From: Taylor, S.B. 1999. Geomorphic Controls on Sediment-Transport Efficiency in the Central Appalachians - A Comparative Analysis of Three Watersheds Underlain by the Acadian Clastic Wedge. Ph.D. Dissertation, West Virginia University

CHAPTER TWO

Surficial and Bedrock Geology of the Fernow Experimental Forest, Monongahela National Forest, Tucker County, West Virginia

ABSTRACT

The bedrock and surficial geology of the Fernow Experimental Forest, Tucker County, West Virginia, were recently mapped as part a cooperative agreement with the USDA Northeastern Forest Experiment Station. This work comprises part of the senior author's dissertation research at West Virginia University, and provides a valuable data set from which to assess watershed transport efficiency in the central Appalachians. This report serves as explanatory text to accompany the set of maps prepared for the Fernow Experimental Forest. The map products include: (1) 1:9,600 topographic base map, (2) 1:9,600 bedrock geology map with cross-sections, (3) 1:9,600 surficial geology map with expanded explanation, and (4) 1:9,600 soils map derived from county soil survey data (Losche and Beverage, 1967).

The 19 km^2 study area lies in the Allegheny Mountain section of the unglaciated Appalachian Plateau. Bedrock is comprised of moderately folded Upper Paleozoic sedimentary strata. The climate is humid continental and soils include Dystrochrepts, Hapuludalfs and Fragiudults. Natural vegetation is that of a mixed-hardwood forest assemblage.

Mappable lithostratigraphic units in the area include the Devonian Foreknobs Formation (Greenland Gap Group), the Devonian Hampshire Formation (Canon Hill and Rowlesburg members), the Mississippian Price (Pocono) Formation, the Mississippian Greenbrier Group, the Mississippian Mauch Chunk Group, the Pennsylvanian Pottsville Group and the Pennsylvanian Allegheny Formation. These strata are comprised primarily of clastic sediments derived from eastern tectonic highlands. The stratigraphic section was subsequently folded and fractured in response to the Late Paleozoic Alleghanian orogeny. The rocks have been exposed through a process of erosional unroofing and isostatic uplift.

Surficial deposits at the Fernow Experimental Forest are mapped on the basis of a four-fold classification including age, origin (genetic process), landform, and material (texture). Large-scale landform units include hillslope, valley-bottom, and karst features. Hillslopes are subdivided into hollows, noses, side slopes, and footslopes. Valley bottoms are comprised of

channels, floodplains, and terraces. Karst landforms include sinkholes, springs, pocket valleys, and cave openings. Hillslope deposits are comprised of colluvial and residual gravel diamicton. Footslope areas are sites of fan and apron deposits. Valley-bottom sequences are composed largely of imbricated coarse-grained facies. The ages of surficial deposits in the study area are unknown; however, regional chronologies suggest that colluvium is in part Late Pleistocene (>10 Ka), while alluvium is mostly Holocene in age (< 10 Ka).

Ecosystem management and global change are at the forefront of public discourse and policy making. Surficial process studies provide the foundation from which to design sustainable forest management plans.

INTRODUCTION

The U.S. Forest Service established the Fernow Experimental Forest in 1934 as part of the Northeastern Forest Experiment Station. The objectives of this facility are to protect water resources in the central Appalachians, and to study the growth and culture of northern hardwoods (Adams and others, 1994). Over 60 years of valuable experimental data have been collected and published by researchers at the Fernow (Goodwin and others, 1993).

The U.S. Forest Service contracted West Virginia University to prepare detailed surficial and bedrock geology maps for the Fernow Experimental Forest (Northeastern Forest Experiment Station Cooperative Agreement No. 23-023). The general objectives of this project are to better understand the influence of geology on forest processes, site hydrology, and ecosystem interactions. This report serves as explanatory text to accompany the set of digital maps included with this document. Table 2-1 summarizes the map products. For convenience to the reader, the large-scale map sheets are reduced and included as page-size figures in the body of text.

GENERAL SETTING

Physiography

The Fernow Experimental Forest is located in Tucker County, West Virginia, approximately 1.3 km south of the town of Parsons (latitude: 39° 02' 00" N to 39° 04' 50" N, longitude: 79° 39' 00" W to 79° 42' 00" W). The 19 km^2 study area lies in the Allegheny Mountain section of the unglaciated Appalachian Plateau physiographic province (Figures 2-1

Table 2-1. Summary of Map Products for the Fernow Experimental Forest.

Map Title	Arcview 3.0 Shape File[1]	Attribute Lookup File	Hardcopy Map
Topographic Map of the Fernow Experimental Forest, Tucker County, West Virginia (1:9,600)	FERNTOPO.SHP	N/A	Plate 2-1.
Bedrock Geology of the Fernow Experimental Forest, Tucker County, West Virginia (1:9,600)	FERNROCK.SHP	FNRKLUP.DBF	Plate 2-2.
Geologic Cross-Sections Along Lines A-A' and B-B' Fernow Experimental Forest, Tucker County, West Virginia (1:9,600)	FERNXSEC.DWG [2]	N/A	Plate 2-3.
Surficial Geology of the Fernow Experimental Forest, Tucker County, West Virginia (1:9,600 with topographic base)	FERNSURF.SHP	FNSRFLUP.DBF	Plate 2-4A.
Surficial Geology of the Fernow Experimental Forest, Tucker County, West Virginia (1:9,600 without topographic base)	FERNSURF.SHP	FNSRFLUP.DBF	Plate 2-4B.
Soils Map of the Fernow Experimental Forest, Tucker County, West Virginia (1:9,600 from Hockman and others, 1979)	FERNSOIL.SHP	FNSOILUP.DBF	Plate 2-5.

1. Arcview 3.0 shape files are available for download / FTP. The accompanying *.dbf, *.shx, and *.lup files are also included. The lookup files are in a dbase-IV format. View "readme.txt" with an ASCII text editor for additional information.

2. The cross-sections have been included in an Autocad 12.0 (DOS) drawing file format only. The *.dwg file may be viewed as an ArcView theme.

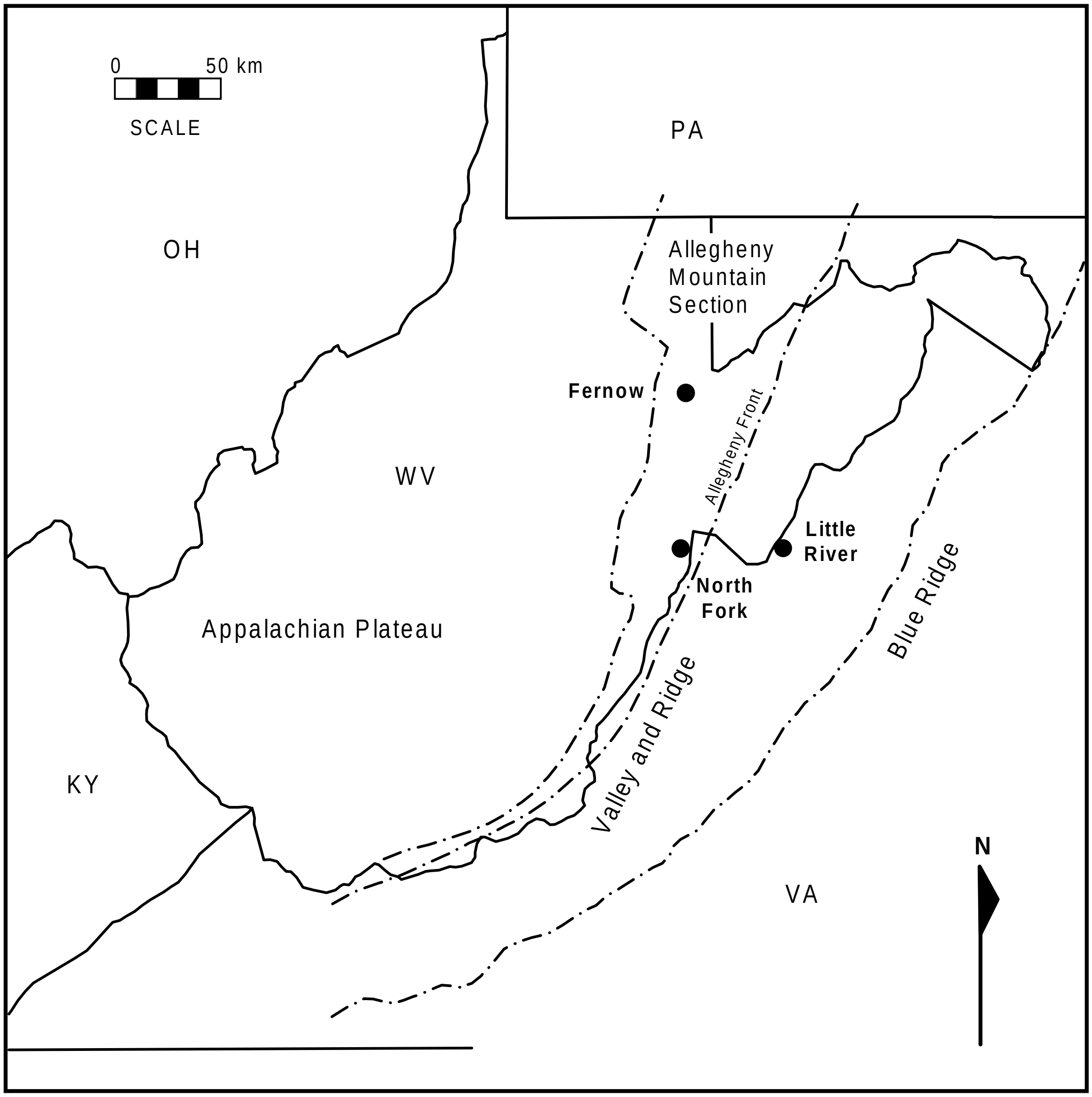


Figure 2-1. Physiographic map of the central Appalachians. Site identification code: "Fernow" = Fernow Experimental Forest, Tucker County, West Virginia. Physiographic base map is from Kulander and Dean (1986).

