DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

SURFICIAL GEOLOGY OF THE FLETCHER, MADISON, STANARDSVILLE, AND SWIFT RUN GAP, 7.5-MINUTE QUADRANGLES, MADISON, GREENE, ALBEMARLE, ROCKINGHAM, AND PAGE COUNTIES, VIRGINIA

BY L. SCOTT EATON, B.A. MORGAN, AND J. L. BLAIR

OPEN-FILE REPORT 01-92

2001

SURFICIAL GEOLOGY OF THE FLETCHER, MADISON, STANARDSVILLE, AND SWIFT RUN GAP, 7.5-MINUTE QUADRANGLES, MADISON, GREENE, ALBEMARLE, ROCKINGHAM, AND PAGE COUNTIES, VIRGINIA

L. Scott Eaton, Benjamin A. Morgan, and J. Luke Blair

INTRODUCTION

The surficial geology of the upper Rapidan River basin and adjacent areas in Madison and Greene Counties was investigated as part of a cooperative program funded by the U. S. Geological Survey (USGS) with the National Park Service (NPS) at Shenandoah National Park (SHEN). The investigations were extended at the request of the Federal Emergency Management Agency (FEMA) following a severe storm in the upper Rapidan basin on June 27, 1995. The resulting debris flows, and evidence of a long history of recurring debris flows in the area became the basis of a Ph.D. dissertation at the University of Virginia (Eaton, 1999). The information resulting from all of these investigations (Eaton and McGeehin, 1997; Morgan and others 1997, 1999a, 1999b; Eaton, 1999; Wieczorek and others, 2000) has been used by FEMA, NPS, and by local county governments to provide better emergency protection to citizens and visitors in the area, and to plan for mitigation of some of the effects of these periodic disasters which affect all of Virginia's Appalachian mountain region. In the course of these studies, the surficial geology of a broad area along the eastern flanks of the Blue Ridge in Madison and Greene Counties was examined and mapped to understand the relationship between the debris-flow event of 1995 and a long history of prehistoric debris-flow activity in the region. This report includes surficial geology maps of the eastern flanks of the Blue Ridge within western Greene and Madison Counties consisting of the upper Rapidan basin and adjacent Swift Run, North Fork of the Rivanna River, and Robinson River basins (**Figure 1**). The maps are compiled on the Madison, Fletcher, Stanardsville, and Swift Run Gap 7.5’ l/24,000-scale quadrangles (**Plates I-IV)**. The accompanying text includes a description of the deposits, and discussion of late Pleistocene and Holocene history of the region based on the stratigraphy and carbon-14 ages of many of the deposits.

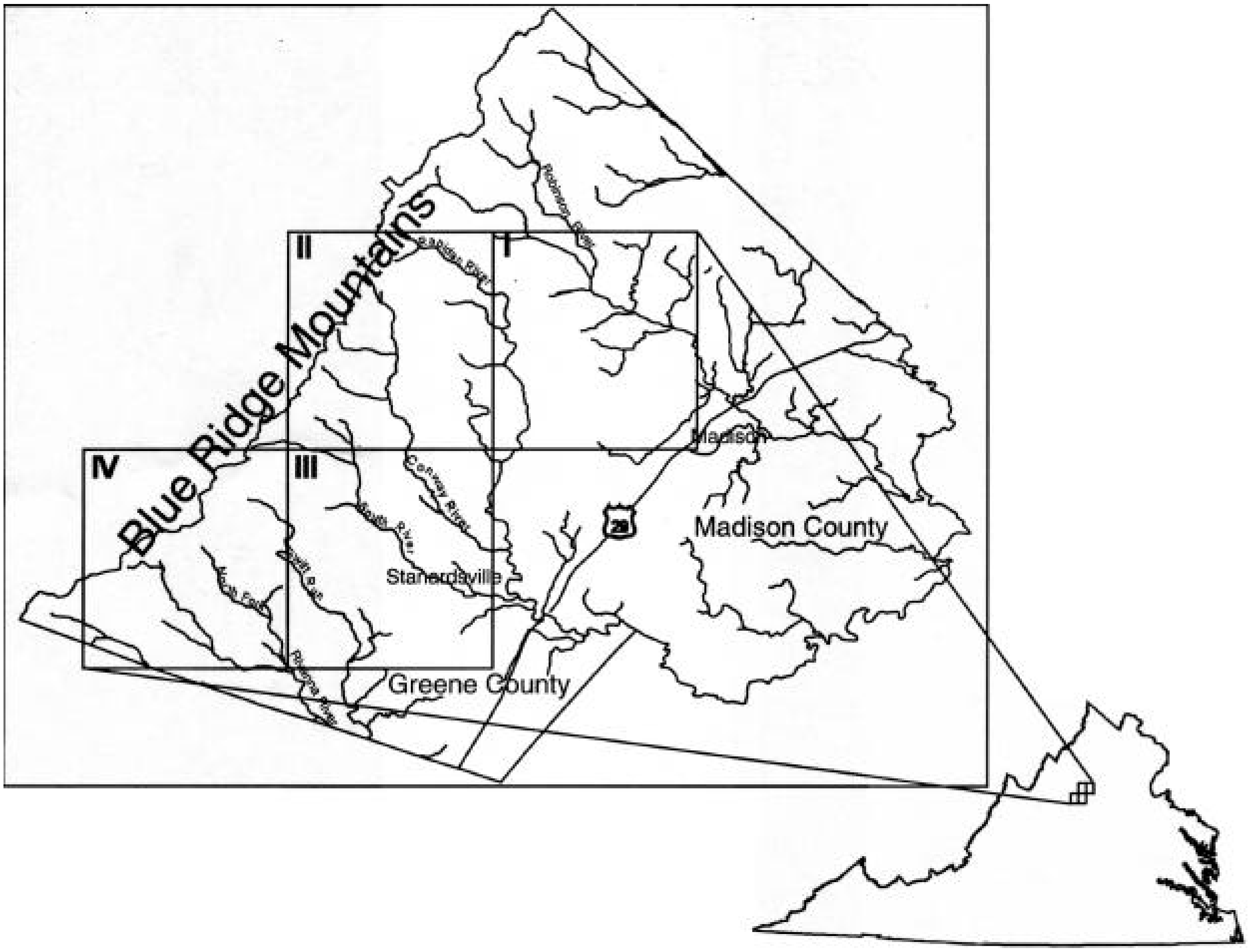

Figure 1: Location of Madison, VA (I), Fletcher, VA (II), Stanardsville, VA (III), and Swift Run Gap, VA (IV) 7.5' 1/24,000-scale quadrangles in Madison and Greene Counties, VA. The Conway River is the county boundary.

REGIONAL SETTING

The Rapidan, Rivanna and Robinson Rivers originate on the eastern flanks of the Blue Ridge Mountains of central Virginia **(Figure 1)**. The area has a humid temperate climate. Temperature and precipitation patterns range considerably from the crest of Blue Ridge to the lowlands where the rivers enter the Piedmont physiographic province. Mean January temperature is -0.3^{o}C at the town of Madison (elevation 180 m) and -4.4^{o}C at Big Meadows (elevation 1,095 m). Mean July temperature is 24.2^{o}C at Madison, and 18.6^{o}C at Big Meadows. Annual precipitation at Madison is 109.0 cm and 130.0 cm at Big Meadows.

The climax vegetation of the basin is the Oak-Hickory division of the temperate deciduous forest group. Pioneer species, including Black Locust, Ailanthus, Virginia Pine, Yellow Poplar, and Paulownia occupy areas disturbed by recent flooding. Timber harvesting during the last half century has been intermittent so that steep hillslopes and mountain hollows have reforested. Much of the lowlands is currently in agricultural use, and crops include soybeans, corn, and hay. Stony ground unfit for production are left as woods, or used as orchards and pastures.

BEDROCK GEOLOGY

The bedrock geology of Madison and Greene Counties has been mapped and described by Allen (1963). More recent summaries of the bedrock geology have been published by Gathright (1976), and by Rader and Evans (1993). The oldest mapped units within the study area are quartzo-feldspathic rocks of mostly granitic composition. Allen (1963) mapped these as parts of the Pedlar, Lovingston, and Marshall Formations. These rocks originated as a series of igneous intrusions that later were deformed and recrystallized about 1 billion years ago during the Greenville Orogeny. The granitic rocks were intruded by diabase dikes about 570 Ma ago that presumably acted as conduits for the basaltic volcanic flows that comprise the Catoctin Formation. The Catoctin Formation unconformably overlies the granitic rocks and crops out to the west of the study area along the summit and western flank of the Blue Ridge; in addition a down-faulted section is on the Conway River. The Catoctin Formation includes basalt lava flows with prominent columnar jointing, volcanic ash, and agglomerates. The Swift Run Formation, composed of thin units of quartzite, conglomerate and siltstone, is found sporadically at the base of the volcanic rocks and similar rocks are intercalated within the Catoctin Formation. Quartzite and slate are down-faulted into the granitic rocks in a long narrow graben or half graben in the Madison and Stanardsville quadrangles. These rocks are the Mechum River Formation and are possibly correlative with rocks of the Swift Run Formation. The Weverton and Harpers Formations of the Chilhowee Group overlie the Catoctin, and crop out in the northwest parts of the Fletcher and Swift Run Gap quadrangles. These are siliclastic conglomerates, quartzite, and phyllites, probably all of lower Cambrian age.

All of these rocks were altered by metamorphism and deformation during the Paleozoic Era. The granitic intrusions were retrograded and pyroxene was replaced by amphibole and chlorite. The basalt was altered to greenstone composed of albite, chlorite, epidote and minor amphibole. Well-defined faults and shear zones cut all rock units in many places, and foliation is prominent and obscures bedding in the greenstones and siliclastic rocks.

The bedrock geology, shown in **Plates I - IV**, was adapted from Allen (1963) and Gathright (1976), but extensively field checked and modified in places by the authors, especially in areas outside Shenandoah National Park. For the purposes of this report and maps of the surficial geology, the granitic rocks are not differentiated, the Swift Run Formation is included with the Catoctin Formation as a single bedrock unit, and the Weverton and Harpers Formations are combined and designated as the Chilhowee Group.

