783 m = the present elevation (and the assumed elevation at the time of deposition) of the alluvium north of Pembroke,

[(8 m.y.-7 m.y.)•(40 m/m.y.)]=40 m = the amount of downcutting of the Blacksburg River between the time it was captured and the time the alluvium was deposited,

and

[(1.7 m/km)•(14 km)] = the elevation gain as a function of gradient and distance between the alluvial deposit and the hypothetical capture point.

The similarity of calculated elevations of the two rivers at the time of capture, 845 m and 850 m (2770 ft and 2785 ft), supports the hypothesis that the Blacksburg River was captured by the Clover Hollow River, and tends to verify the internal consistency of the Z/T ratio lines.

Drainage adjustments 6 m.y. B.P. to present

Figure 40 shows the modern drainage of the area. In this last configuration, Johns Creek is shown to have captured the headwaters of Clover Hollow River and to have

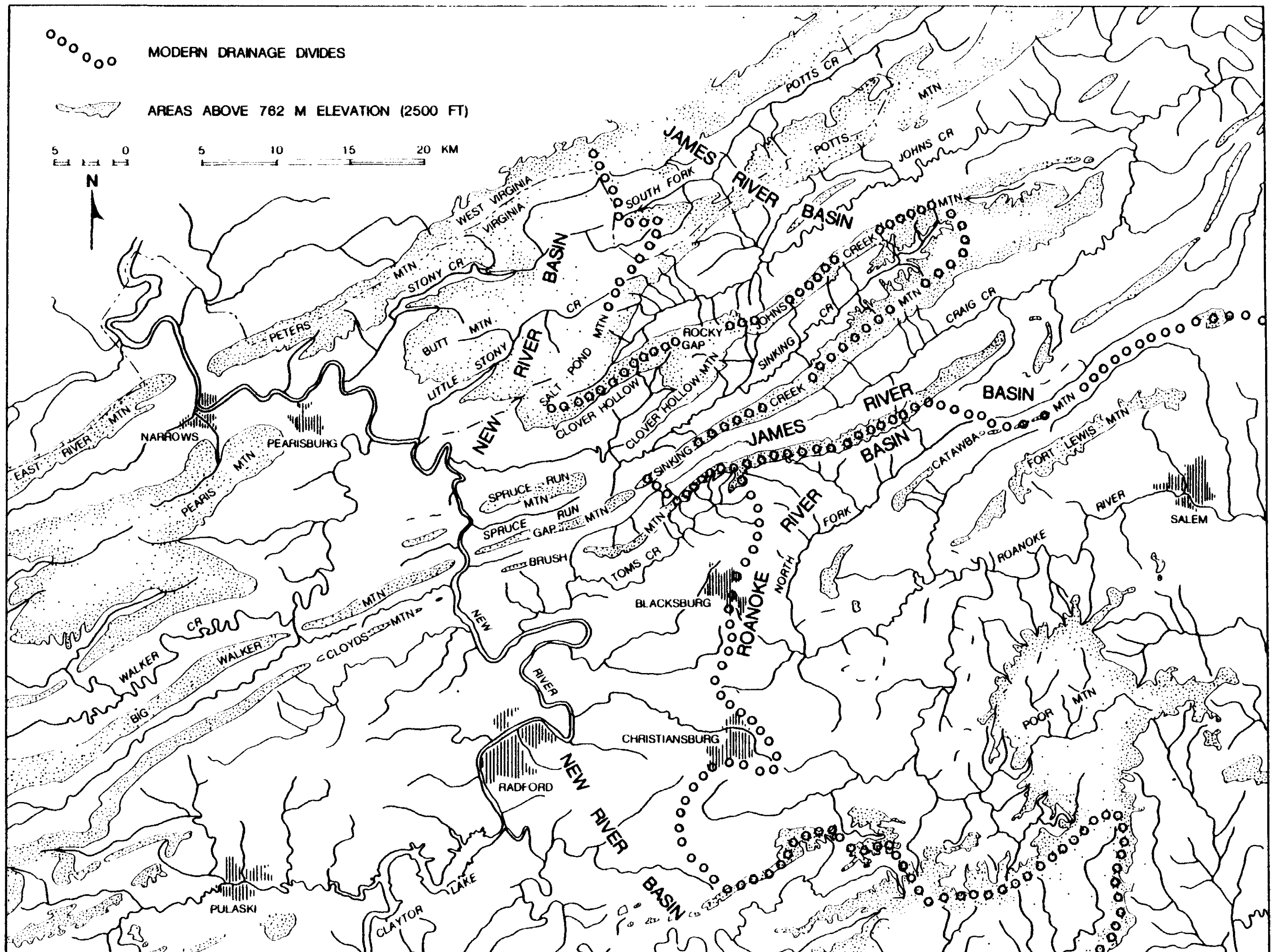


Figure 40.--Modern drainage of the study area in Virginia.