and 2-2). Topography is characterized by dissected uplands and narrow V-shaped valleys (Figures 2-3 and 2-4; Plate 2-1). The area is bounded by Fork Mountain to the northwest and McGowan Mountain to the southeast. Surface elevations range from 513 to 1,100 meters (1683 to 3609 ft) AMSL. Elklick Run and Stonelick Run form the primary drainages at the Fernow (Figure 2-2). These tributaries merge with Black Fork and Shavers Fork to comprise part of the upper Cheat-Monongahela river system.

Climate

Climate of the study area is classified as humid continental with hot summers, cold winters, and abundant precipitation (Lockwood, 1985). The Fernow averages 1450 mm (57 in) of precipitation per year, with the greatest amount occurring in the spring and summer months (Figures 2-5 and 2-6). Annual snowfall averages 1370 mm (54 in) in the valley bottom near Parsons. Mean monthly air temperatures range from -1° C in January to 25° C in July (Adams and others, 1994). Rain-on-snow hydrometeorological events are a source of flooding in winter. Weather systems are directed primarily from the west, with mid-latitude frontal systems and large-scale cyclonic disturbances common (Hirschboeck, 1991). Moisture-laden air from the Gulf of Mexico is directed northward during the warm months along the topographic grain of the Appalachians (NOAA, 1974). The region is sporadically prone to torrential rainfall associated with the extratropical-phase of hurricanes (Colucci and others, 1993). Streamflow discharge is generally at a maximum during late winter-early spring, and at a minimum during autumn (Adams and others, 1994).

A geomorphically significant storm event occurred in the central Appalachian region on November 3-5, 1985 (Jacobson, 1993). Low-intensity, long duration rainfall was produced by complex tropospheric interaction between low-pressure cyclones and a stationary high-pressure system located in eastern Canada (Colucci and others, 1993). Flooding in the Cheat River basin was stimulated by high antecedent soil moisture and greater than 150 mm of rain in a 48 hour period (Kite and Linton, 1993). Most of the gaging stations at the Fernow watersheds experienced record peak discharges during this event (Figure 2-7). Both the Cheat and Potomac basins were subject to extensive geomorphic alteration via overbank erosion and deposition (Miller, 1990; Kite and Linton, 1993; Miller and Parkinson, 1993).

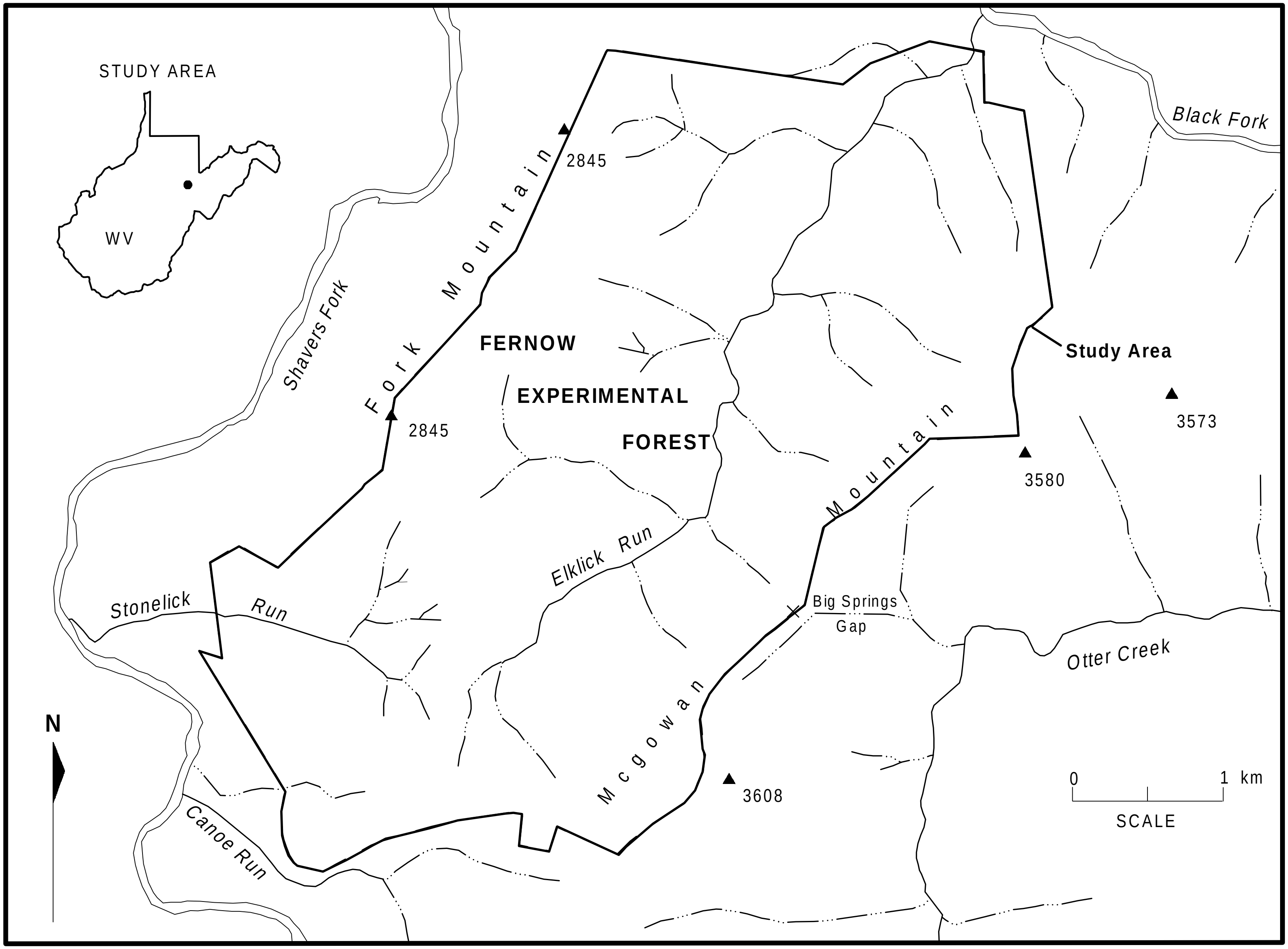


Figure 2-2. Location map of Fernow Experimental Forest, Tucker County, West Virginia. Spot elevations given in feet AMSL.