SURFICIAL GEOLOGY

The surficial landforms within **Plates I – IV** include flood plains, river channels, river terraces and debris fans. Associated with these landforms are alluvial flood plain deposits, alluvial channel deposits, river terrace gravel, debris flow deposits, and slope wash deposits.

Erosion of debris flow fans, chutes, and older drainages by the June, 1995 storm and Hurricane Fran in 1996 exposed thick, continuous sections of surficial deposits in the Fletcher and Madison VA quadrangles. This provided unusual opportunities for obtaining carbon samples for dating and viewing stratigraphic relationships. Thirty-nine samples of carbon from surficial deposits (shown on Plates I and II) provided carbon-14 age determinations. Descriptions of each sample, its site, and the age determination are in Table 1. A more complete description of stratigraphic relations of some samples is given in Appendix 1. Most of the samples providing datable material are of late Pleistocene age (Eaton, 1999). The ages provided by these samples date debris flow events, provide estimates for recurrence of debris flows in the area, and date the development of the cold-weather slope wash and stratified slope wash.

Regolith mantles most of the landscape, and is thickest on debris fans and in hollows, and thinnest on planar and convex-shaped hillslopes. Most of the soils in the study area are derived from transported material resulting from mass failure on steep slopes. The soil orders developed from the regolith are primarily Ultisols, Inceptisols, and Entisols (Soil Survey Staff, 1975). The Ultisols are found on high river terraces, historically-inactive debris fans, and residual upland surfaces. The Inceptisols occupy mountainous slopes, low river terraces, and historically-inactive debris fans. The Entisols are located on steep mountain slopes, historically-active debris fans, and river flood plains. Pedogenic characteristics of many of the soils show a weathering history spanning at least hundreds of thousands of years (Soil Survey Staff, 1975).

River Terraces

The oldest surficial landforms present are strath river terraces **(Plates I - IV)**. They are traceable for approximately 160 km from the Fall Zone at Fredericksburg, Virginia to the confluence of Kinsey Run and the Rapidan River (Dunford-Jackson, 1978). The terraces are also present in the valleys of the Robinson, Conway, South River and Swift Run drainages. The high strath terrace is the most extensive, and was once probably continuous along the upper Rapidan, Robinson, and South River valleys prior to its advanced stage of fluvial dissection. This terrace surface is as much as 120 feet (36 meters) above the adjacent active floodplain in the study area. Several units mapped as terraces (for example at Stanardsville in the Stanardsville 7.5' quadrangle, and near Mulatto Run in the Madison 7.5' quadrangle) show little relationship to the present drainage patterns and may be relicts of much earlier drainage systems. The high terraces frequently have only a thin veneer of deeply weathered, alluvium that overlies saprolite. Approximately a third of the mapped terraces have rounded vein quartz and granitic cobbles on the surface, indicative of fluvial transport. However, numerous large flat surfaces apparently have been stripped of alluvium and only saprolite is exposed.

The soils found on most of the terraces are of the Dyke Series and Braddock Series, both characterized by 2.5 YR to 10 R Munsell colors, thick argillic horizons, and deeply weathered clasts of granitic material. The Dyke Series is a clayey, mixed, mesic, typic Rhodudults. The Braddock Series is a clayey, mixed, mesic, typic Hapludults.

The high strath terrace deposits of the Rapidan River has weathering characteristics similar to both the early Pleistocene and late Tertiary deposits of the Fall Zone and Inner Coastal Plain of Virginia as described by Howard and others (1993). The clay content, Munsell colors, and weathering characteristics of the Dyke and Braddock soil series, Rhodudult and Hapludult respectively, are similar to pedological characteristics found in the Paleudult soils of the Fall Zone terraces dated 3.4 Mybp to 5.3 Mybp. In contrast, the Dyke soil series has a greater rubification and clay content than the Hapludult terrace soils at the Fall Zone (700 Kybp to 1.6 Mybp.) (Howard and others, 1993). Although different parent materials could be a factor, correlation of soils from the Fall Zone to the Blue Ridge suggests that the highest terraces in the study area are early Pleistocene to late Pliocene in age.

A lower set of terraces as much as 40 feet (12 meters) above the modern flood plain is present in places in the four mapped quadrangles. Soils on the lower surfaces were collectively mapped as the Unison Series, classified as a clayey, mixed, mesic, typic Hapludults, and exhibit slightly less clay and rubification than the Dyke and Braddock Series (Soil Survey Staff, 1975).

Slope Wash Deposits

Slope wash deposits are a product of quasi-laminar flow of soliflucted surficial material during a climate characterized by widespread permafrost. These deposits are crudely bedded with rock slabs and larger boulders aligned parallel to the slope of the hillside.
Deposits that have rhythmic layers of clast-supported and matrix-supported platy, angular, pebble-sized rock chips are termed stratified slope wash. Stratified slope wash deposits have been reported on hillslopes of gradients as great as 45^{o} and as little as 2^{o} (Van Steijn and others, 1995). Stratified slope wash deposits are frequently associated with limestones and shale, but also with foliated rock, sandstone, conglomerate, slate and granite (DeWolf, 1988). The commonality of these deposits is ample supply of fractured or foliated source rock.

A number of mechanisms explaining the origin of slope wash deposits have been proposed, and nearly all require frost action to initially prepare the source material for transport. Hypotheses of the origin of formation have included snowmelt and slope wash (Watson, 1965), solifluction (Journaux, 1976, Bertran and others, 1992), and a slope wash-debris flow combination (Guillien, 1951; Gardner and others, 1991). The primary difficulty of interpreting the processes of formation is the lack of information about presently developing slope wash deposits (Van Steijn and others, 1995). A few laboratory studies (Van Steijn, 1984) have attempted to model this process, but conclude that additional work is needed to refine the mechanics of slope deposit formation.

Although slope wash deposits have been widely regarded as having a periglacial origin in the European literature, they have received very little attention outside Europe (Washburn, 1985). Jobling (1969) described a deposit of rhythmically-bedded shale clasts along a hillslope exposure in Pennsylvania. He interpreted the deposit as a *grezes litee* and proposed solifluction as the mechanism of emplacement. Sevon and Berg (1979), and also Gardner and others (1991) provide descriptions of shale-chip rubble deposits in Pennsylvania that have descriptions similar to the Rapidan basin sites. Clark and Ciolkosz (1988) note that similar slope deposits have been found as far south as northern Virginia. Similar deposits were observed in a steep, north-facing hollow in Nelson County,Virginia exposed by debris flows during the 1969 Hurricane Camille flood (Alan Howard, Univ. VA, oral comm.) and in the Great Smoky Mountains National Park (Scott Southworth, written comm.).

Slope wash deposits were observed at several locations in the Rapidan basin. They are nearly always a thin (±1 meter) deposit and exposed only along stream incisions produced by recent floods, or in walls of chutes left by the debris flows from the June, 1995 storm. In the Fletcher, VA quadrangle **(Plate II),** two areas exposed by the flooding have units extensive and thick enough to depict on a map. These are on Kinsey Run and the basin forming the headwaters of the Conway River. The deposits are exposed at the base of planar or slightly concave shaped hillslopes where stream channels or debris fans had been incised. The most extensive stratified slope wash deposit documented in the study area is the Kinsey Run debris fan site in the upper Rapidan basin **(Plate II, 8-9).** The 1995 flood exposed 6.5 vertical meters of stratified slope wash deposits with individual beds that are laterally continuous for a minimum of 50 meters. The deposit is thickest at the downslope end, and gradually thins upslope. Another site is located on a small Rapidan River tributary near the Rhodes farm, 0.5 km south of Graves Mill. **(Plate I, 21-25).** The Rhodes site is not as well exposed as the Kinsey Run site, but possesses similar sedimentologic characteristics. The deposits there are 1.9 m thick and are overlain by three debris flows. Individual units are laterally continuous for approximately 20 meters. Both the Kinsey Run and Rhodes sites have numerous thinly-bedded (2 to 5 cm) units that dip 7^{o} - 12^{o} subparallel to the hillslope. Both sites are on southwesterly facing slopes.

The clasts at both sites consist mainly of pebbles of highly sheared gneiss, greenstone, and vein quartz. Cobbles are few in number, and boulders are notably absent. The clasts are generally tabular in dimension and angular-to-subangular, largely due to the combination of strongly developed foliation, short transport distance, and weathering along discontinuities. The median pebble length is 5 cm (long axis) by 4 cm (intermediate axis) and is much finer-grained than the debris-flow deposits. The maximum size generally does not exceed 12 cm. The matrix consists of sand, sandy loam, and loam. Munsell soil colors are dominantly 10 YR and rarely 7.5 YR hues. The units are poorly sorted and chiefly grain-supported; however, matrix-supported pebbles were observed. Particle orientation subparallels the dip surface of the hillslope.

The timing and rate of deposition of these stratified slope deposits were determined by radiocarbon dating (Table 1). At Kinsey Run, 6.5 m of slope deposits were deposited between 24,570 ybp and 15,800 ybp, indicating an accumulation rate of at least 74.1 cm/l000 yr. An additional meter of slope deposits overlies the 15,800 ybp unit, and some of the topmost layers may have been removed by the 1995 storm, so accumulation may have continued until the end of the Pleistocene. Pollen studies carried out at Kinsey Run by R. Litwin (USGS, written comm., 1998) suggest a mean annual temperature of approximately 19^{o}C at 24,570 ybp (relative to a present-day mean annual temperature of 23^{o}C). Unfortunately the upper section is oxidized and no pollen was observed. Similar accumulation rates of stratified slope wash were observed at the Rhodes site. Slope activity began as early as 27,410 ybp and continued up to 24,450 ybp, and then was interrupted by a probable basin-wide debris flow event, suggested by radiocarbon dates. During the 2,960 years of activity, 1.59 m of sedimentation occurred with a minimum accumulation rate of 53.7 cm/1000 yr.