drained all of the Johns Creek syncline to the northeast. The Blacksburg River has been captured by the Roanoke River, and the presence of barbed stream patterns between Christiansburg and the Blue Ridge indicates that headward erosion by tributaries of the Roanoke River is continuing.

The approximate time of capture of the Blacksburg River, 6 m.y. B.P., is calculated from the elevation of alluvium preserved in the wind gap between Sinking Creek Mtn. and Gap Mountain. Location of the alluvium at the lowest point in the gap suggests that it is a channel deposit and was probably deposited a relatively short time before or after capture of the headwaters of the river.

The assumption that elevation of this wind gap (758 m (2486 ft)) represents the approximate time of capture of the Blacksburg River is supported by similar elevation of the wind gap on Brush Mountain (777 m (2550 ft)), which would have been abandoned at the same time. The gradient of a stream flowing between the two gaps would be 6 m/km (32 ft/mi). This is a fairly high gradient (higher than modern Sinking Creek, for example). The high gradient suggests that the elevation of one or both of the gaps may have been modified by a small stream which continued to flow in the river channel for a short time following the capture.

CHAPTER 7

SUMMARY

This is an investigation of the surficial geology and geomorphology of part of the New River drainage basin in Giles County, Virginia. The surficial materials (particularly alluvium) were classified and mapped, and their heavy minerals were identified. Data derived from the study of the surficial materials, in conjunction with other field observations, have led to a number of diverse conclusions regarding deposition and (or) accumulation of surficial materials and evolution of the drainage system of the area. The more important conclusions and observations are listed below, in the order of their discussion in the text.

1. Bouldery surficial materials on ridge flanks are transported downslope primarily by running water in intermittent stream channels during floods and by debris avalanche. Because water plays the major role in the transport of these materials, in this investigation the bouldery deposits of the ridge flanks are classified and mapped as alluvium rather than colluvium. The term "colluvium" is restricted to materials near ridge crests where stream-channel incisement is not present or is minimal.

The distinction between alluvium and colluvium is, in part, a somewhat artificial semantic problem because of the gradational nature of the boundary separating primarily gravitational transport mechanisms from mechanisms which are primarily hydrological. It is nonetheless an important distinction because of the difference in the relative speed of transport which can be accomplished by the two mechanisms. Transport of surficial materials by water is much faster, and therefore the average age of the bouldery materials on ridge flanks is probably younger than if the detritus were being moved downslope by gravity alone.

2. Nonquartzose igneous and metamorphic clasts do not survive transport distances of more than a few tens of kilometers in the fluvial systems of the Central and Southern Appalachians. These lithologies (schists, gneisses, and so forth) disaggregate to the scale of individual mineral grains and are transported as sand and silt-size particles.

   Clasts of Blue Ridge-derived quartzose rocks which show sheared to mylonitic textures and presumably were derived from cataclastic zones are preferentially enriched relative to clasts of unsheared quartzose rocks. Coarsely crystalline, milky colored vein quartz is rare as clasts larger than pebbles.

The most common lithology among cobble-size clasts is unfractured colorless to very pale red or yellow quartz consisting of moderate-size equidimensional crystals.

3. Perhaps the most important observation is that in a humid, temperate climate surficial materials tend to be preserved if they overlie bedrock which weathers chemically but tend to be eroded from bedrock which weathers mechanically. Preferential preservation is caused by the paucity of surface runoff in carbonate terrains as compared to areas of clastic bedrock. In carbonate terrains, surficial materials are let down in place by solution of the underlying limestone--in areas of clastic bedrock, surficial materials are carried away by surface streams. Thus, carbonate-floored valleys are characterized by a layer of residuum and alluvium which is nearly continuous and varies in thickness from a few centimeters to greater than 50 m.

Some previous investigators have thought this layer of surficial materials to be anomalous in terms of the present erosional regime. They have called upon significantly different past climates and (or) the formation and preservation of old erosion surfaces to explain the presence of the deposits of residuum and alluvium. However, special conditions are not required to explain either the distribution or the thickness of deposits of surficial materials in limestone and dolomite valleys if it is realized that they have been accumulating in a piecemeal fashion over a time period which, in some areas, may include all of Cenozoic time.