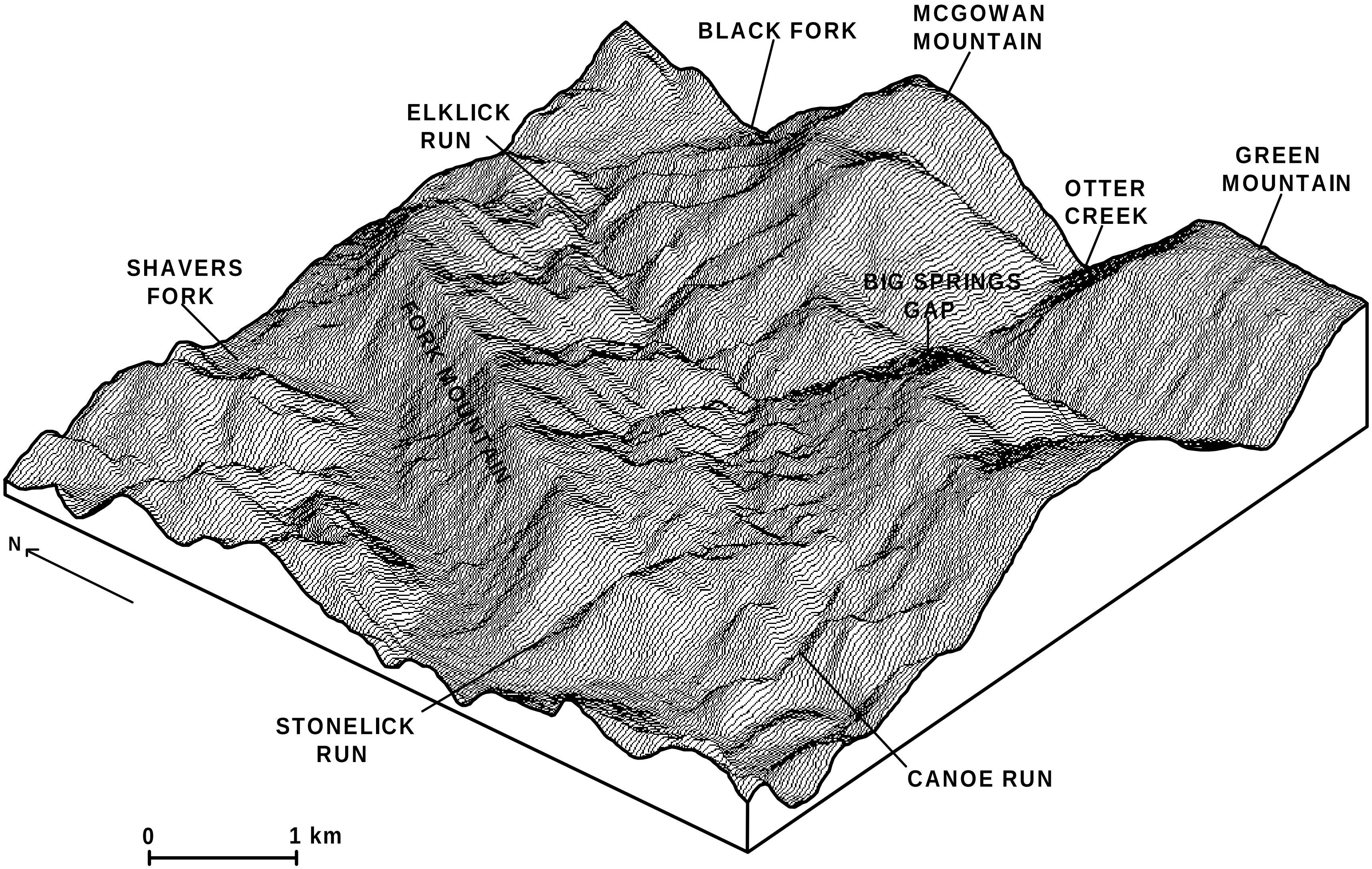


Figure 2-3. 3-D digital elevation model of the Fernow Experimental Forest. Model developed from USGS 30-m DEM for the Parsons 7.5-minute Quadrangle. Surface generated by IDRISI GIS software (Eastman, 1995); view is to the northeast.

Figure 2-4. Photo showing overview of Fernow landscape. View is northeast from McGowan Mountain overlooking Elklick Run. Field of view is approximately 2 km.

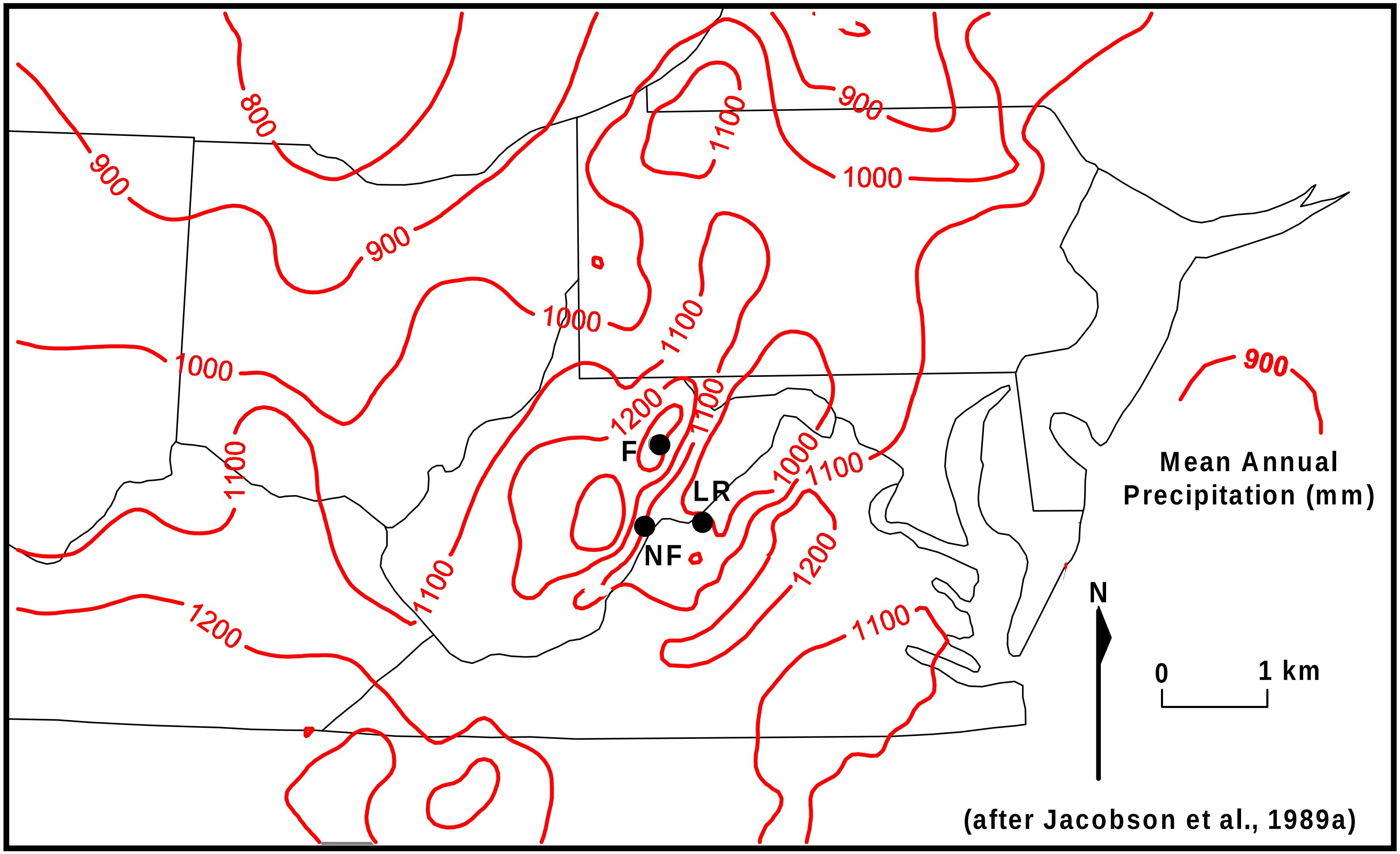


Figure 2-5. Mean annual precipitation map for the central Appalachian region. Location "F" refers to Fernow Experimental Forest (this study).