The ages of the stratified slope wash in the Rapidan basin bracket the last major glacial period and suggest that the Blue Ridge, located about 400 km south of the Wisconsin glacial border, experienced permafrost conditions. Slope wash deposition was probably continuous even as climate cooled during the height of the late Wisconsin glaciation, since there is no observable evidence of pedogenesis, ice wedging, or variations in weathering of pebbles in the deposits. The deposits provide critical information about the amount of vegetation covering the slopes and about the prevailing climatic conditions. If continuous, uninterrupted bedding is indicative of a vegetation-free surface during formation (Sevon and Berg, 1979; DeWolf, 1988), then many southwest-facing slopes at elevations greater than 300 m in the Blue Ridge may have been relatively free of vegetation from 25Kybp to at least 15Kybp.

On upper slopes in the Madison and Fletcher quadrangles, traces of late Pleistocene slope are exposed in ravines created by the 1995 debris flows and in eroded bluffs on the Rapidan River. In all of these outcrops, slope wash lies directly on bedrock or on saprolite. This suggests that the Blue Ridge was largely denuded of colluvium before the onset of the last cold climate cycle.

Talus and tors

At higher elevations above approximately 2200 feet (667 meters) the summits and shoulders of the Blue Ridge are mantled with a thin, blocky colluvium (Morgan, 1998). In the Fletcher, VA 7.5' quadrangle, scattered talus deposits are widely interspersed with colluvium. Within the Staunton River drainage, rock streams are developed in several of the first order drainages. The origin of the talus and rock streams is controversial (for an extended discussion, see Mills, 1988). Systematic mapping of blocky colluvium and talus was not attempted because deposits are thin, widespread, gradational and interspersed with bedrock outcrops. Tors are on several ridge summits in the Fletcher quadrangle. Examples are on the summits of Bearfence Mountain, Fork Mountain, and Jones Mountain at Bear Church Rock. The balanced rocks as well as chimneys and spires at the summits are typical of periglacial tors that have been described in Great Britain and elsewhere (Ballantyne and Harris, 1994). These are the product of intense weathering and denudation characteristic of conditions imposed by a periglacial climate during the late Pleistocene Epoch in the Blue Ridge (Eaton, 1999).

Debris-Flow Deposits

Debris fans are the constructional features formed by the deposition of sediment from debris flows. The narrow stream valleys typical of much of the eastern flanks of the Blue Ridge prevent the formation of the classical fan-like morphology in plan view (Kochel, 1990) seen, for example, in the Basin and Range region of the western United States. Most of the debris fans are elongated longitudinally, and are convex in cross section. Maximum fan thicknesses of 4 m were observed in the 1995 scour zones near the apices. Seismic refraction and ground resistivity surveys on the main body of several fans in the upper Rapidan basin suggest that thicknesses may exceed 30 m (Daniels, 1997).

Deposits related to prehistoric debris flows and the 1995 debris flows form prominent fans near the foot slopes of the Blue Ridge, and remnants of fans form terrace deposits along the Conway, Staunton, and Rapidan Rivers. Extensive scour within debris-flow chutes resulting from storms on the Rapidan and Conway Rivers, expose multiple debris-flow deposits generally interbedded with slope wash deposits. Fragments of wood and charcoal in these deposits yield a radiocarbon date of late Pleistocene. Deposits from multiple flows can create substantial fans that coalesce in aprons along the base of mountain slopes. Debris-flow fans are prominent geomorphic features along the eastern flank of the Blue Ridge in the Madison, Fletcher and Swift

Run Gap quadrangles **(Plates I, II, and IV).** The fans within these quadrangles are dissected by multiple, entrenched, minor streams, and form an easily recognizable pattern of contours on topographic maps. Fans are agriculturally desirable because of moderate slopes and good drainage of cold air and moisture. Many are utilized for pastures, orchards, and vineyards.

Remnants of major debris-flow deposits are also preserved as narrow terraces along the major drainages. These are derived from debris flows that moved down the drainage channel and filled the floor of the prehistoric channel. Subsequent channel incision has left terrace-like fragments of debris-flow deposits on the channel sides. The headwaters of both the Staunton and Rapidan Rivers are on extremely stoney ground that is mapped as debris-flow deposits. The slopes of the headwater basins are gentle, often less than 12^{o}, and are characteristic of fans. However, the boulders in the debris have edge-edge contacts and no matrix. Exposures of similar deposits in the upper part of Wilson Run, a tributary of the Staunton River, indicate that the older debris deposits have a well-developed matrix near the base of the deposit, but little or none near the exposed surface. Based on this indirect evidence, the loose, matrix-free, boulder materials in the upper Rapidan and Staunton Rivers are mapped as debris-flow deposits.

Sedimentologic characteristics of the debris-flow deposits include a bimodal distribution of grain sizes, minimal or an absence of clast imbrication, occasional inversely graded-bedding, and multiple clast lithologies. Differences among the deposits include the type of clast support (fabric), pedogenic clay content, induration of the fabric sediment, and the degree of weathering of the clasts. The debris-flow deposits contain two distinct sediment size groupings. The larger gravel fraction includes pebble, cobble, and boulder-sized material, and range from 60% to nearly 100% of the total volume of the deposits. Deposits that are younger than 50,000 ybp show no correlation between the concentration of gravel and age. The fine fraction of deposits younger than 50,000 yr. is high in sand. The clay contents of the 1995 and late Holocene deposits only average 3%, but are slightly higher for late Pleistocene deposits. In contrast, deposits older than 50,000 ybp have lower gravel and much higher clay concentrations. The highest clay concentrations, up to 80%, are in deposits with fully disintegrated cobbles and boulders.

The type of clast support of the deposits shows no correlation with age except for those deposits that exhibit advanced stages of weathering. These units have Munsell colors of 5 YR or 2.5 YR, and contain heavily weathered cobbles that are suspended in a sand-silt-clay matrix. In contrast, younger deposits spanning the Holocene and late Pleistocene are both matrix supported and clast supported. Munsell colors are dominantly 10 YR hues. Cobbles exposed on the surface of the1995 deposits are clast supported, but are increasingly matrix supported with depth.

No trend between clast imbrication and age of deposit was observed. The degree of clast imbrication ranges from none to minor. The 1995 deposits are more highly imbricated in middle and distal zones of debris fans, probably due to the reworking by subsequent flooding associated with the storm. Inverse grading was present in several of the 1995 deposits, and was also noted in both Holocene and late Pleistocene age deposits.

The thickness of weathering rinds on clasts was used as an indicator of the relative age of debris flow deposits. Fine-grained crystalline rocks provide the most consistent rinds for quantitative analysis (Mills and Allison, 1995), and have been successfully used for relative age determinations in the western United States (Coleman and Pierce, 1981). For this study, the clasts were measured on the side (excluding corners) showing the thickest rind. The Catoctin Formation, containing fine-grained volcanic rocks, is the only unit in the study area that has well-defined weathering rinds. Most of the 1995 flood cobbles lack weathering rinds, but highly weathered clasts are occasionally interspersed with the unweathered cobbles. Clast weathering of the greenstone cobbles is minimal in deposits that range in age from recent to 35,000 ybp. In situ cobbles of early Holocene deposits have weathering rinds that average 1 mm thick. Both the 35,000 ybp deposit and the ?50,000 ybp deposits have 2 mm thick average weathering rinds. The feldspar in the granitic cobbles in the ?50,000 ybp deposit show moderate deterioration (loss of fresh cleavage surfaces and alteration to clay minerals), whereas cobbles of similar mineralogy in 35,000 ybp-deposits exhibit little or no alteration of feldspars. Cementation of the matrix qualitatively shows more variability than the weathering rind trends. Holocene deposits that range from 6,500 ybp to modern show no detectable cementation of the matrix fraction. Late Pleistocene age deposits (14,000 ybp to 35,000 ybp) are slightly cemented. Older deposits ?50,000 ybp range from slight cementation and a moderate bulk density to a higher degree of cementation and a greater bulk density.

Until recently, knowledge of the recurrence interval of debris flow activity in the central Blue Ridge was limited. Kochel and Johnson (1984) determined that the debris-flow recurrence interval of small river basins in western Nelson County, Virginia ranged from 3,000 to 6,000 years. Their analysis was based on 6 radiocarbon dates obtained from debris fans and flood plain located in the small river basin of Davis Creek. The oldest radiocarbon age of a debris flow deposit was dated as early Holocene.

The data obtained from radiometric dating organic-rich deposits exposed by the June, 1995 storm and Hurricane Fran in 1996 show debris flow activity extending back into the late Pleistocene **(Figure 2, Table 1, and Appendix 1)**. Two carbon samples from debris-flow deposits exceeded the 50,000 ybp limit of radiocarbon dating. The oldest carbon that could be dated is 50,000 ybp from the base of a debris-flow deposit in the Kirtley Mountain debris-flow fan in the Fletcher, VA quadrangle **(Plate II, 16)**. Also from the Fletcher, VA quadrangle, a 0.7 m thick organic deposit was dated at 34,770 ybp **(Plate II, 10)** and is covered by a debris-flow deposit. The next youngest sample related to a debris-flow event was dated at 24,900 ybp. This event impacted numerous first and second order basins in the Rapidan basin. From this event through the remainder of the late Pleistocene, at least six separate debris flow-events are recorded over a 10,880-year period, or a frequency of one event every 2,200 years (Eaton and McGeehin, 1997). No radiocarbon dates were obtained from the end of the Pleistocene (13,990 ybp.) through the middle Holocene (6,520 ybp, **Plate II, 7**). At least five debris flow events have occurred since the middle-to-late Holocene, including the 1995 flood, or one event every 1,600 years. If the entire period from the time of the approximate onset of the late Wisconsin glacial maximum (25,000 ybp) to the present is considered, debris-flow activity has on average recurred in the upper Rapidan basin once every 2,500 years.