4. Analysis of the transparent heavy-mineral assemblages contained in the modern alluvium and older alluvial deposits of the area indicates that radiation-damaged zircon (intermediate and metamict) is unstable under conditions of subaerial weathering. Earlier workers have suggested that zircon is dissolved by acid ground water. This study supports these earlier suggestions and further demonstrates in a semiquantitative manner that the solution rate of radiation-damaged zircon may be a linear function of time as measured against either tourmaline or normal zircon. The estimated period of time over which the solution rate of zircon appears to be linear is on the order of 10 m.y.

5. The areal distribution and lithology of alluvial deposits provide evidence which can be used to reconstruct the late Cenozoic evolution of part of the New River drainage system within the Valley and Ridge Province.

These data, in conjunction with assumptions involving lithologic and structural variations within the stratigraphic section which has been removed by erosion, suggest that the James and Roanoke Rivers have captured three northeastern tributaries of the New River during the Neogene. Within this time period no evidence was found of major changes in the course of the New River itself (except for meander loops) between Radford and Narrows.

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APPENDIX

Description of Sample Localities

Sample locality No.	Description
10	Older alluvium: Valley and Ridge tributary alluvium; Clover Hollow River(?); at least 6 m thick. Elevation: sample 610 m (2000 ft); top of deposit not mapped; maximum height of deposit above modern drainage not known. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; northeast side of county road 685 - 0.1 km north of junction of 685 and 601. Exposure: roadcut, 3 m high. Comments: clasts of Paleozoic sedimentary rocks; majority of clasts are subrounded to rounded; some clasts are stream polished; maximum clast size is 0.5 m; chert fragments are highly weathered.
11	Older alluvium: Valley and Ridge tributary alluvium; Clover Hollow River; ≥5 m thick. Elevation: sample 658 m (2160 ft); top of deposit not mapped; maximum height of deposit above modern drainage not known. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; north side of county road 639, 0.2 km east of junction of 639 and 601. Exposure: roadcut and pit silo, 3 m high. Comments: clasts of Paleozoic sedimentary rocks; maximum clast size is 0.7 m; some of the clasts are well rounded and well polished (fig. A1A); some orthoquartzite clasts exposed in the walls of the pit silo are deeply weathered (fig. A1B).

A

B

Figure A1.--Alluvium at sample locality 11. A, A mixture of angular to well-rounded sandstone clasts in the road cut. B, Weathered sandstone boulder, 0.3 m to the left of the hammer, exposed in the wall of the pit silo. The freshly broken surface of this clast crumbled to sand when touched.

Sample locality No.	Description
12	Colluvium: colluvial soil; $\gtrsim$1 m thick. Elevation: sample 957 m (3140 ft). Location: Newport, Va., 7 1/2-minute quad.; Giles-Craig Co. line; northwest side of county road 601 - 0.3 km southwest of junction of 601 and Appalachian Trail at Rocky Gap. Exposure: roadcut, $\sim$1 m high. Comments: colluvial soil composed of sandy loam and unsorted Ordovician, Silurian, and Devonian(?) sandstone clasts ranging in size from pebbles to boulders.
13	Residuum: $\sim$5 m thick. Elevation: sample - 740 m (2430 ft). Location: Newport, Va., 7 1/2-minute quad.; Craig Co.; southeast side of county road 630 - 1.8 km from junction of 630 and State road 42. Exposure: roadcut and hill slope. Comments: residual soil developed on the Eggleston Formation or the lower part of the Martinsburg Formation; overlain by first-stage alluvium.
14	Older alluvium: Valley and Ridge tributary alluvium; Sinking Creek; $\sim$7 m thick. Elevation: sample 658 m (2160 ft); top of deposit not mapped; maximum height of deposit above modern drainage not known. Location: Newport, Va., 7 1/2-minute quad.; Craig Co.; west side of county road 630, 0.5 km south of junction of 630 and 629.