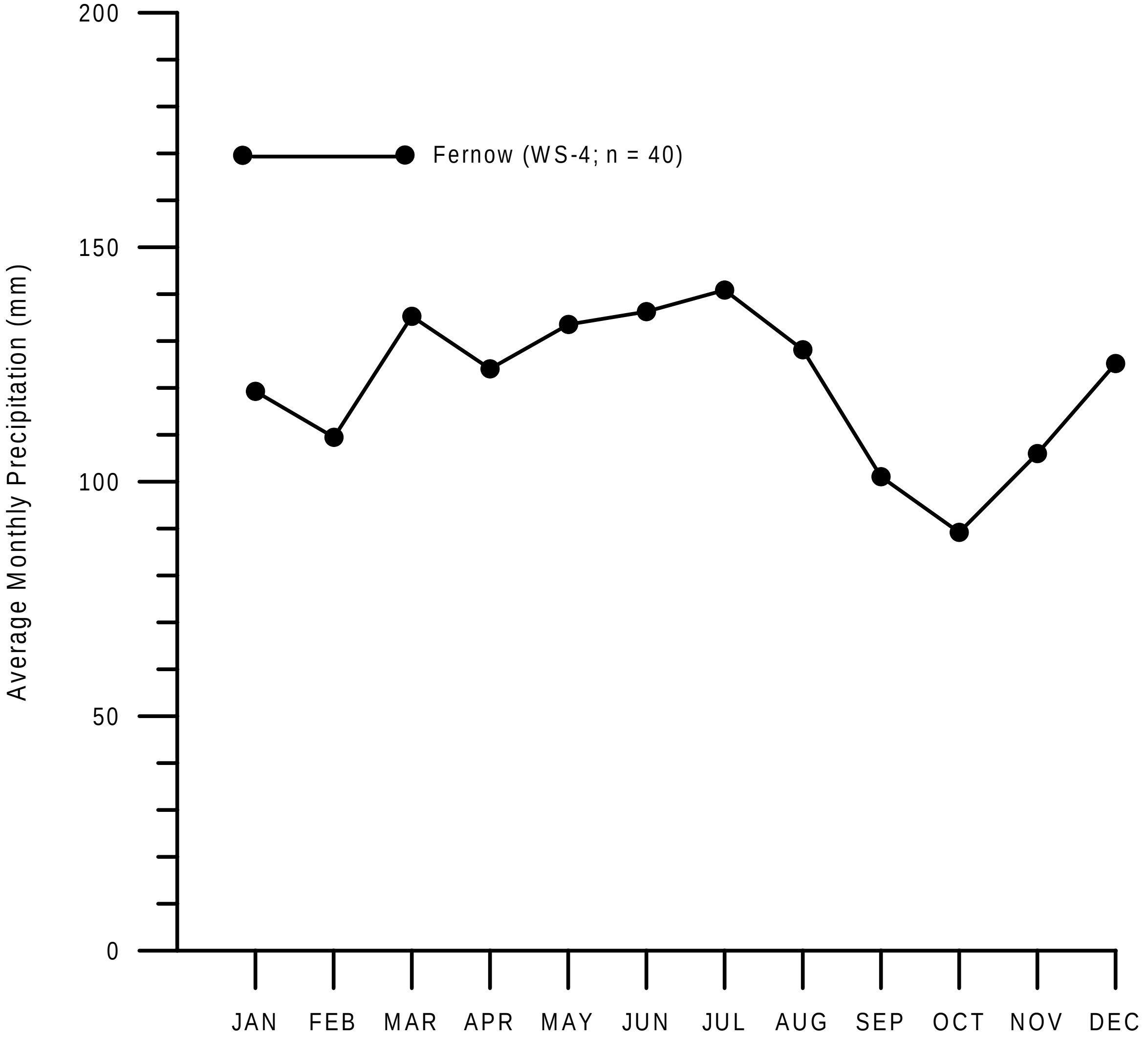


Figure 2-6. Graph of average monthly precipitation for the Fernow study area. Data collected at Watershed-4 (WS-4), 1951-1996 (Lat. = 39.069, Long. = -79.694) (Adams and others, 1994).

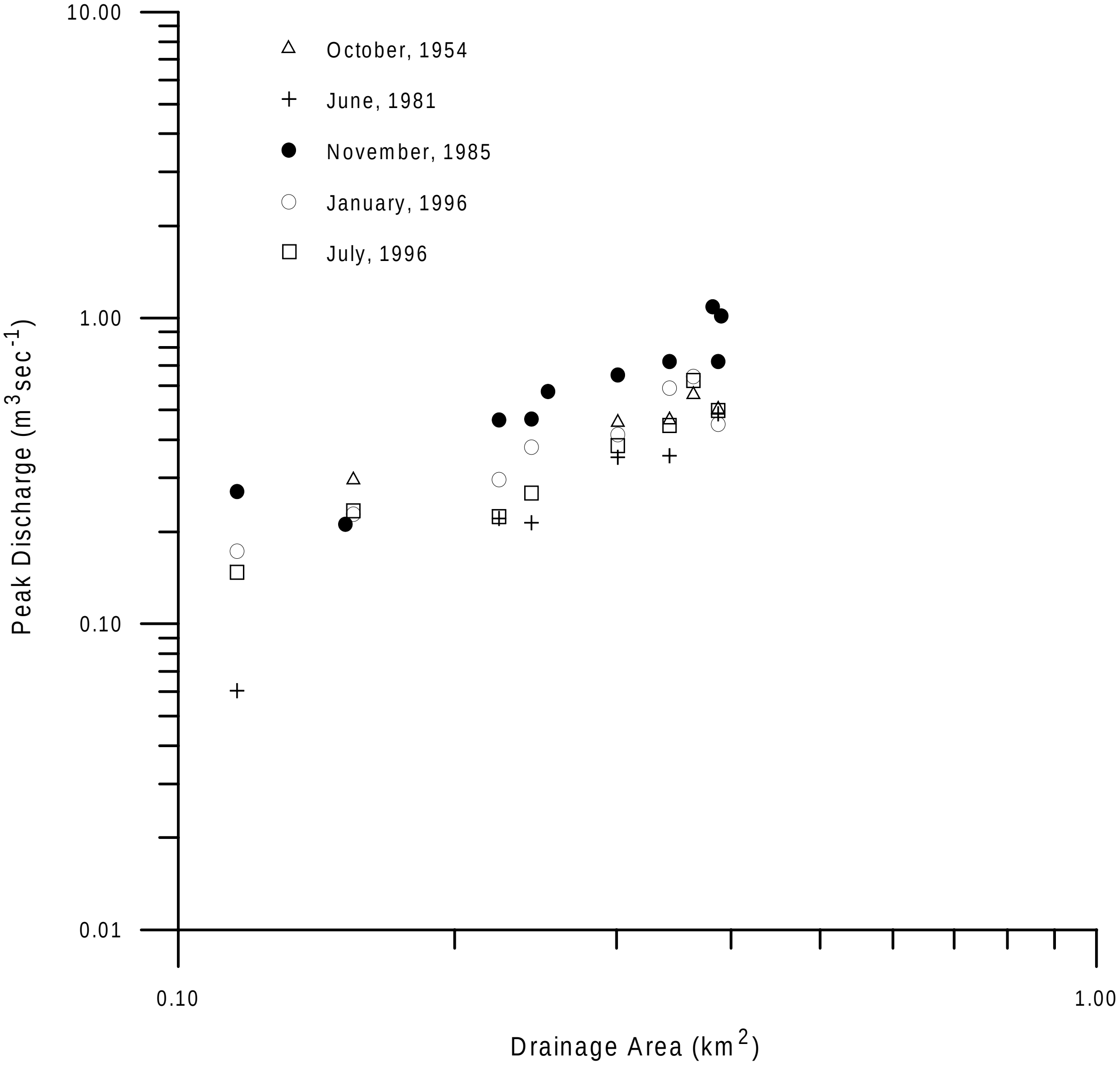


Figure 2-7. Log-log plot of drainage area (km^2) vs. peak discharge (m^3sec^{-1}) for the largest flood events of record at the Fernow Experimental Forest, Tucker County, West Virginia. Data provided by the U.S. Forest Service, Timber and Watershed Laboratory, Parsons, West Virginia.

Soils and Vegetation

Many soils in the central Appalachians are classified as Inceptisols; characteristics include low base saturation (acidic), thin poorly-developed A horizon, and weakly- to moderately-developed B horizon (Ciolkosz and others, 1989; Brady and Weil, 1996). These soils commonly form on weathered bedrock hillslopes mantled with colluvium and residuum. Soils at the Fernow Experimental Forest are comprised primarily of channery loams and silt loams of the Calvin and Berks-Muskingam series (Typic Dystrochrepts), Belmont series (Typic Hapuludalfs), and Meckesville series (Typic Fragiudults) (Adams and others, 1994; Losche and Beverage, 1967; Table 2-2, Figure 2-8, Plate 2-5). Valley bottoms are associated with undifferentiated Fluvents developed on gravelly alluvium. These poorly-developed valley soils are products of flooding and fluvial reworking.

Natural vegetation in the area is characterized by a mixed hardwood forest assemblage with species including yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*), white ash (*Fraxinus alba*), basswood (*Tilia americana*), red oak (*Quercus cocinea*), hickory (*Carya* sp.), sourwood (*Oxydendrum arboreum*) and sassafras (*Sassafras albidum*) (Core, 1966). Chestnut (*Castanea dentata*) was a dominant species on the Appalachian landscape before European settlement, but populations were severely diminished with the importation of blight. The entire central Appalachian region was subject to heavy logging during the early 1900's (Adams and others, 1994; Core, 1966).

BEDROCK GEOLOGY

Methodology

The bedrock geology of the Fernow Experimental Forest is updated and incorporated as part of the 1:9,600 digital map products (Figures 2-9 and 2-10, Plates 2-2 and 2-3). Previous geologic maps of the area include the 1:62,500 Tucker County Geologic Map (Reger, 1923) and the 1:250,000 West Virginia State Geologic Map (Cardwell and Others, 1968). The bedrock geology described herein is based on direct field observation and augments these previous works.

Field mapping of the Fernow Experimental Forest was conducted primarily in the Summer and Fall of 1995. Reconnaissance maps were prepared from air photos at a scale of 1:4,800 and contour interval of 10 ft (Greenhorne and O'Mara, Inc., unpublished maps). Final

Table 2-2. Summary of Soils at Fernow Experimental Forest, Parsons, WV (after Losche and Beverage, 1967).