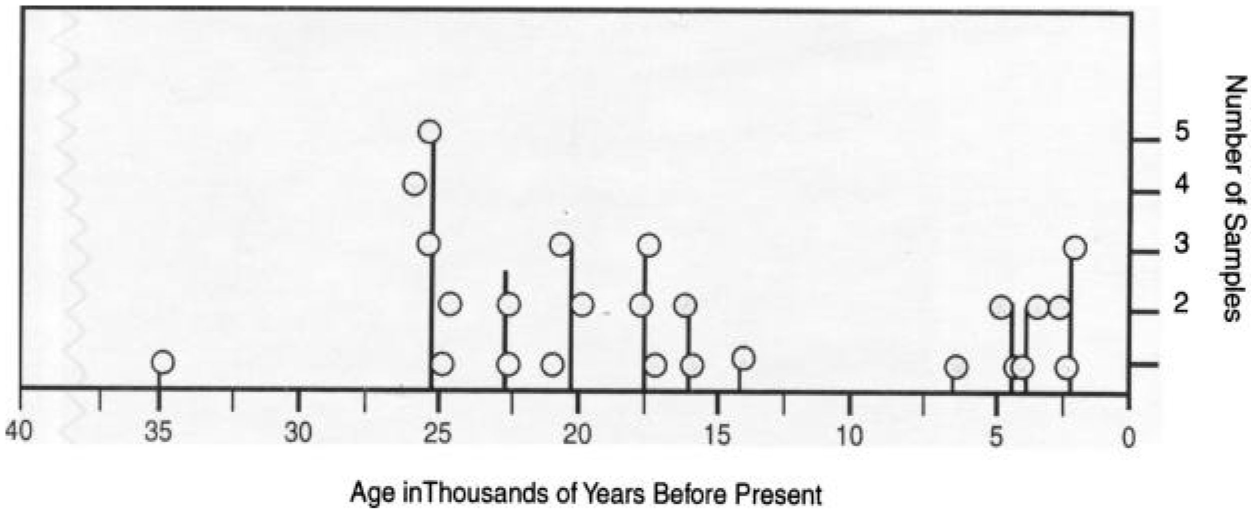

Figure 2: Ages of 11 debris flows in the upper drainage basin of the Rapidan River, Madison County, Virginia. Recurrence of debris flows was approximately every 2,500 years (Eaton, 1999). The small circles represent samples from debris-flow deposits and the vertical lines are interpreted as separate debris-flow events.

The colluvium mobilized by the debris flows appears to mostly be derived from Pleistocene slope wash, talus, and boulder streams, as well as saprolitic bedrock, rather than from Holocene materials that accumulated in hollows and areas downslope from ridge lines. If true, then sediment supply for the debris-flows is not a steady-state phenomena in which a balance is maintained between sediment accumulation and catastrophic removal. The longer term evolution of the region appears to be one of periodic and catastrophic removal of older colluvium from the upper slopes of the Blue Ridge, and a tendency for a gradual return to pre-Pleistocene conditions marked by continuous weathering and gradual removal of soil derived from weathered bedrock by creep or sheet wash.

During the past half-century, storms producing debris flows in the much larger region of the Appalachian Mountains of Virginia and West Virginia (Hack and Goodlett, 1960; Williams and Guy, 1973; Jacobson and others, 1993; Morgan and Wieczorek, 1996; Morgan and others, 1999) have recurred at approximately ten-year intervals. **Figure 3** shows areas in central Virginia that have been affected by debris flows from 1949 to 1996. It is uncertain if this average recurrence is typical over the entire historical period of approximately 300 years; debris flows occur in mountainous regions that were sparsely populated, and records are not available. Floods affecting larger areas and many people downstream have been more commonly reported.

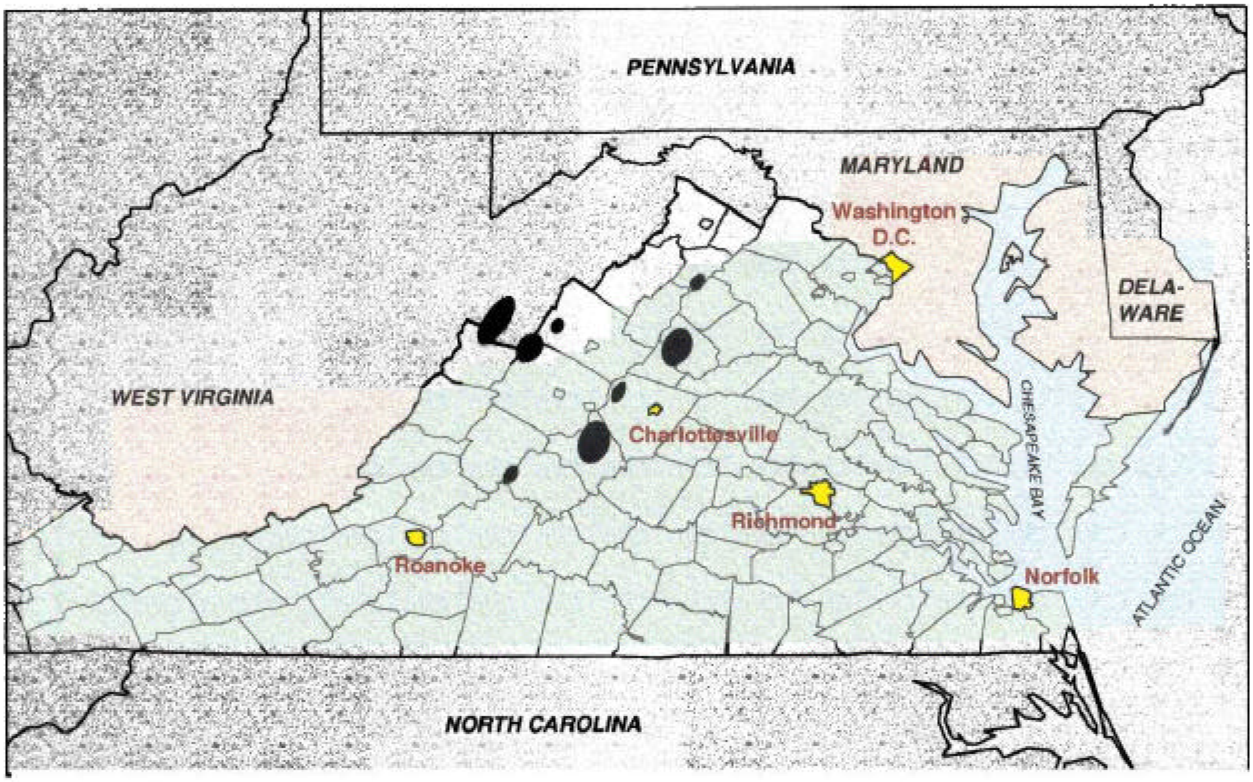

Figure 3. Areas affected by debris-flow events in Virginia and West Virginia from 1949 to 1996.

Alluvial Flood Plain Deposits

The majority of fluvial deposits in the Rapidan basin are found in the flood plains of the Rapidan, Robinson, Conway and South Rivers and several of their larger tributaries. Geophysical data (Daniels, 1997) suggests that the thickness of the alluvium of the Rapidan River near its confluence with Kinsey Run may be locally as great as 15 m to 20 m. Excavations made during bridge construction near this confluence exposed probable bedrock saprolite 10 to 12 m below the surface.

Floods during the June 1995 storm and the 1996 Hurricane Fran severely scoured and incised the Rapidan flood plain at many locations and created exposures of the alluvium. Most sites have a basal sequence that is about 80 percent cobbles, overlain by interbedded sand, silt, and clay layers. The cobbles are rounded-to-subrounded, highly imbricated, and the matrix is a mixture of pebbles, granules, and sand. These coarse-grained materials were probably deposited by the lateral migration of the Rapidan channel or as flood deposits. Fine-grained sediment that is probably overbank deposits were observed in nearly all exposures. Sand, silt, and clay also occur in paleosols and in abandoned channel deposits. Similar stratigraphic sequences are present in the other drainage basins included in this study. Alluvium that includes overbank materials are mapped as Alluvial flood plain deposits (Qal). Alluvial deposits of coarse material within narrow streams valleys with gradients greater than 1-4? lack the finer-grained sediment from overbank deposition and are mapped as alluvial channel deposits (Qcd).

A partial history of flood plain deposition was determined by radiometrically dating carbon-rich sediments from two localities exposed by the floods. A stratigraphic profile of a flood plain site **(Plate I, 26-27)** exposed during the 1995 storm exhibits a channel fill inset into a laterally continuous 2.5 m thick cobble unit. The sequence is 3 m thick, extends laterally for 5 m, and is composed of sand, silt, clay and lesser amounts of pebbles and cobbles. Its basal contact extends below the present channel thalweg. Radiocarbon data indicate that the channel fill is younger than 4,500 ybp. Flood plain aggradation rates were determined from measurements of stratigraphic thicknesses and the radiocarbon ages of sediments. The basal organic-rich unit is a silty clay, and was dated at 4,450 ybp. This unit was buried by 2.61 m of interbedded sand, silt, and clay layers, resulting in a net accumulation rate of 58.7 cm/l,000 yr. The accumulation rate from 4,450 to 3,880 ybp. increased nearly a full order of magnitude to 264.9 cm/l,000 yr., and may be the result of a single storm event that also produced debris-flow activity. The accumulation rate from 3.880 ybp to present was 26.8 cm/1,000 yr. The stratigraphic record of radiocarbon dated organic units at this site also appear to coincide with 3 episodes of Holocene debris flow activity recorded in an adjacent debris fan **(Plate I, 28-32)**.

In another site in the Rapidan flood plain (**Plate I, 20**), charcoal was retrieved from a 26 cm thick clayey loam paleosol, radiocarbon dated at 1,550 ybp., interlayered between two cobble deposits. The paleosol is truncated by a prehistoric channel deposit that contains rounded cobbles. The exposure was capped by a 39 cm unit of cobbles and a 21 cm unit of a fine sandy loam. The sediment accumulation rate at this site is 39 cm/1,000 yr.

SUMMARY: PLEISTOCENE AND HOLOCENE HISTORY

The geologic record preserved in surficial deposits in the drainage basins on the eastern flank of the Blue Ridge is greatly restricted because the area has been one of uplift and denudation since well before the end of the Cenozoic. Nevertheless, two major themes emerge from the record.