Sample locality No.	Description
14 (Con.)	Exposure: cut bank on a hillside above farm road, ~2 m high.
	Comments: clasts of Paleozoic sedimentary rocks; mixture of angular chert fragments and subrounded to rounded cobbles.
15	Older alluvium: Valley and Ridge tributary alluvium; Sinking Creek; 8-10 m thick.
	Elevation: sample 600 m (1970 ft); top of deposit 689 m (2260 ft); maximum height of deposit above modern drainage 93 m (305 ft).
	Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; southeast bank of Sinking Creek, at a farm-road bridge, 1.4 km southwest of Giles-Craig Co. line.
	Exposure: eroded bank outside a curve of Sinking Creek, 3-5 m high.
	Comments: clasts of Paleozoic sedimentary rocks; very poorly sorted sand to boulders in silty clay matrix.
16	Older alluvium: Valley and Ridge tributary alluvium; Sinking Creek; ≥1 m thick.
	Elevation: sample 619 m (2030 ft); top of deposit 664 m (2180 ft); maximum height of deposit above modern drainage 101 m (330 ft).
	Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; hillside 0.25 km northwest of the junction of Virginia route 42 and old U.S. route 460 at Newport.
	Exposure: gullies as much as 1 m deep on hillside.

Sample locality No.	Description
16 (Con.)	Comments: poorly exposed alluvial deposit containing pebbles and cobbles as the most obvious clast sizes in dark, reddish-brown, silty soil; most of the clasts are of Paleozoic sedimentary rocks; about 10 percent of the clasts are of Blue Ridge-derived quartzose rocks.
17	Older alluvium: Valley and Ridge tributary alluvium; cave system in Sinking Creek Valley; at least 2 m thick. Elevation: sample 549 m (1800 ft); top of deposit not mapped; maximum height of deposit above modern drainage not known. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; north side of U.S. route 460, 1.2 km east of junction of U.S. 460 with county road 730. Exposure: roadcut, 2 m high. Comments: clasts of Paleozoic sedimentary rocks; subangular to rounded; sizes range from clay through small boulders; many chert pebbles are highly polished.
18	Residuum: 8 m thick. Elevation: sample 655 m (2150 ft). Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; southwest side of U.S. route 460, across the road from the Newport cemetary. Exposure: roadcut, ~10 m high. Comments: residuum developed on carbonate rock of the Knox Group; consists of clay, chert and limestone fragments, and abundant manganese oxide nodules; the dominant clay mineral is smectite.

Sample locality No.	Description
19	Older alluvium: New River alluvium; 5 m or more thick.
	Elevation: sample 533 m (1750 ft); top of deposit 637 m (2090 ft); maximum height of deposit above modern drainage 155 m (510 ft).
	Location: Pearisburg, Va., 7 1/2-minute quad.; Giles Co.; northeast side of U.S. route 460, 0.3 km southeast of the bridge over the New River.
	Exposure: roadcut, 2 m high.
	Comments: alluvium containing clasts of Paleozoic sedimentary rocks and Blue Ridge-derived quartzose clasts; figure A2 shows the general appearance of the deposit in a roadcut 0.8 km northeast of the sample location; most clasts are well rounded; sizes range from clay to boulders (0.5 m, long axis); lithologies of the cobble-size clasts are as follows: 42 percent vein quartz, 11 percent metaquartzite, 27 percent orthoquartzite, 17 percent Rose Hill sandstone, 3 percent chert; lithologies of boulders are 8 percent vein quartz and metaquartzite and 92 percent orthoquartzite and sandstone.
20	Older alluvium: Valley and Ridge tributary alluvium; Sinking Creek; at least 3 m thick.
	Elevation: sample 518 m (1700 ft); top of deposit 527 m (1730 ft); maximum height of deposit above modern drainage 18 m (60 ft).
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; east side of county road 772, 0.1 km southeast of bridge across Sinking Creek.
	Exposure: roadcut about 3 m high.

Figure A2.--Outcrop of New River alluvium containing abundant large, rounded clasts east of the New River near Pearisburg, Virginia.

Sample locality No.	Description
20 (Con.)	Comments: Sinking Creek alluvium and reworked New River alluvium; lithologies of the cobble-size clasts are as follows: 4 percent vein quartz, 4 percent metaquartzite, 51 percent orthoquartzite, 26 percent Rose Hill sandstone, 13 percent chert, 2 percent iron oxide nodules; general appearance of the deposit is shown in figure A3.
21	Older alluvium: New River alluvium; at least 1 m thick.
	Elevation: sample 607 m (1990 ft); top of deposit 678 m (2225 ft); maximum height of deposit above modern drainage 183 m (600 ft).
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co., northwest side of county road 682, 1.2 km northeast of the New River.
	Exposure: roadcut, 1 m high.
	Comments: This alluvial deposit is poorly exposed with the exception of two large rock-piles near the edge of a field; lithologies of the cobble-size clasts in one of the rockpiles adjacent to county road 682 are as follows: 82 percent Blue Ridge-derived quartzose clasts, 10 percent orthoquartzite, 8 percent Rose Hill sandstone.
22	Older alluvium: Valley and Ridge tributary alluvium; Spruce Run; as much as 8 m thick.
	Elevation: sample 573 m (1880 ft); top of deposit 671 m (2200 ft); maximum height of deposit above modern drainage 107 m (350 ft).
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; north side of county road 605, 0.2 km northeast of Spruce Run Church.
	Exposure: roadcut, 8 m high.