Soils Map Unit	**Soil Series**	**Slope**	**Soil Texture**	**Parent Bedrock**	**Depth to Bedrock**	**Topographic Occurrence**	**Comments**
AbC	Albrights	8-15%	silt loam	siltstone?	38 + in	drainageways	rare, colluvial soil
Al	Alluvial Land	level to sloping	gravel, sand, silt	alluvial		streams	recent stream deposits
At	Atkins	level	silt loam	alluvial	33 in	floodplains	alluvial soils
Ba	Barbour and Pope	level	fine sandy loam	alluvial	40 in	floodplains	alluvial soils, flooded
Bb	Barbour and Pope	level	fine sandy loam	alluvial	40 in	floodplains	alluvial soils, high bottoms rarely flooded
Bc	Barbour and Pope	level	gravelly sandy loam	alluvial	40 in	floodplains	alluvial soils, flooded
BmB	Belmont	3-10%	silt loam	limestone, calc sh	20-50 in	gentle slopes, benches	
BmC	Belmont	10-20%	silt loam	limestone, calc sh	20-50 in		
BmD	Belmont	20-30%	silt loam	limestone, calc sh	20-50 in		some limestone fragments
BmE	Belmont	30-40%	silt loam	limestone, calc sh	20-50 in	hillslopes	assoc. with limestone outcrop
BnE	Belmont	30-40%	very stony silt loam	limestone, calc sh	20-50 in		limestone, sandstone fragments common
BnF	Belmont	40-70%	very stony silt loam	limestone, calc sh	20-50 in		limestone, sandstone cobbles common
BrC	Brinkerton	8-15%	silt loam	?	up to 88 in	intermittant drainageways	
CaB	Calvin	3-10%	channery silt loam	ss, red sh	22-48 in	uplands	
CaC	Calvin	10-20%	channery silt loam	ss, red sh	22-48 in	uplands	soil on ridges
CaD	Calvin	20-30%	channery silt loam	ss, red sh	22-48 in	uplands	
CaE	Calvin	30-40%	channery silt loam	ss, red sh	22-48 in	uplands	
CaF	Calvin	40-65%	channery silt loam	ss, red sh	22-48 in	uplands	extensive occurrence
ChB	Calvin	3-10%	channery silt loam	ss, red sh	22-48 in	ridges, benches	ss frags on surface
ChC	Calvin	10-20%	channery silt loam	ss, red sh	22-48 in	ridges, benches	ss frags. cover surface
ChD	Calvin	20-30%	channery silt loam	ss, red sh	22-48 in	dissected covex slopes	ss frags. cover surface
ChE	Calvin	30-40%	channery silt loam	ss, red sh	22-48 in	concave slopes	ss frags. cover surface
ChF	Calvin	40-60%	channery silt loam	ss, red sh	22-48 in	very steep slopes	ss frags. cover surface; outcrop in places
CnC	Calvin	3-20%	extremely stony silt loam	ss, red sh	22-48 in	benches	ss cobbles, boulder accumulation
CnE	Calvin	20-40%	extremely stony silt loam	ss, red sh	22-48 in	steep slopes	ss outcrop common, ss cobbles/boulders
CnF	Calvin	40-65%	extremely stony silt loam	ss, red sh	22-48 in	steep slopes	ss outcrop common, ss cobbles/boulders

Table 2-2 (Cont.).

Soils Map Unit	Soil Series	Slope	Soil Texture	Parent Bedrock	Depth to Bedrock	Topographic Occurrence	Comments
CoB	Cookport	2-10%	silt loam	ss, sh	> 40 in	ridgetops	rare
DaB	Dekalb	3-10%	channery loam	ss, sltst	20-48 in	sl. convex topography	15% ss frags. on surface
DaC	Dekalb	10-20%	channery loam	ss, sltst	20-48 in	plateaus,benches, ridges	channery frags. on surface
DaD	Dekalb	20-30%	channery loam	ss, sltst	20-48 in	smooth side slopes	ss frags, no boulders
DaF	Dekalb	40-65%	channery loam	ss, sltst	20-48 in	mtn. slopes	near ss outcrops
DkB	Dekalb	3-10%	loam	ss, sltst	20-48 in	plateaus, ridge tops	stone free loam
DkC	Dekalb	10-20%	loam	ss, sltst	20-48 in	plateaus, ridge tops	stone free loam
DmC	Dekalb	3-20%	extremely stony loam	ss	20-48 in	ridgetops, benches	40% cobbles at surface
DmE	Dekalb	20-40%	extremely stony loam	ss	20-48 in	mtn slopes	40% cobbles to boulders at surface
DmF	Dekalb	40-70%	extremely stony loam	ss	20-48 in	mtn slopes	cobbles-boulders @surface, ss outcrop
EnB	Ernest	3-8%	silt loam	sltst-sh, some ss	to 72 in	near drainageways	
EnC	Ernest	8-15%	silt loam	sltst-sh, some ss	to 72 in	toe slopes, drainages	
EnD	Ernest	15-25%	silt loam	sltst-sh, some ss	to 72 in	toe slopes, drainages	
ErC	Ernest	3-15%	extremely stony silt loam	sltst-sh, some ss	to 72 in	drainageways	3-15% surface cover of cobbles and boulders
ErD	Ernest	15-35%	extremely stony silt loam	sltst-sh, some ss	to 72 in	drainages, slope benches	3-15% surface cover of cobbles and boulders
GcC	Gilpin	10-20%	channery silt loam	sh-ss	20-36 in	narrow ridgetops	thin soil (20 in) on ridges, ss/sh frags
GcD	Gilpin	20-30%	channery silt loam	sh-ss	20-36 in	ridges, upper side slopes	ss/sh frags
GcE	Gilpin	30-40%	channery silt loam	sh-ss	20-36 in	gullied side slopes	ss/sh frags
GcF	Gilpin	40-70%	channery silt loam	sh-ss	20-36 in	slopes	sandstone outcrop at upper slopes
McC	Meckesville	8-15%	silt loam	ls/ss?	44 + in	dissected slopes	assoc. with ls-Belmont soils
MkD	Meckesville	15-30%	very stony silt loam	ls/ss?	44 + in	dissected slopes	cobbles/boulders @surface
MoB	Monongahela	3-8%	silt loam	terrace	>36 in	terraces	rare in occurrence on Shaver's Fork
Ph	Philo	level	silt loam	alluvial	> 38 in	channel ways	found along Shaver's Fork
Sa	Sandst. Rubble Land	??	cobbles, boulders	sandstone		slopes, ridges	sandstone rubble, boulder fields on Pottsville
Sl	Stony Alluvial Land	??	gravel, cobbles	alluvial		channel ways	gravel bars in Shaver's Fork
VdE	Very Stony Land	20-40%	cobbles, boulders	sandstone??		mountain slopes	associated with Brinkerton soils
VdF	Very Stony Land	40-80%	cobbles, boulders	sandstone??		mountain slopes	associated with Brinkerton soils