In the Late Tertiary and Early Pleistocene, the extent of strath terraces suggests that the eastern slopes of the Blue Ridge were drained by streams with broad flood plains at least two- to three-times the width of the modern flood plains. In places these plains were broad enough to define a pediment covered by a thin veneer of alluvial gravel. Near the end of the Pleistocene, climate cooling was accompanied by shattering of bedrock from frost action, by vigorous production of colluvium and extensive mass wasting of the steeper slopes of the Blue Ridge. Streams were rejuvenated and the older flood plains and pediments are preserved as strath terraces along all of the major streams within the study area. The prominent landscape features of the Blue Ridge were formed during this period with the development of tors, blockfields, talus sheets, and debris fans. With the return of more moderate climate in the Holocene, debris-flow activity has continued, activated by major storms. These debris flows mine the Pleistocene colluvium, but contributions to the debris fans are not sufficient to cause further aggradation. Many of the fans have been entrenched by streams and are beginning to show evidence of decay.

Surficial deposits of early or middle Pleistocene age are few within the exposures of debris-flow fans, and almost completely absent from the upper slopes of the Blue Ridge. Several deeply weathered debris-flow deposits were found (especially **Plate II, 1,** a small roadcut exposure cropping out below a younger debris-flow deposit) that may provide more information about the transition from a broad stable landform with pediment development along the base of the Blue Ridge, to a more dynamic environment characterized by abundant debris flows. The basal sections of debris fans may contain deposits that predate the late Pleistocene. An older section within a fan **(Plate 1, .05 km. NE Graves Mill)** was revealed by scour during the June 1995 storm event but was covered over during agricultural reclamation early in 1996 before the site could be carefully examined.

REFERENCES

Allen, R.M., 1963, Geology and Mineral Resources of Greene and Madison Counties: Virginia Division of Mineral Resources, Bulletin 78,102 p.

Ballantyne,C.M., and Harris, Charles, 1994, The periglaciation of Great Britain: Cambridge University Press, 330 p.

Bertran. P. Coutard, J. Francou, B., Ozouf, J., and Texier. J., 1992. New data on grezes bedding and their paleoclimatic implications, Geographic Physique et Quaternaire. v.46. p.97-112.

Clark, G.M., and Ciolkosz, E.J., 1988, Periglacial geomorphology of the Appalachian Highlands and Interior Highlands south of the glacial border - a review. Geomorphology, v.1, p.191-220.

Coleman, S.M., and Pierce, K.L., 1981, Weathering rinds on andesitic and basaltic stones as a Quaternary age indicator, western United States: U. S. Geological Survey Professional Paper 1210, 56 p.

Daniels, N., 1997, The role of debris flows in landscape evolution in the Blue Ridge Mountains, Madison County, Virginia, senior thesis, Bucknell University, 78 p.

DeWolf, Y., 1988, Stratified slope deposits, *in* Advances in Periglacial Geomorphology Clark, M.J., (ed.), p.91-110.

Dunford-Jackson, C.S., 1978, The geomorphic evolution of the Rappahannock River basin, M.S. Thesis, University of Virginia, Charlottesville, VA. 92 p.

Eaton, L. S., 1999, Debris flows and Landscape evolution in the Upper Rapidan Basin, Blue Ridge Mountains, Central Virginia, unpub. Ph.D. thesis, University of Virginia, 154 p.

Eaton, L.S. and McGeehin, J.P., 1997, Frequency of debris flows and their role in long term landscape evolution in the central Blue Ridge, Virginia, (abstr.), Geol. Soc. America Abs. with Programs, v.29, n. 6. p.410.

Gardner, T.W., Ritter, J.B., Shuman, C.A., Bell, J.C., Sasowsky, K.C.., and Pinter. N.. 1991, A periglacial stratified slope deposit in the Valley and Ridge province of central Pennsylvania, USA: sedimentology, stratigraphy, and geomorphic evolution: Permafrost and Periglacial Processes, v.2, p.141-162.

Gathright, T.M. II, 1976, Geology of the Shenandoah National Park, Virginia: Virginia Division of Mineral Resources, Bulletin 86, 93 p.

Guillien, Y., 1951, Les grezes litees de Charentes: Revue de Geographic des Pyrenees et du Sud Ouest, 22, p.155-162.

Hack, J.T., and Goodlett, J.C., 1960, Geomorphology and forest ecology of a mountain region in the central Appalachians. U.S. Geol. Surv., Prof. Pap., 347: 66 p.

Howard, J.L., Arnos, D.F., and Daniels, W.L., 1993, Alluvial soil chronosequences in the inner Coastal Plain. central Virginia: Quat. Res., v.39, p.201-213.

Jacobson, R.B., 1993, Introduction: Geomorphic studies of the storm and flood of November 3-5, 1985, in the upper Potomac and Cheat River Basins. U.S. Geol. Surv. Prof. Pap. 1981, p. A1-A3.

Jobling, J. L., 1969, The origin of shale chip deposits in southeastern Centre County. Pennsylvania, M.S. Thesis. Pennsylvania State University, University Park, PA, 51 p.

Journaux. A..l976, Les grezes litees du Chatillonnais, Bul. Ass. Fr. Et. du Quatennaire. 48-9, p.123-38.

Kochel, R.C., 1990, Humid fans of the Appalachian Mountains, *in* Alluvial Fans: A Field Approach, Rachochi, A.H., and Church, M., (eds.) p.109-129.

Kochel, R.C., and Johnson, R.A., 1984, Geomorphology and sedimentology of humid-temperate alluvial fans, central Virginia: *in* Gravels and Conglomerates, E. Koster and R. Steel, (eds.)., Canadian Society of Petroleum Geologists Mem.10., p. 109-122.

Mills, H.H., 1988, Surficial geology and geomorphology of the Mountain Lake area, Giles County, Virginia, including sedimentological studies of colluvium and boulder streams: U. S. Geological Survey Professional Paper 1469, 93 p.

Mills, H.H., and Allison, J.B., 1995, Weathering rinds and the evolution of piedmont slopes in the southern Blue Ridge Mountains, Journal of Geology, v.103, p.379-394.

Morgan, B.A., 1998, Surficial geology of Shaver Hollow, Shenandoah National Park: U. S. Geological Survey Open-File Report 98-343, 12 p.

Morgan, B.A., Wieczorek, G.F., Campbell, R.H., and Gori, P.L., 1997, Debris flow hazards in areas affected by the June 27, 1995 storm in Madison County, Virginia: U. S. Geological Survey Open File Report 97-438, 15 p., 2 maps, scale, 1/24,000.

Morgan, B.A., and Wieczorek, G.R., 1996, Debris flows and landslides resulting from the June 27, 1995, storm on the North Fork of the Moormans River, Shenandoah National Park, Virginia. U.S. Geol. Surv. Open File Report 96-503.

Morgan, B. A., Wieczorek, G. F., and Campbell, R.H., 1999, Map of rainfall, debris flows, and flood effects of the June27, 1995 storm in Madison County, Virginia: U.S. Geological Survey Investigations Map I-2623-A, scale, 1/24,000.

Morgan, B. A., Wieczorek, G. F., and Campbell, R. H., 1999, Historical and potential debris-flow hazard map of the area affected by the June27, 1995 storm in Madison County, Virginia: U.S. Geological Survey Investigations Map I-2623-B, scale, 1/24,000.

Rader, E.K., and Evans, N.H., (eds.), 1993, Geologic map of Virginia - Expanded Explanation: Virginia Division of Mineral Resources, 80 p., map, scele 1/500,000.

Sevon, W.D. and Berg, T.M., 1979, Pennsylvania shale-chip rubble. PA Geol., 10, p.2-7

Soil Survey Staff, 1975, Soil Survey of Madison County, Virginia, USDA, Government Printing Office, Washington, DC, 143 p.

Van Steijn, H., 1984, Laboratory experiments on gelifluction using greze litee material. Z. Geomorphol. Supplementband, v.49, p.195-201.

Van Steijn, H., Beitran, P., Francon, B., Hetu, B., Texier, J., 1995, Models for the genetic and environmental interpretation of stratified slope wash deposits, Permafrost and Periglacial Processes, v.6, p.125-146.

Washburn, A.L., 1985, Periglacial Problems, *in:* Church, M., and Slaymaker, O. (eds.). Field and Theory, Lectures in Geocryology: University of British Columbia Press, Vancouver, B.C., p.36-56.

Watson, E., 1965, Grezes ritees ou eboulis tardiglaciares dans la region d'Aberystwyth: Bul. Ass. Geogr. Fr., 338(9), p.16-25.

Wieczorek, G.F., Morgan. B.A., and Campbell, R.H., 2000, Debris-flow hazards in the Blue Ridge of central Virginia: Environmental and Engineering Geoscience, Vol. 6, pp. 3-23.

Williams, G.P., and Guy, H.P., 1973, Erosional and depositional aspects of Hurricane Camille in Virginia, 1969. U.S. Geol. Surv., Prof. Pap., 804: 80 p.