Figure A3.--Outcrop of Sinking Creek alluvium at sample locality 20. This exposure is typical of many Valley and Ridge-derived alluvial deposits.

Sample locality No.	Description
22 (Con.)	Comments: abundant rounded orthoquartzite and Rose Hill sandstone clasts; abundant chert; minor number of angular orthoquartzite boulders as much as 0.6 m (long axis); two Blue Ridge-derived quartzose cobbles were seen.
24	Older alluvium: Blacksburg River alluvium; at least 1.5 m thick. Elevation: sample 683 m (2240 ft); top of deposit 707 m (2320 ft); maximum height of deposit above modern drainage 209 m (685 ft). Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; north side of county road 605, at Divide Ridge, 1.9 km southwest of junction of 605 with U.S. route 460. Exposure: roadcut, 1.5 m high. Comments: poorly exposed alluvial deposit containing Blue Ridge-derived quartzose clasts and clasts of Paleozoic sedimentary rocks; lithologies of the cobble-size clasts are as follows: 32 percent vein quartz, 2 percent metaquartzite, 13 percent orthoquartzite, 48 percent Rose Hill sandstone, 5 percent chert.
25	Residuum: at least 2 m thick. Elevation: sample 664 m (2180 ft). Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; northwest side of county road 605, 1.6 km southwest of the junction of 605 with U.S. route 460. Exposure: roadcut, 2 m high.

Sample locality No.	Description
25 (Con.)	Comments: Clayey and silty residuum developed on carbonate rock of the lower part of the Knox Group; contains "ghosts" of weathered chert fragments.
26	Older alluvium: first-stage, second-stage, and Valley and Ridge tributary alluvium (Sinking Creek); 7-8 m thick.
	Elevation: sample 536 m (1760 ft); top of deposit not applicable, see Comments.
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; south side of county road 730 at the junction of 730 with U.S. route 460.
	Exposure: roadcut, 7 m high.
	Comments: alluvium deposited by a high-energy, intermittent stream which drained the northwest side of Spruce Run Mountain in this area; the deposit displays channeling and high-angle crossbedding and contains a mixture of reworked alluvium. Figure A4 shows three fining-upward sediment cycles which may represent mudflows.
27	Older alluvium: second-stage alluvium; at least 1 m thick.
	Elevation: sample 637 m (2090 ft); top of deposit 707 m (2320 ft); maximum height of deposit above modern drainage 85 m (280 ft).
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; south side of unnumbered road 0.6 km southwest of junction with U.S. route 460; junction of unnumbered road with 460 is 0.3 km northwest of junction of 460 and Virginia route 42.
	Exposure: roadcut, 1 m high.

Figure A4.--Three fining-upward sediment units possibly deposited as mudflows near the mouth of a small intermittent stream. Dashed lines mark the top and bottom of the middle cycle.

Sample locality No.	Description
27 (Con.)	Comments: poorly sorted alluvium ranging in size from silt to boulders, 0.25 m (long axis); clasts of Paleozoic sedimentary rocks; abundant angular Copper Ridge Sandstone fragments.
28	Older alluvium: Valley and Ridge tributary alluvium; Greenbrier Branch(?); at least 3 m thick. Elevation: sample 689 m (2260 ft); top of deposit 707 m (2320 ft); maximum height of deposit above modern drainage 128 m (420 ft). Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; southwest side of U.S. route 460, 1.1 km northwest of the intersection of 460 with the Giles-Montgomery Co. line. Exposure: roadcut, 3 m high. Comments: clasts of Paleozoic sedimentary rocks and rare Blue Ridge-derived quartzose rocks; silt and clay-size fractions are dark reddish brown.
30	Modern alluvium: Little River. Location: Va.; Floyd-Montgomery Co. line; intersection of Little River and Virginia route 8. Comments: one sample collected from the stream channel; two samples collected from sandy bank areas.
31	Modern alluvium: Little River. Location: Va.; Pulaski-Montgomery Co. line; intersection of Little River and county road 693 at Snowville.