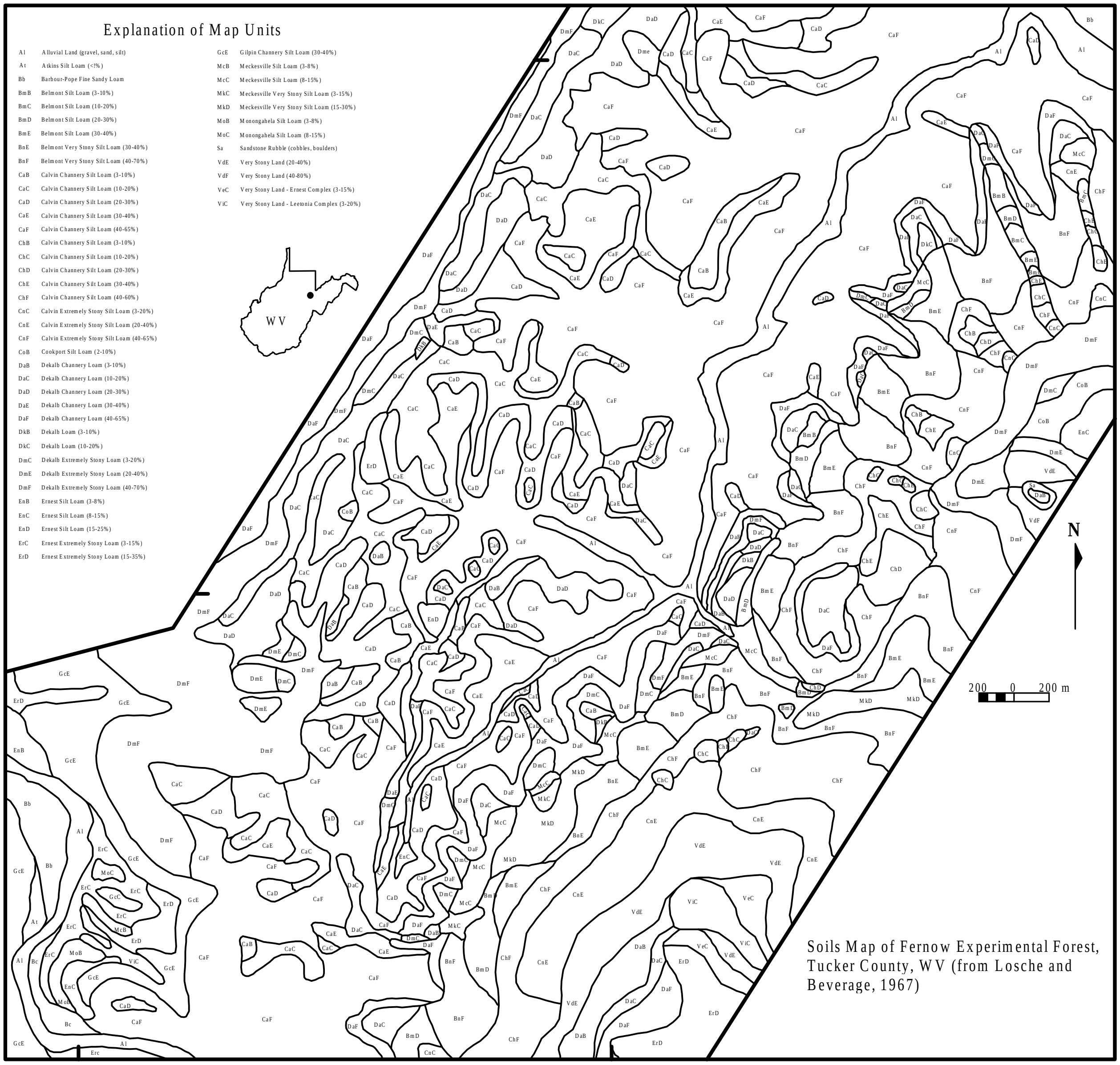


Figure 2-8. Soil survey map for the Fernow Experimental Forest (from Losche and Beverage, 1967). Refer to Plate 2-5 for the 1:9,600 scale version.

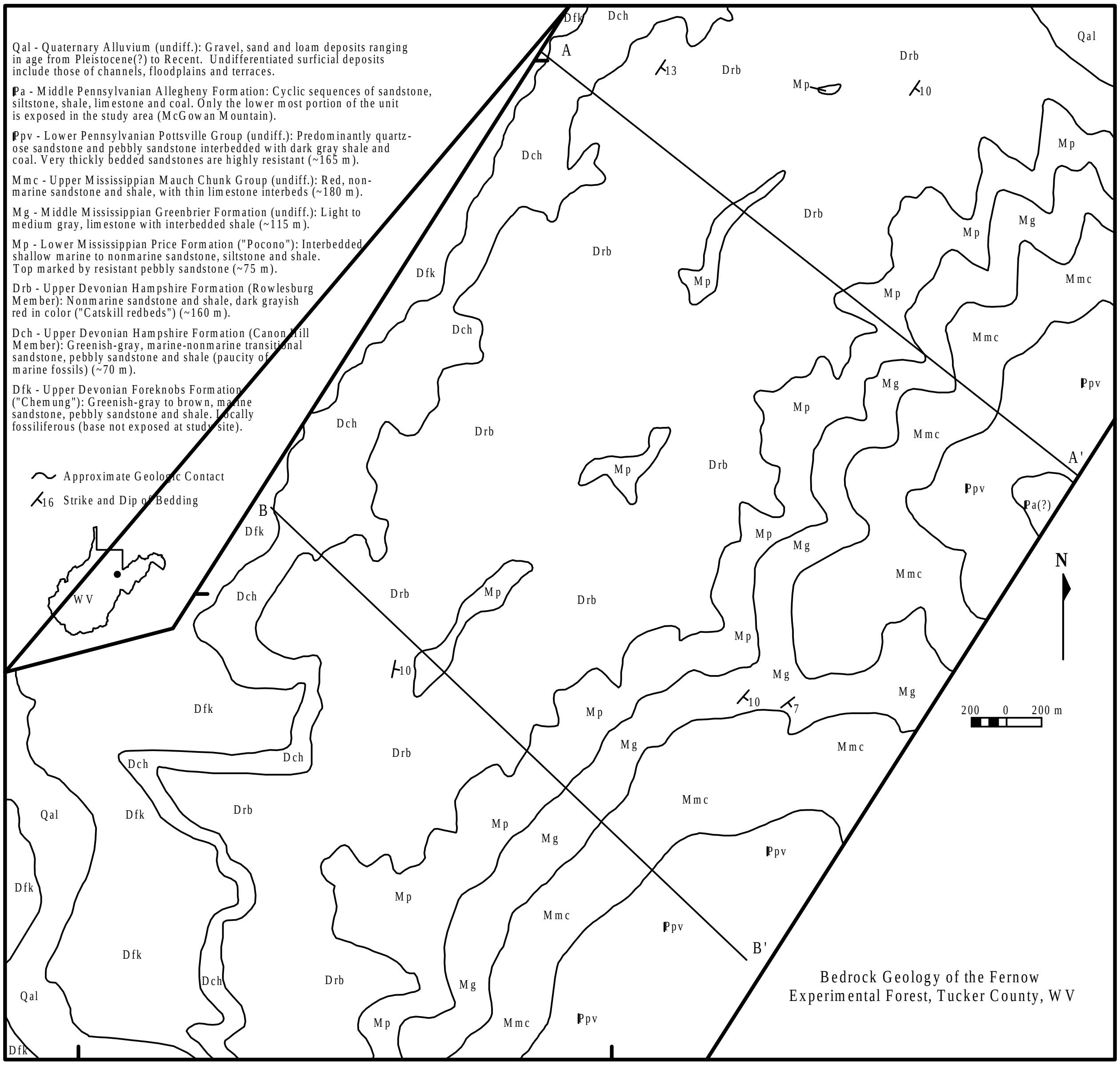
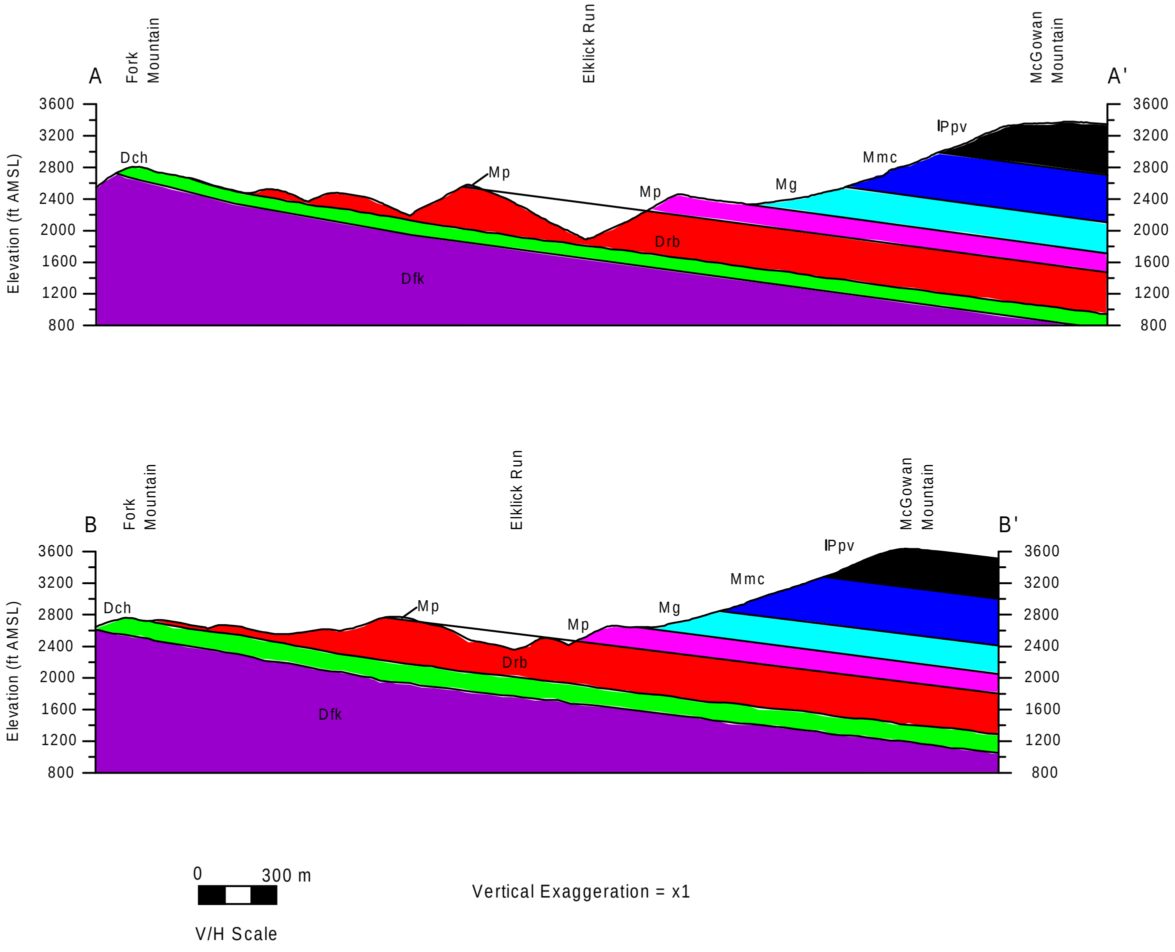


Figure 2-9. Bedrock geology of the Fernow Experimental Forest, Tucker County, West Virginia. Refer to Plate 2-2 for the 1:9,600 scale version. Cross-sections A-A' and B-B' are shown on Figure 2-10 and Plate 2-3.