TABLE 1 SAMPLE NUMBERS, CARBON 14 AGE DETERMINATIONS, AND LOCATIONS

Sample No.	Age ybp	Location and Description
1 (971017A)	>50,000	Road cut on Rapidan Fire Road near Hoover Camp Fletcher Quadrangle - Wood Partly decomposed clasts of Catoctin greenstone floating in clay-rich matrix containing wood fragments and beneath extensive, more recent, debris-flow deposit with no matrix
2 (971021A)	18920+60	Bluff in Rapidan River Bank near Hoover Camp Fletcher Quadrangle - Wood Slope wash deposit with .5 meter thick clay-rich unit beneath debris-flow deposit with no matrix
3 (41696B)	17,l20?80	Wilson Run Fletcher Quadrangle - charcoal In slope wash deposit lying below undated debris-flow deposit
4 (41696E)	13,990?60	Wilson Run Fletcher Quadrangle - Charcoal In slope wash deposit lying below undated debris-flow deposit
5 (41696G)	14,370?70	Wilson Run Fletcher Quadrangle - Charcoal In slope wash deposit
6 (41696H)	14,530?70	Wilson Run Fletcher Quadrangle - Charcoal In slope wash deposit
7 (41696F2)	6,520?60	Wilson Run Fletcher Quadrangle - Charcoal At base of debris-flow deposit with boulders of Pedlar Formation floating at base of deposit in sandy matrix. Top of deposit free of all matrix
8 (Madison1)	24,570?180	Kinsey Run Fletcher Quadrangle Spruce limb or trunk below debris-flow deposit overlain by 6.5 meters of stratified slope wash
9 (100696A1)	15,800?70	Kinsey Run

		Fletcher Quadrangle - Organic sediment Top of 6.5 m thick stratified slope wash section
10(Madison 3)	34,770?690	Kinsey Run Fletcher Quadrangle - Wood fragments from peat At base of river bank section at temporary road, and overlain by two debris-flow deposits
11(100196A1)	22,430?100	Kinsey Run Fletcher Quadrangle - Wood fragments in sandy loam Stratigraphically overlies sample 10 and two debris flows. At top of river bank section at temporary road
12(062696B4)	24,910?120	Kirtley Mountain debris-flow fan deposit Fletcher Quadrangle - Charcoal
13(062696B2)	15,990?70	Kirtley Mountain organic rich layer between two debris-flow fan deposits Stratigraphically overlies sample 12 Fletcher Quadrangle - Charcoal
14(103196A)	20,660?70	Kirtley Mountain debris-flow fan deposit Fletcher Quadrangle - Wood Buried organic-rich layer of clay capped by red debris-flow deposit
15(052898)	17,560?70	Kirtley Mountain debris-flow fan deposit Clayey sand unit at base of debris flow Stratigraphically overlies sample 16 Fletcher Quadrangle - Charcoal
16(052898C)	50,000?2,900	Kirtley Mountain debris-flow fan deposit Clayey sand unit at base of debris flow Fletcher Quadrangle - Charcoal
17(N. Conway)	16,430?80	Conway River tributary east of Camp Shiloh Fletcher Quadrangle - Wood fragments In clay-rich unit at base of debris-flow deposit
18(980811A)	24,650?120	Bluff in Conway River near Middle River Chapel Fletcher Quadrangle - Charcoal Clay layer above saprolite and below slope wash and overlain by debris-flow deposit
19(070897B)	24,230?120	Tributary to Conway River southwest of Buzzard Rocks

		Fletcher Quadrangle - Charcoal Fine sand layer overlain by two distinct debris-flow deposits. Debris flows are separated by 70 cm of slope wash.
20 (091796Y-3)	1,550?50	Floodplain, Rapidan River near Route 676 Madison Quadrangle - Charcoal From fine layer of gravel within scour channel in floodplain and 60 cm below modern surface
21 (092196B-2)	22,350?80	Mouth of Judy Run, left bank Madison Quadrangle - Charcoal Stratified slope wash deposit Stratigraphically overlies sample 22
22 (092196B-3)	24,450?110	Mouth of Judy Run, left bank Madison Quadrangle - Charcoal Stratified slope wash deposit Stratigraphically overlies sample 23
23(092196B-4)	27,410	Mouth of Judy Run, left bank Madison Quadrangle - Charcoal Stratified slope wash deposit
24(070897D)	23,300?90	Mouth of Judy Run, right bank Madison Quadrangle - Charcoal Stratified slope wash deposit Stratigraphically overlies sample 25
25(070897E)	24,740?110	Mouth of Judy Run, right bank Madison Quadrangle - Charcoal Stratified slope wash deposit
26(092196A-6)	3,880?50	Rapidan River at Graves Mill Madison Quadrangle - Charcoal Organic layer in flood plain 1.1m below modern surface
27(092196A-12)	4,450?60	Rapidan River at Graves Mill Madison Quadrangle - Charcoal Clay silt layer in flood plain 2.6m below modern surface
28 (071196A-2)	2,430?60	Lillard Run, left bank at apex of debris-flow fan Madison Quadrangle - Charcoal Cobble layer between two debris-flow deposits
29 (071196A-4)	3,700?50	Lillard Run, left bank at apex of debris-flow fan

		Madison Quadrangle - Charcoal Cobble layer below two debris-flow deposits
30 (070896A-3)	2,080?50	Lillard Run, right bank at apex of debris fan Madison Quadrangle - Charcoal Cobble layer below debris-flow deposit
31 (070896A-7)	4,240?50	Lillard Run, right bank at apex of debris fan Madison Quadrangle - Charcoal Cobble layer below 2 debris-flow deposits
32 (070896A-9)	?50,000	Lillard Run, right bank at apex of debris fan Madison Quadrangle - Charcoal Cobble layer at base of section containing samples 30 and 31
33 (102296C)	25,860?120	Rapidan River at Rapidan Ranch above Graves Mill Madison Quadrangle - Wood fragments Organic rich layer overlain by two debris-flow deposits
34 (111696A)	25,290?90	Unnamed drainage adjacent to Rapidan Ranch Madison Quadrangle - Wood fragments Organic rich layer 25 - 80 cm thick between two debris-flow deposits
35 (092296A1)	2,240?50	Rapidan River, Shenandoah National park Madison Quadrangle - Wood fragments Exhumed in situ tree stump buried in prehistoric debris-flow deposit
36 (100396A-2)	80?50	Rapidan River flood plain near Rhodes Farm Madison Quadrangle - Wood fragments Scour channel containing 19th century drainage tile
37 (100396A-3)	17,760?70	Rapidan River flood plain near Rhodes Farm Madison Quadrangle - Wood fragments Basal unit in exposure about 2.5 m below surface
38 (M-85a)	20,470?110	Flattop Mountain, tributary draining to east Madison Quadrangle Organic layer below debris-flow deposits
39 (M-85b)	19,760?110	Flattop Mountain, tributary draining to east Madison Quadrangle Organic layer below debris-flow deposits

Appendix 1

Field Descriptions of Radiocarbon Sites

Site 3.

Drainage Basin: Wilson Run,
Fletcher VA Quadrangle
Site No. 041696B Date:06-10-96 Time : 13:00
Geomorphic Surface Left Channel Parent Material(s): Granite and Gneiss

Carbon Samples Present:

17120? 80ybp

Depth (m)	Unit	Sample	Color (Moist)	Gravel %	Texture of Matrix	Mean gravel Length (cm)	Max gravel length (cm)	Clast Fabric	Carbon Present	Lower Boundary Contact
0 -0.4	1	041696B-1	Not recorded	100	Gravel	Not recorded	370	G	no	Abrupt,Wavy
0.4 -0.63	2	041696B-2	Dark Brown(organic)	80	Pebbly coarse sand	80	5	G	**yes**	Abrupt,Slightly Wavy
0.63 - 0.87	3	041696B-3	Gray	50	Coarse sand	3	6	GM	no	Abrupt,Smooth
0.87 - 1.07	4	041696B-4	Gray	40	Gravelly loam	2	13	GM	no	Abrupt,Wavy
1.07 -1.67	5	041696B-5	OrangeBrown	70	Sandy clay loam	9	25	GM	no	NotSeen

NOTES: Texture is from field determinations
Weak iron cement in unit 3; well-defined imbrication of pebbles in unit 4; iron cement present in unit 5.
M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Site 4.

Drainage Basin: Wilson Run,
Fletcher, VA Quadrangle
Site Number: 041696E

Time: 15:35

Parent Material: granite-gneiss

Geomorphic Surface: Left channel

Carbon Samples Present:

041696E	13,990 ? 60ybp

[3]

Depth (m)	Unit	Color Moist	Gravel %	Texture of Matrix (cm)	Mean grav. Length (cm)	Max grav. Length (cm)	Clast Fabric	Lower Bound Contact	Bou Slo
0 -0.5	1		80	Gravely Sand	30 cm [4]	70x40	G	Diff. to Determ.	4
0.5 -1.80	2		100	Gravel	90x70	320x160	G	Abrupt,Wavy	6
1.80 - 1.91	3	Orange Brown	70	Gravely Loam	2x2	9x6	GM	Abrupt,Almost Smooth	5
1.91 - 2.04	4	Light Gray at top [3]	40	Coarse Sndy Cl Loam	< 1 cm	4x2.5	MG	Clear,Wavy	8
2.04 -2.38	5	Brownish Gray [2]	30	Coarse Sandy Clay	1.5 x2	5.5x3.5	MG	Abrupt,Smooth	1
2.38 -2.48	6	Dark Gray	10	SandyClay	xx	xx	M	Not Seen	Not S

[1] at base of organic unit
[2] iron pan is 5.5 cm
[3] iron pan at bottom 2.5 cm
[4] matrix has gravels @ 2 cm
xx no sizable grains present for measurement

Notes: Texture is from field determinations
Clast support range from grain, grain-matrix, matrix-grain, and matrix

Comments: Unit 1 is from 1995 flood. Mg stains in unit 2. All lower pans below unit 2 appear to have iron pan. Small pebbles present in unit 6.

Site 5.

Drainage Basin: Wilson Run, Fletcher, VA Quadrangle
Site Number: 041696G
Date: 6-11-96 Time : 17:00
Geomorphic Surface: Left channel
Parent Material: granite-gneiss

Carbon Samples Present:

061696G 14,370 ? 70

Depth (m)	Unit	Color (moist)	Gravel%	Texture of Matrix (cm)	Mean grav. length (cm)	Max grav. length (cm)	Clast Fabric	Lower Bound Contact	Boundary Slope (deg)	Carbon Present
0 - 0.6	1		50	Gravely Sandy Loam	6x4	100x60	GM	Gradual, Wavy	6	no
0.6 - 2.4	2	Orange Brown	50	Pebbly Sandy Loam	6x5	40x30	GM	Abrupt, Smooth	6	no
2.4 - 2.5	3	Medium Gray	50	Pebbly Sandy Loam	3x2	19x7	MG	not determined	6	yes

NOTES:

Texture from field determinations
Thin cap of 1995 material above unit 1

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Site 6.