Sample locality No.	Description
31 (Con.)	Comments: two samples collected from the stream channel; one sample collected from a sandy bank.
32	Modern alluvium: New River. Location: Va.; Pulaski Co.; county road 693 at Allisonia. Comments: two samples collected from the stream channel; one sample collected from a sandy bank.
33	Modern alluvium: Big Reed Island Creek. Location: Va.; Pulaski Co.; intersection of Big Reed Island Creek and county road 693 between Allisonia and Sylvatus. Comments: three samples collected from the stream channel; one sample collected from a sandy bank.
34	Modern alluvium: New River. Location: Va.; Wythe Co.; intersection of New River with Virginia route 100. Comments: samples collected from bank.
35	Modern alluvium: New River. Location: N.C.; Alleghany Co.; intersection of U.S. route 21 and New River, between Independence, Va., and Twin Oaks, N.C. Comments: samples collected from bank.

Sample locality No.	Description
36	Modern alluvium: South Fork of the New River. Location: N.C.; Ashe Co.; intersection of South Fork of the New River with U.S. route 221 southwest of Scottville, N.C. Comments: samples collected from bank.
37	Modern alluvium: North Fork of the New River. Location: N.C.; Ashe Co.; intersection of North Fork of the New River with N.C. route 16 near Crumpler, N.C. Comments: samples collected from bank.
38	Older alluvium: New River alluvium; at least 3 m thick. Elevation: sample 578 m (1895 ft); top of deposit on clastic bedrock 625 m (2050 ft); top of deposit on carbonate bedrock 585 m (1920 ft); maximum height of deposit above modern drainage 116 m (380 ft) on clastic bedrock and 76 m (250 ft) on carbonate bed-rock. Location: Radford North, Va., 7 1/2-minute quad.; Montgomery Co.; along county road 652 just west of the junction of 652 with county road 696. Exposure: roadcuts, 3 m high. Comments: contains major amounts of both Blue Ridge-derived quartzose clasts and clasts of Paleozoic sedimentary rocks; also contains clasts of highly weathered metamorphic rocks and rocks of unknown original lithologies; X-ray diffraction patterns of crushed whole-rock samples show that these highly weathered rocks are composed of clay minerals, quartz, and hematite.

Sample locality No.	Description
39	Modern alluvium: New River. Location: Radford North, Va., 7 1/2-minute quad.; Montgomery Co.; between Brush Mountain and Gap Mountain. Comments: sample collected from a sand bar about 0.1 km downstream from the mouth of Norris Run.
40	Modern alluvium: Spruce Run. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at a bridge on county road 605 across Spruce Run, 6.6 km southwest of the junction of 605 with U.S. route 460. Comments: sample collected from the stream channel.
41	Modern alluvium: Spruce Run. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at a bridge on county road 605 across Spruce Run, near Oakview Church, 5.0 km southwest of the junction of 605 with U.S. route 460. Comments: sample collected from the stream channel.
42	Modern alluvium: Spruce Run. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; near the head of Spruce Run, 0.4 km southwest of Divide Ridge; 0.15 km southwest of county road 605. Comments: stream is intermittent; sample collected from several shallow gullies which make up the stream channel.

Sample locality No.	Description
43	Modern alluvium: Clover Hollow Creek. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 601, 0.6 km northeast of junction of 601 with county road 604. Comments: sample collected from stream channel.
44	Modern alluvium: Clover Hollow Creek. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; at farm-road bridge across Clover Hollow Creek adjacent to county road 601, 0.6 km northeast of the junction of 601 with county road 685. Comments: sample collected from stream channel.
45	Modern alluvium: Clover Hollow Creek. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 601, 0.3 km southwest of the junction of 601 with county road 639. Comments: sample collected from dry stream channel.
50	Modern alluvium: Sinking Creek. Location: Newport, Va., 7 1/2-minute quad.; Craig Co.; adjacent to county road 629, 1.1 km east of the junction of 629 with Virginia route 42. Comments: sample collected from stream channel.