⬛ IPpv - Lower Pennsylvanian Pottsville Group (undiff.): Predominantly quartzose sandstone and pebbly sandstone interbedded with dark gray shale and coal. Sandstone lithofacies are very thickly bedded, cross-stratified and erosionally resistant. Typically associated with very bouldery regolith and sandstone rubble land (clasts > 2 m diameter). The unit is approximately 150 m thick in the study area (Reger, 1923).

🟦 Mmc - Upper Mississippian Mauch Chunk Group (undiff.): Red, non-marine sandstone and shale, with thin limestone interbeds. Associated with red soils of the Calvin Series. Pedogenic features are similar to those of the Hampshire Formation (Rowlesburg Member). The unit has an estimated thickness of 180 m. The upper contact is commonly covered by large colluvial sandstone boulders of the overlying Pottsville Group.

🟦 Mg - Middle Mississippian Greenbrier Formation (undiff.): Light to medium gray limestone with interbedded shale. The unit has a total thickness of over 100 m in the study area (Reger, 1923). Greenbrier strata are associated with calcic soils of the Belmont Series and karst surface features.

🟪 Mp - Lower Mississippian Price (Pocono) Formation (undiff.): Comprised predominantly of brown and gray, coarse-grained sandstone and pebbly sandstone, medium to thick bedded. Typically associated with brown soils of the Dekalb Series. The unit has an estimated thickness of 75 m in the study area. The top of the Price Formation is marked by a resistant pebbly sandstone member that forms pronounced bedrock benches on the southeastern side of Elklick Run. Stratigraphic nomenclature is after Kammer and Bjerstedt (1986).

🟥 Drb - Upper Devonian Hampshire Formation, Rowlesburg Member: Interbedded nonmarine sandstone and shale, grayish red to bright red in color ("Catskill Redbeds"). Sandstone lithofacies are fine- to medium-grained and cross-bedded. Typically associated with red soils of the Calvin series. Thickness of the unit is approximately 160 m in the study area (nomenclature after Boswell and others, 1987).

🟩 Dch - Upper Devonian Hampshire Formation, Canon Hill Member: Predominantly olive-gray and brown, nonmarine sandstone with subordinate grayish-red interbeds. This unit was originally mapped as part of the "Chemung Group" by Reger (1923). Boswell and others (1987) interpreted the unit as a lower member of the Hampshire Formation, transitional between the fossiliferous marine strata ("Chemung" fauna) and the overlying continental red beds of the Rowlesburg Member. The unit has an estimated thickness of 70 m and includes a pebbly sandstone lithofacies mapped as "Hendricks sandstone" by Reger (1923). Typically associated with brown soils of the Dekalb series.

🟪 Dfk - Upper Devonian Foreknobs Formation (Greenland Gap Group): Interbedded olive-gray and yellowish-brown sandstone, siltstone and shale. This unit includes the fossiliferous, marine strata that were traditionally mapped as "Chemung Group" in West Virginia (e.g. Reger, 1923). The unit has an estimated thickness greater than 750 m in the vicinity of the study area (Reger, 1923). Typically associated with the Dekalb and Gilpin soils series.

Figure 2-10. Geologic cross-section drawn along lines A-A' and B-B'. See Plate 2-3 for 1:9,600 scale version. Refer to Figure 2-9 and Plate 2-2 for section lines. View is to the northeast.

base maps were digitally converted from the Parsons, 7.5-minute quadrangle by automated vectorization procedures (compiled by Computer Mapping Consultants, Inc., Oakdale, Maryland). The final topographic base was compiled in an AutoCAD 12.0 (Autodesk, 1992) format using the West Virginia State Plane - North coordinate system (Lambert projection, 1927 North American Datum), a contour interval of 40 ft, and a scale of 1:9,600 (Plate 2-1). Field traverses were completed using a Brunton compass and aneroid altimeter. Air-photo analysis was used to supplement field reconnaissance. Spatial data were manually digitized using a Calcomp 9500 digitizing tablet and AutoCAD 12.0 (Autodesk, 1992). The vectorized data were subsequently compiled into a GIS database using a combination of Idrisi (Clark Labs, 1997), ArcView (Environmental Systems Research Institute, 1996), and Arc/Info (Environmental Systems Research Institute, 1994). Digital coverages were exported into ArcView shape files and are included with this document.

Bedrock exposure in the study area is less than 10 percent of total surface area. Weathered regolith, soils, and vegetation extensively cover strata. Outcrops are limited to resistant sandstone interbeds exposed locally along drainageways, road cuts, and hillslopes. Given the rather poor quality of outcrop and low dip angles, it is not possible to measure detailed stratigraphic sections in the study area. The lithostratigraphic units are in large part undifferentiated and generalized in terms of lithofacies distribution. Geologic contacts were mapped on the basis of surficial clast composition, topographic expression, and structural-stratigraphic relationships. Contacts were delineated primarily by completing survey traverses along topographic noses. Colluvial transport in hollows has resulted in mixing of regolith, making lithostratigraphic breaks difficult to identify. Thus, all geologic contacts depicted on the bedrock geology map (Plate 2-2) are considered approximate and "covered".

Bedrock Map Units

The Fernow Experimental Forest is underlain by Upper Paleozoic sedimentary strata that were weakly deformed into broad and open folds (Figures 2-9 and 2-10, Plates 2-2 and 2-3). Strata range in age from Late Devonian to Pennsylvanian (Table 2-3). In ascending order, these units include the Devonian Foreknobs Formation (Greenland Gap Group), the Devonian Hampshire Formation (Canon Hill and Rowlesburg members), the Mississippian Price (Pocono)

Table 2-3. Summary of Lithostratigraphic Units at the Fernow Experimental Forest, Tucker County, West Virginia.

Chronostratigraphy (Series / System)	Bedrock Stratigraphy			% Surface Exposure in Study Area	Unit Thickness (meters)
	Original Nomenclature	Current Nomenclature	Lithostratigraphic Units Recognized in This Study		
Middle Pennsylvanian	Allegheny Formation (1,2)	Allegheny Formation (1,2)	Allegheny Formation (Undifferentiated)	<1	T.F.E.
	Upper Freeport Coal	Upper Freeport Coal			
	Lower Freeport Coal	Lower Freeport Coal			
	Lower Kittanning Coal	Lower Kittanning Coal			
Lower Pennsylvanian	Pottsville Group (1,2)	Pottsville Group (1,2)	Pottsville Group (Undifferentiated)	4	170
	Kanawha Formation	Kanawha Formation			N/A
	New River Formation	New River Formation			N/A
Upper Mississippian	Mauch Chunk Group (1,2)	Mauch Chunk Group (1,2)	Mauch Chunk Group (Undifferentiated)	9	180
	Princeton Conglomerate	Princeton Conglomerate			
	Hinton Limestone	Hinton Limestone			
	Webster Springs Sandstone	Webster Springs Sandstone			
Lower Mississippian	Greenbrier Group (1,2)	Greenbrier Group (1,2)	Greenbrier Group	9	110
Lower Missippian	Pocono Group (1,2)	Price Formation (3)	Price Formation (Undifferentiated)	13	80
		Patton Shale Member			
		Rockwell (Sandstone) Member			
		Riddlesburg Shale Member			
Upper Devonian		Oswayo Member			
Upper Devonian	Hampshire Formation	Hampshire Group (4)	Hampshire Formation		
	("Catskill Series")	Rowlesburg Formation	Rowlesburg Member	54	160
		Canon Hill Formation	Canon Hill Member	7	70
Upper Devonian	Chemung Group (1,2)	Greenland Gap Group (5,6)			
		Foreknobs Formation	Foreknobs Formation (Undifferentiated)	4	B.N.E.
		Scherr Formation			

T.F.E. = Top of Formation Eroded B.N.E. = Base Note Exposed

References: 1 = Reger, 1923; 2 = Cardwell and others, 1968; 3 = Bjerstedt and Kammer, 1988; 4 = Boswell and others, 1987; 5 = Dennison, 1970; 6 = Dennison and others, Formation, the Mississippian Greenbrier Group, the Mississippian Mauch Chunk Group, the Pennsylvanian Pottsville Group, and the Pennsylvanian Allegheny Formation. Stratigraphic terminology utilized in this study is that developed by a number of workers including Bjerstedt and Kammer (1988), Boswell and others (1987), Cardwell and others (1968), Dennison (1970), Dennison and others (1994), and Reger (1923). This nomenclature is updated with respect to the Tucker County (Reger, 1923) and West Virginia state (Cardwell and others, 1968) geologic maps (refer to Table 2-3).