Drainage Basin: Wilson Run,
Fletcher, VA quadrangle
Site Number: 041696H
Date: 6-11-96 Time : 17:45
Geomorphic Surface: Left channel
Parent Material: granite-gneiss, greenstone

Carbon Samples Present:

041696H 14,530 ? 70

Depth (m)	Unit	Color (moist)	Gravel %	Texture of Matrix (cm)	Mean grav. length	Max grav.	Clast Fabric	Lower Bound Contact	Boundary Slope	Carbon Present
					(cm)	length		(deg)		
0 - 0.7	1		70	Gravely Loam	5.0x2.5	2.0x0.8	GM	21	Clear, Smooth	no
0.7 - 2.3	2	Gray Brown	85	Pebbly Sandy Loam	3.0x2.0	3.0x2.0	GM	15	Diffuse, Wavy	no
2.3 - 3.1	3	Gray	85	Pebbly Sandy Loam	3.0x2.0	3.0x2.0	GM	Not Determ.	Not Determ.	yes

NOTES:

Texture is from field determinations
Thin cap of 1995 material above
unit 1

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Site 7.

Drainage Basin: Wilson Run,
Fletcher, VA quadrangle
Site Number: 041696F2
Date: 6-11-96 Time : 14:05

Carbon Samples Present:

041696F 6,520 ? 60

Geomorphic Surface: Left channel
Parent Material: granite-gneiss

Depth (m)	Unit	Color moist	Gravel %	Texture of Matrix (cm)	Mean grav. Length (cm)	Max grav. Length	Clast Fabric	Lower Bound Contact	Boundary Slope	Carbon Present
0 -1.4	1		95	Gravely Sand	110x50	180x100	G	21	Abrupt,Wavy	no
1.4 -1.57	2	Reddish Orange	40	Pebbly Sandy Loam	3x2	6x5	GM	15	Clear,Wavy	no
1.57 - 1.64	3	Yellow Gray	80	Clayey Sand	3x1.5	21x11	G	Not Determ	Abrupt, Smooth	no
1.64 - 1.70	4	Orange	15	Clayey Sand	< 1.0 cm	3x2	MG	Not Determ	Diffuse,Wavy	No
1.70 -2.30	5	Dark Gray	<10	Sandy Clay Loam	< 1.0 cm	18x15	M	Not Visible	Not Visible	6,520 ? 60

NOTES:

Texture is from field determinations
Units 2,3,4 may be of fluvial origin based on clast imbrication.
Unit 3 contained 0.1 cm weathering rind in greenstone.
A thin (less than 0.2 m) capping of 1995 material is present at the site.

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Sites 8, 10.
Written Correspondence with Kelvin Ramsey, Delaware Geological Survey, Feb. 4, 1997

"Lower Kinsey run: DGS sample no. 58233 (34,770 ybp.)

Quaternary age, cool temperate climate
Pinus dominates, low percentages of Picea and Quercus, followed by Alnus, Polypodiaceae

Upper Kinsey run: DGS sample no. 58234 (24,570 yr B.P.)

Quaternary age, dry, cool climate, cooler than that of 58233
Pinus dominates, followed by Picea, also present Lycopodium, Compositae, Polypodiaceae, Caryophyllaceae"

"My spin on the samples. Both samples indicate that the forest was pine dominated. Whereas the lower Kinsey Run sample has some oak (Quercus) and a little spruce (Picea), the upper Kinsey Run has more spruce and no oak to speak of, hence a cooler climate. Upper Kinsey also has some moss spores and some grasses that indicate a drier climate than lower Kinsey where alder (Alnus) is present. "

Sites 12, 13.

Carbon Sites are 052696A-1, 052696A-2 1052696A-4
Drainage Basin : Southwestern basin, Kirtley Mt, Fletcher, VA Quadrangle
Site No. 062696B Date: 6-26-96 Time : 17:00
Geomorphic Surface Left Channel Parent Material(s): Gneiss, greenstone

Depth (cm)	Unit	Submitted Sample Bag #	Color ----------- moist/dry	Gravel %	Texture (matrix)	Mean gravel diam. (cm)	Max gravel diam (cm)	grain or matrix	Lower Boundary Contact
0 - 150	1		Slightly reddish brown	60	gravelly sandy loam	0.15 x 0.08	0.65 x 0.24	M	clear smooth
150 - 160	1a	062696A-1 no carbon	Grey brown	40	sandy clay	1.5 x 0.5	2.0 x 1.0	MG	Undeter-mined
160 - 195	2		dark red brown	50	pebbly sand	0.04 x 0.02	0.26 x 0.1	GM	abrupt, wavy
195 - 213	2a	062696A-2 15,990 ybp	tannish gray brown	40 (at base of Org.	loamy sand (top) silty clay (bottom)	1.5 x 1.0	0.1 x 0.07	GM (bottom) M (top)	abrupt wavy
213 - 293	3		reddish brown	80	sandy loam	0.13 x 0.05	0.4 x 0.3	GM	undeterm ined
293 -323	4	062696A-4 24,910 ybp	dark gray	30	clay loam	4.0 x 2.0	0.1 x 0.7	M	N/A

Large fragments (1 cm) of carbon collected from basal unit (unit 4). Carbon submitted from units 1a, 2a, and 4. Basal carbon unit is laterally continuous for tens of meters downstream of site.
M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Site 14. Kirtley Mountain, Fletcher, VA quadrangle
Silty clay organic unit overlain by two debris flows. Colors 7.5 YR

Site 15. Kirtley Mountain, Fletcher, VA quadrangle
Light black organic layer comprised of fine sandy loam; thickness is 18-20 cm.
Overlain by a slightly indurated debris flow, and underlain by a moderately indurated debris flow.
Munsell colors are between 10 YR and 7.5 YR.

Site 16. Kirtley Mountain, Fletcher, VA quadrangle
Site contains a major unconformity. The south side of the channel has multiple stacks of "ancient" debris flows that have heavily weathered cobbles, high clay content, and 2.5 YR colors. Two to 3 discrete debris flows are present, with a paleosol separating the basal flow from the middle flow. The basal flow resides on saprolite. The upper debris flow is overlain by a strikingly more "modern" debris flow; marking the unconfomity. The beds can be projected across the stream channel to the north side of the channel, where sample 052898C was taken. Between 3 to 4 debris flows are present, the basal is radiometrically dated as greater than 50,000 yr B.P. The basal debris flow has a few greenstone clasts that have on average a 1 mm weathering rind. The feldspar crystals show the beginning stages of degradation, however. The fabric of the flow, grain-matrix supported, showed slightly moderate induration. Carbon flecks was extracted from a sandy-silt layer, 25 cm thick

Site 19. Tributary of Conway River, Fletcher, VA quadrangle

Tributary of Conway River

Upper debris flow unit:

?? Thickness is 60 cm

?? matrix supported

?? large clasts; largest is 70-80 cm, average is 30 cm.

?? 7.5 YR colors

Slope wash unit:

?? 70 cm thick

Middle debris flow unit:

?? 50 cm thick

?? 7.5 YR colors

Organic Unit:

?? fine sand with carbon flecks present (24,230 yr B.P.)

?? 30 cm thick

Lower debris flow unit:

?? 300 cm thick

?? base is covered

?? cobbles are grain supported

Site 20.

Drainage Basin: Rapidan River, Madison, VA quadrangle

Carbon Samples Present:

Site Number: 091796Y

1,550 ? 50 ybp

Date: 09-17-96 Time : 14:05

Surface Slope: ?

Geomorphic Surface: Left scour channel in flood plain

Parent Material: granite-gneiss-greenstone

Depth (cm)	Unit	Gravel %	Mean gravel length (cm)	Max gravel Length (cm)	Carbon Present
0 - 21	1	20	7 * 4		
21 - 60	2	100	8.1 * 5.5	26 * 14	
60 - 86	3	5	< 1 cm	1 * 1	yes
86 -	4	100	10.4 * 6.8	19 * 11	
	5	100	7.3 * 5.0	15 * 9	

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Sites 21, 22, 23 .

Drainage Basin: Judy Run, mouth,
Madison, VA quadrangle
Site Number: 092196B

Carbon Samples Present:

092196B-2 22,350 ? 80 ybp
092196B-3 24,450 ? 110 ybp
092196B-4 27,410 ? 150 ybp

Surface Slope: not available
Geomorphic Surface: Left bank, near top of drainage basin at inflection point and 50 m downstream from major failure
Parent Material: schists, gneiss, greenstone

Depth (cm)	Unit	Color moist	Gravel %	Texture of Matrix	Mean Gravel Length (cm)	Max Gravel Length (cm)	Clast Fabric	Lower Boundary Contact	Boundary Slope (deg)	Carbon Present
0 - 18	1	Reddish Brown	0	Sand	< 1	< 1	M	Abrupt, Wavy	13	No
18 - 127	2	Reddish Brown	30	Pebbly Sand	13 * 7	28 * 10	MG	Abrupt, Wavy	10	No
127 – 222	3	Gray w/ Orange Streaks	< 10	Silty Sand	5 * 3	17 * 10	G	Abrupt, Wavy	8	Yes
222 – 293	4	Tan	80	Pebbly Sand	4 * 3	15 * 8	G	Abrupt, Wavy	Not available	No
293 – 403	5	Medium Gray	15	Silty Sand	10 * 6	25 * 15	G	Abrupt, Wavy	Not available	Yes
403 – 468	6	Tan	90	Sand	15 * 10	100 * 60	G	Abrupt, Wavy	Not available	No
468 – 480	7	Dark Black Gray	< 5	Silty Sand	< 1 cm	< 1	G / GM	Covered	Not available	Yes

Unit 2. hyperconcentrated flow, imbrications are upstream2. hyperconcentrated flow, minor imbrication
Unit 3. two bands of gravel layers present in this unit
Unit 3. Carbon is at the top, 2 significant cobble layers, silty-sand 2-3 cm thick
Unit 3. buried "soil" has slight reddish tint
Unit 3. 12 cm of sand at top, followed by a gravel lense, then a weakly developed soil, followed by 39 cm of sand, and a basal gravel lense at the bottom of the sequence.
Unit 5. 1 strongly buried O horizon. 2 weak O horizons. Multiple layers deposited via wash
Unit 5. Capped by a weak O horizon, followed by 21 cm of sand, then 3 cm of a strong O horizon, followed by multiple cm of sand, then a final weakly developed O horizon

Sites 26, 27.