Sample locality No.	Description
51	Modern alluvium: Sinking Creek. Location: Newport, Va., 7 1/2-minute quad.; Craig Co.; at the bridge on county road 630 across Sinking Creek, 0.1 km southeast of the junction of 630 and Virginia route 42, 1.0 km southwest of Huffman. Comments: sample collected from stream channel.
52	Modern alluvium: Sinking Creek. Location: Newport, Va., 7 1/2-minute quad.; Craig Co.; at a farm-road bridge across Sinking Creek 0.2 km southeast of Virginia route 42, 1.0 km northeast of Giles-Craig Co. line. Comments: sample collected from stream channel.
53	Modern alluvium: Sinking Creek. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; adjacent to a farm road 0.2 km southeast of Virginia route 42, 1.8 km northeast of the junction of 42 with county road 604. Comments: very bouldery stream bed; sandy sediment was collected with difficulty from interstices among the boulders.
54	Modern alluvium: Sinking Creek. Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 604, 0.7 km northwest of the junction of 604 with Virginia route 42. Comments: sample collected from stream channel; sample area is 0.5 km downstream from a mill dam.

Sample locality No.	Description
55	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; south side of Sinking Creek, 0.1 km upstream from the bridge on county road 700 across Sinking Creek. Comments: sample collected from sandy bank adjacent to the stream.
55a	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 604, 0.3 km southeast of the junction of 604 with county road 603. Comments: sample collected from stream channel.
55b	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; south side of Sinking Creek, 0.2 km upstream from the bridge on county road 700 across Sinking Creek. Comments: sample collected from a sandy bank upstream from the area where the spring from Tawneys Cave enters the creek.
55c	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 604, 0.2 km northwest of the junction of 604 with county road 603. Comments: sample taken from stream channel upstream from the point where the spring from Smoke Hole Cave enters Sinking Creek.

Sample locality No.	Description
56	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at the U.S. route 460 bridge across Sinking Creek near the Lucas Memorial Chapel. Comments: sample collected from a large bar in the middle of the stream.
57	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at the bridge on county road 625 across Sinking Creek. Comments: sample collected from dry stream bed.
58	Modern alluvium: Sinking Creek. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at an old ford adjacent to county road 772, 2.5 km southwest of the junction of 772 with U.S. route 460. Comments: sample collected from dry stream bed.
60	Modern alluvium: New River. Location: Narrows, Va., W. Va., 7 1/2-minute quad.; Giles Co.; adjacent to U.S. route 460, 5 km northwest of Narrows, Va. Comments: sample collected from a sandy beach.
61	Older alluvium: New River alluvium; at least 1 m thick. Elevation: sample 536 m (1760 ft); top of deposit 582 m (1910 ft); maximum height of deposit above modern drainage 78 m (255 ft).

Sample locality No.	Description
61 (Con.)	<u>Location</u>: Radford North, Va., 7 1/2-minute quad.; Montgomery County; adjacent to a graded road 0.1 km east of county road 625, 0.8 km north of the junction of 625 with county road 652.
	<u>Exposure</u>: roadcut, 1 m high.
	<u>Comments</u>: poorly exposed alluvial deposit of the New River; typical exposure is boulders and cobbles scattered about on the ground surface.
65a	<u>Older alluvium</u>: Valley and Ridge tributary alluvium; Sinking Creek; as much as 5 m thick.
	<u>Elevation</u>: sample 543 m (1780 ft); top of deposit 561 m (1840 ft); maximum height of deposit above modern drainage 30 m (100 ft).
	<u>Location</u>: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; south side of U.S. route 460, 0.2 km east of the junction of 460 with county road 730.
	<u>Exposure</u>: roadcut, about 7 m high.
	<u>Comments</u>: thick sequence of silty sand with indistinct horizontal bedding, possibly an overbank deposit; separated in places from the underlying carbonate bedrock by 15-30 cm of well-sorted, fine- to medium-grained sand.
66	<u>Older alluvium</u>: Blacksburg River alluvium; at least 1 m thick.
	<u>Elevation</u>: sample 786 m (2580 ft); top of deposit 786 m (2580 ft); maximum height of deposit above modern drainage 305 m (1000 ft).
	<u>Location</u>: Pearisburg, Va., 7 1/2-minute quad.; Giles Co.; adjacent to county road 688, 2.3 km northwest of the junction of 688 with county road 623.