Drainage Basin: Rapidan River, Madison Va quadrangle
Site Number: 092196A
Date: 09-12-96 Time : 14:05
Surface Slope: ?
Geomorphic Surface: Left channel
Parent Material: granite-gneiss-greenstone

Carbon Samples Present:

092196A-6
092196A-12

Depth (cm)	Unit	Gravel %	Texture of Matrix (cm)	Mean gravel Length (cm)	Clast Fabric	Lower Boundary Contact	Carbon Present
0 - 5	1	100	Cobbly sand		G	Smooth, Abrupt	No
5 - 18	2	<10	Sand	<1 cm	G	Smooth, Abrupt	No
18 - 23	3	<10	Organic	<1 cm	G	Smooth, Abrupt	Yes
23 - 52	4	<10	Sand	<1 cm	G	Smooth, Abrupt	No
52 - 104	5	<10	Sand	<1 cm	G	Smooth, Abrupt	No
104 - 115	6	<10	Organic	<1 cm	G	Smooth, Abrupt	3,880 ? 50
115 - 125	7	<10	Sand	<1 cm	G	Smooth, Abrupt	No
125 - 137	8	100	Gravel		G	Smooth, Abrupt	No
137 - 160	9	<10	Sand	<1 cm	G	Smooth, Abrupt	Yes
160 - 228	10	<10	Sand	<1 cm	G	Smooth, Abrupt	No
228 - 255	11	<10	Coarse Sand	<1 cm	G	Smooth, Abrupt	No
255 - 267	12	<10	Clay slt w/org @base	<1 cm	G	Smooth, Abrupt	4450 ? 60
267 - 287	13	<10	Coarse sand	<1 cm	G	Smooth, Abrupt	No

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Sites 28, 29.

Drainage Basin: Lillard Run,
Madison, VA quadrangle
Site Number: 071196A
Time: 11:50
Surface Slope: 5.5 (as estimated from opposite bank)
Geomorphic Surface: Left bank, at apex of debris fan
Parent Material: weakly foliated quartz rich, granite-gneiss

Carbon Samples Present:

071196A-2
071196A-4

Depth (cm)	Unit	Color Moist	Gravel %	Texture of Matrix	Mean gravel length (cm)	Max gravel length (cm)	Clast Fabric	Lower Boundary Contact	Boundary Slope (deg)	Carbon Present
0-90	1	10YR3/3	75	Pebbly sandy loam	12 * 7	53 * 26	MG	clear, wavy	4.5	No
90-108	2	7.5YR4/4	10	Coarse sandy silt loam	2 * 2	7 * 4.5	M	clear, irreg.	6	2,430 ? 60
108-238	3	10YR3/4	65	Pebbly sandy loam	17 * 10	76 * 26	M	clear, wavy	8	No
238-256	4	10YR3/2	10	Sandy clay loam	2.5 * 2	7.5 * 3.5	M	gradual, wavy	8	3,700 ? 50
256-361	5	10YR2/2	65	Coarse sandy loam	9 * 6	22 * 36	MG	Not available	Not available	no

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Sites 30, 31, 32.

Drainage Basin: Lillard Run,
Madison, VA quadrangle
Site Number: 070896A
Time: 12:10
Surface Slope: 5.5
Geomorphic Surface: Right bank, at apex of debris fan
Parent Material: weakly foliated quartz rich, granite-gneiss

Carbon Samples Present:

070896A-3
070896A-7
070896A-9

Depth (cm)	Unit	Color moist	Gravel %	Texture of Matrix	Mean gravel Length (cm)	Max gravel Length (cm)	Clast Fabric	Lower Boundary Contact	Boundary Slope (deg)	Carbon Present
0-13	1	10YR2/2	<10	Sandy silt loam	<1.0	5 * 3	M	gradual, wavy	8	no
13-59	2	10YR2/2	80	Pebbly silt loam	20 * 12	120 * 70	M	abrupt, smooth	5	no
59-66	3	10YR2/1	20	Gravelly silt loam	3.5 * 2.0	7 * 5	MG	clear, smooth	6	2,080 ? 50
66-72	4	10YR3/3	70	Coarse sand loam	4.5 * 2.0	11 * 8	GM	clear, smooth	8	No
72-94	5	10YR3/6	<10	Pebbly sand loam	< 1.0	3 * 2	M	clear, smooth	4	No
94-274	6	7.5YR4/4	80	Pebbly sand loam	7 * 3	18.5 * 12	GM	covered	Not avail.	No
274-369	7	7.5YR5/8	90	Pebbly clay loam	10 * 7	72 * 70	GM	gradual, wavy	6	4,240 ? 50
369-421	8	7.5YR5/6	90	Gravelly sand loam	10 * 6	60 * 40	G	grades into stream	Not avail.	No
421-501	9	5YR5/8	10	Clayey sand loam	12 * 4	35 * 40	M	n/a	Not avail.	> 50,800

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported

Site 33.
Organic "outcrop" of 20-30 cm thick overlain by 2 younger debris flows, and underlain by at least one. Carbon layer is 25,860 ybp. The side of this exposure is seen in figure 7 of the Madison County soils survey, located directly at the bend of the Rapidan River.

Site 34.
The site is referred to as “clay canyon” due to the abundance of bedded light gray silts and clays. An organic fine grain material is overlain by a single debris flow, and covers a nearly saprolitized debris flow. The younger unit is matrix supported, lacks imbrication, and has two large boulders (4 meters, long axis) in length at the surface. Thickness is 2 m, color is 7.5 YR 4/6. Weathering rind of single greenstone clast is 0.1 cm. The organic unit, dated 25,290 yr B.P., dips 4? (about the same as the surface slope) and is ranges in thickness from 25-80 cm, eventually truncated by the upper debris flow. Colors are 10 YR 7/1. The older debris flow is highly matrix supported, 3.2 m thick, and the maximum boulder size is 0.8 m. Munsell colors are 5 YR 5/6.

Site 35.

Site 092296A1, Madison, VA quadrangle
In situ tree stump buried in prehistoric debris flow
Radiocarbon age: 2,240 ? 50 ybp.

The site is located at the base of a first order tributary 20 m upstream of where it enters a small tributary of the Rapidan River. The radiocarbon sample was taken from an in situ tree stump identified as Oak, and was exhumed by the Rapidan flood. The stump is implanted in a sandy, cobbly diamicton that is interpreted as emplaced by a late Holocene debris flow.

The dendrology analysis by Tom Yanosky ,USGS (written communication) is as follows:

“Much of the natural color (of the specimen) is gone, and its density is much less than I would expect from a recent specimen. The rings are much narrower than I would expect, which leads me to believe the tree grew under very poor conditions -- either in a very dense stand, or where growth was limited by very dry conditions (most likely a function of site) or by a short growing season.”

“I don’t believe the oak was a riparian tree, or at least not one that exhibits the kind of growth expected from a living oak. Rings of this tree consist mostly of earlywood rather than also having considerable latewood. Thus, the growth pattern is consistent with that of a tree growing on a hillside amidst lots of company--one uprooted by a cataclysmic event and subsequently buried somewhere downgradient. Furthermore there is still some bark evident, so the outer rings are clearly part of the sapwood, and the decomposition within the sapwood is not greater than that within the heartwood. (In comparison) Look in the woods at an old downed oak sometime and notice that decomposition is greatest in the outermost rings, because that is where the tree stored carbohydrates and lacked some of the decay-resisting compounds typically associated with the heartwood. Thus, this tree SEEMS to have been killed quickly and buried quickly also.”

Sites 36, 37.

Site was located in a drainage ditch (that has since been filled), created by Hurricane Fran.
Stratigraphy was extremely complex due to anthropogenic modification and scour and fill channels. The basal unit, 40 + cm are gray horizontal fine sandy layers interpreted as Rapidan River flood plain sediments (17,760 ybp.). Overlying this unit are multiple fine grained units of coarse sands and pebbles; weak soil structure was detected. Dominant colors are gray and light yellow, thickness 85 cm. Next unit above is a 50 cm sand and coarser pebble/small cobble unit. This unit is covered by 68 cm of brown/yellow sand, and capped by a buried soil. Cut into the entire previously described section is a scour channel, which contained modern artifacts (19^{th} century drainage tile). The radiocarbon date was 80 ybp.

Sites 38, 39.

Drainage Basin: Flattop Mt.
Madison, VA quadrangle
Site Number: 073096B
Time: 13:45
Surface Slope:not available
Geomorphic Surface: Left bank, near top of drainage basin and near several tributary confluences
Parent Material: schists, gneiss, greenstone

Carbon Samples Present:

M-85a	20,470
M-89b	19,760

Depth (cm)	Unit	Gravel %	Texture of Matrix	Mean gravel length (cm)	Max gravel length (cm)	Clast Fabric	Lower Boundary Contact	Boundary Slope (deg)	Carbon Present
0-65	1	60	Pebbly loamy sand	11.7 * 8.5	39 * 20	M	Clear, Wavy	13	No
65-113	2	20	Clayey sandy loam	1.0 * 0.5	9 * 7	MG	Abrupt, Wavy	10	No
113-196	3	80	Pebbly clayey sand	13.2 * 7.5	32 * 25	GM	Gradual, Smooth	8	No
196-246	4	80	Pebbly sandy loam	8.0 * 5.5	21 * 7	GM	Clear, Irregular	8	No
246-250	5	<10	Sandy silty loam	< 1 cm	< 1 cm	M	Clear, Broken	8	No
250-295	6	90	Pebbly sand	6.7 * 4.5	17 * 7	G	Abrupt, Smooth	8	No
295-319	7	<10	Clayey silty loam	< 1 cm	< 1 cm	M	Clear, Broken	8	No
319-340	8	90	Pebbly clay loam	6.7 * 4.6	42 * 22	G	Abrupt, Broken	8	No
340-378	9	<10	Silty clay	< 1 cm	5 * 3.5	M	Not available	8	Yes

M = matrix supported
MG = matrix-grain supported
GM =grain-matrix supported
G = grain supported