Sample locality No.	Description
66 (Con.)	Exposure: roadcuts, 0.5-1.0 m high, on either side of a farm-road gate. Comments: abundant, well-rounded Rose Hill sandstone cobbles and Blue Ridge-derived quartzose cobbles exposed in the unpaved road and on the shoulders; a collection of typical clasts is shown in figure A5.
74	Older alluvium: New River alluvium; about 3 m thick. Elevation: sample 524 m (1720 ft); top of deposit 530 m (1740 ft); maximum height of deposit above modern drainage 26 m (85 ft). Location: Radford North, Va., 7 1/2-minute quad.; Montgomery Co.; east side of county road 625, 0.8 km north of the junction of 625 with county road 652. Exposure: vegetated roadcut, 3 m high. Comments: New River alluvial deposit, downslope and separated from the base of the New River alluvial deposit represented by sample 61 by a 12-m (40-ft) erosional scarp.
75	Older alluvium: New River alluvium; at least 2 m thick. Elevation: sample 518 m (1700 ft); top of deposit 555 m (1820 ft); maximum height of deposit above modern drainage 61 m (200 ft). Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at the outside of a right-angle turn on county road 730, 0.9 km east of the bridge on 730 across the New River. Exposure: roadcut, 2 m high, on an abandoned road that intersects county road 730.

Figure A5.--Clasts of Blacksburg River alluvium near sample locality 66. The well-rounded cobble to the left of the hammer is Blue Ridge-derived vein quartz or meta-quartzite. The sandstone boulder at the end of the hammer handle may be derived from local first-stage alluvium.

Sample locality No.	Description
75 (Con.)	Comments: areally extensive but poorly exposed New River alluvial deposit; probably consists of both point-bar and overbank deposits.
77	Older alluvium: New River alluvium; at least 2 m thick.
	Elevation: sample 521 m (1710 ft); top of deposit 548 m (1800 ft); maximum height of deposit above modern drainage 56 m (185 ft).
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; at the end of the county-maintained part of county road 617, 0.2 km east of the New River.
	Exposure: gravel bank, about 1.5 m high, on farm road just south of county road 617.
	Comments: poorly exposed New River alluvial deposit; top of deposit assumed to be at an abrupt break in slope at about 548 m (1800 ft).
78	Older alluvium: Valley and Ridge tributary alluvium; at least 1.5 m thick.
	Elevation: sample 613 m (2010 ft); top of deposit not mapped; maximum height of deposit above modern drainage not known.
	Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; on the inside of a right-angle turn on county road 617, about 0.75 km west of Hoges Chapel.
	Exposure: roadcut, 1 m high.
	Comments: silt through cobble-size alluvium; subrounded to rounded; clasts are of Paleozoic sedimentary rocks with rare clasts of Blue Ridge-derived quartzose rocks.

Sample locality No.	Description
79	Older alluvium: Blacksburg River; at least 0.5 m thick. Elevation: sample 677 m (2220 ft); top of deposit 678 m (2225 ft); maximum height of deposit above modern drainage 180 m (590 ft). Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; in a clearing on the northwest side of Sinking Creek Mountain, 0.85 km north-northwest of the gap on Gap-Sinking Creek Mountain and 1.25 km east-southeast of Newport. Exposure: pebbles and cobbles in a plowed field and the root pit of an uprooted tree. Comments: poorly exposed alluvial deposit; cobbles and pebbles of Blue Ridge-derived quartzose rocks are common to abundant; some boulders composed of vitreous Paleozoic orthoquartzite are as much as 0.75 m across and show well-developed percussion marks.
80	Older alluvium: Blacksburg River alluvium; 3-4 m thick. Elevation: sample 758 m (2486 ft); top of deposit 760 m (2495 ft); maximum height of deposit above modern drainage 260 m (853 ft). Location: Newport, Va., 7 1/2-minute quad.; Giles Co.; northwest side of a jeep trail just northeast of U.S. route 460 at the gap between Gap Mountain and Sinking Creek Mountain. Exposure: vegetated roadcut, 3 m high. Comments: alluvial deposit incompletely cemented with goethite; contains abundant angular to subrounded boulders and cobbles of Paleozoic orthoquartzite and sparse to common, well-rounded, Blue Ridge-derived quartzose cobbles (fig. A6).

Figure A6.--Exposure of goethite-cemented Blacksburg River alluvium at sample locality 80. Much of the rock on the left side of the photograph is massive goethite. The cobble immediately to the left of the hammer is vein quartz.

Sample locality No.	Description
81	Modern alluvium: stream in Tawneys Cave. Location: Eggleston, Va., 7 1/2-minute quad.; Giles Co.; 0.2 km north of county road 604, between county roads 603 and 700. Comments: sample taken from the stream in Tawneys Cave, near the southwest entrance.