Foreknobs Formation

The Foreknobs Formation comprises the upper part of the Greenland Gap Group. This unit encompasses strata originally mapped as "Chemung" by Reger (1923) and Woodward (1943). Dennison (1970) applied the term "Foreknobs Formation" to Chemung-type strata along the Allegheny Front. McGhee and Dennison (1976) subsequently divided the Foreknobs into five members based on measured stratigraphic sections, drilling data, and fossil evidence. The West Virginia and Virginia geological surveys currently recognize the Foreknobs terminology (R. McDowell, personal communication; E. Rader, personal communication, 1998).

In the vicinity of the Fernow area, the unit is comprised of over 760 meters of interbedded olive-gray, medium- to coarse-grained sandstone and shale (Table 2-3). These clastic strata are fossiliferous and were deposited in a shallow-marine shelf setting (Dennison and others, 1988). Outcrop of the Foreknobs is limited to the western flank of Fork Mountain and the lower reaches of Stonelick Run (Figures 2-9 and 2-10, Plate 2-2). Foreknobs strata are well exposed along U.S. Route 219 south of Parsons.

Hampshire Formation

Darton (1892) originally applied the term "Hampshire Formation" to red sandstone and shale lithofacies of the "Catskill delta" sequence. In West Virginia, the Hampshire Formation includes all Upper Devonian strata from the lowest, thick red-bed sequence to the base of grayish-white, massive sandstones of the Price (Pocono) Formation (Cardwell and others, 1968). Boswell and others (1987) elevated the Hampshire to group status, dividing it into the lower Canon Hill Formation and the upper Rowlesburg Formation. Canon Hill was applied to mixed red beds and olive-gray lithofacies, transitional to the underlying Foreknobs Formation. Rowlesburg was applied to the nonmarine red-bed lithofacies characteristic of the "Catskill delta". Dennison and others (1988) suggested that Hampshire strata are best classified at the formation level, with Canon Hill and Rowlesburg separated as members. This study follows the formation-member nomenclature.

Greater than 60% of the Fernow study area is underlain by sandstones and shales of the Hampshire Formation. The unit is 230 meters thick, and is exposed primarily along the northwest side of Elklick Run (Figures 2-9 and 2-10, Plate 2-2). The Rowlesburg Member is composed of approximately 160 meters of interbedded red sandstone and shale. Sandstone lithofacies are fine- to medium-grained, thinly to medium-bedded ("flaggy") with trough and planar stratification common (Figure 2-11). Olive-gray sandstone lithofacies in the Canon Hill Member are relatively resistant to erosion and support the crest of Fork Mountain (Figures 2-9 and 2-10, Plate 2-2). The Hendricks Sandstone of Reger (1923) forms a conglomeratic marker horizon approximately 30 meters below the base of the Rowlesburg Member. Table 2-4 presents the results of lithofacies analysis conducted on the Hampshire section 15 km north of the study area.

Price (Pocono) Formation

Lesley (1876) first applied "Pocono Formation" to nonmarine strata that mark the base of the Carboniferous in northeastern Pennsylvania. Darton (1892, 1894) applied the term to a similar stratigraphic sequence in Virginia and West Virginia. Kammer and Bjersted (1986) concluded the "Pocono Formation" of West Virginia is equivalent to the Price Formation in southwestern Virginia. They argued that "Pocono" lithofacies in West Virginia are more akin to Price strata and bear no rock-stratigraphic relation to equivalent-aged sandstones in northeastern Pennsylvania. As a result, Kammer and Bjerstedt (1986) recommended replacing the term "Pocono" in West Virginia with "Price".

In this study, the Price Formation is defined as the first brown to gray sandstone above red beds of the Hampshire Formation (Rowlesburg Member). The Hampshire-Price contact is marked by a subtle break in slope and change in regolith texture. The Price is over 38 meters thick and consists mostly of medium-grained sandstone and pebbly sandstone. The section thins

Figure 2-11. Outcrop of the Hampshire Formation (Rowlesburg Member), as exposed along West Virginia Route 72, 15 km north of the Fernow Experimental Forest. Note relative abundance of shale lithofacies and occurrence of thinly-bedded, single-storey sandstone bodies.

Table 2-4. Summary of Lithofacies Relationships for the Hampshire Formation in the Vicinity of the Fernow Experimental Forest.

	Hannahsville	Rowlesburg
Basin Position	West (Distal)	West (Distal)
Total Section Thickness (m)	60	176
SS/Sh Ratio	0.91	1.2
Mean SS Bed Thickness (cm)	36.3	74.4
Mean Sh Bed Thickness (cm)	54.4	82.7
Ratio: M/S Type SS Members	1.69	3.0
% Coarse Member / Total Section	32.6	61.7
Depositional Environment	Nonmarine / Fluvial	Nonmarine / Fluvial

SS = sandstone, Sh = Shale, M = multi-storey sandstone body, S = single-storey sandstone body. Basin position refers to proximity relative to Acadian source terrane. Coarse members comprised of over 90% sandstone lithofacies.

* The measured sections are located ~10-15 km north of the Fernow site and are locally representative of the Hampshire Formation.

considerably in the Fernow vicinity compared to a maximum of 300 meters in southern West Virginia. The Price (Pocono) interval is marked by an unconformity in western Randolph County (Dally, 1956). Bjerstedt and Kammer (1988) interpreted the Price as a shallow-marine deltaic complex that drained from source areas east of the Fernow area. Topographically, the top of the Price Formation is resistant to erosion, forming prominent bedrock benches on the eastern side of the study area (Figures 2-9 and 2-10; Plate 2-2). The lowermost portion of the Price also supports localized resistant knobs along the northwest side of Elklick Run.

Greenbrier Group

The Greenbrier Group unconformably overlies the Price Formation and is composed of interbedded gray, marine limestones and calcareous shales. The unit has a total thickness of over 75 meters in the study area (Reger, 1923). Sedimentologically, Greenbrier strata represent a transgressive phase of deposition, with open marine limestones deposited on top of the Price-deltaic complex (Smosna and Carney, 1992). The unit is recognized in the field by the occurrence of limestone regolith and a distinct increase in slope above the Price benches. Greenbrier strata crop out on the southeastern side of the study area, along mid-slope elevations of McGowan Mountain (Figures 2-9 and 2-10; Plate 2-2).

Mauch Chunk Group

The Mauch Chunk Group is comprised of greater than 178 meters of red, nonmarine sandstone and shale. These clastic strata are the products of Mississippian uplift in eastern source areas, with westward progradation into the Greenbrier sea (Neal, 1992). Mauch Chunk regolith is similar in appearance to that of the Hampshire Formation; however, the shaley nature of the unit results in very poor exposure. The lower contact is defined by the absence of Greenbrier limestone clasts, and the presence of sandstone-dominated regolith. The upper contact of the Mauch Chunk is obscured by large sandstone boulders (> 1 meter diameter) colluviated from the overlying Pottsville Group. Similar to the Greenbrier, the Mauch Chunk also crops out along the mid-flanks of McGowan Mountain (Figures 2-9 and 2-10; Plate 2-2).

Pottsville Group

The Lower Pennsylvanian Pottsville Group is composed of resistant, thickly bedded, coarse-grained sandstone and pebbly sandstone. Unit thickness in the study area is greater than 150 meters (Reger, 1923). Traditionally, the Pottsville Group is subdivided into the lower New River Formation and the upper Kanawha Formation. Given the poor exposures, it is not possible to delineate these subunits in the Fernow Forest. Both formations, however, are comprised of massive pebbly, quartzose sandstone with thinly bedded shale and coal (Cardwell and others, 1968). Pottsville strata represent braided fluvial deposits, derived from highlands to the southeast (Donaldson and Shumaker, 1981; Presley, 1979). Sandstones of this unit are the most prominent ridge former in the area, and support the upper slopes of McGowan Mountain (Figures 2-9 and 2-10; Plate 2-2). The Pottsville-Mauch Chunk contact is delineated by a transition from red-clast regolith to large-diameter sandstone boulders.

Allegheny Formation

Cardwell and others (1968) and Reger (1923) mapped portions of the Allegheny Formation along the highest elevation ridgetops of McGowan Mountain. In north-central West Virginia, this unit is characterized by fluvial-deltaic sequences of sandstone, shale, and coal (Donaldson and Shumaker, 1981). The base of the Allegheny is separated from the Pottsville Group by the Lower Kittanning Coal. Following the Tucker County Geologic Report (Reger, 1923), the Allegheny Formation is tentatively mapped on the highest knobs of McGowan Mountain (Figures 2-9 and 2-10; Plate 2-2); however, the author has not directly observed the Pottsville-Allegheny contact.

Structure and Tectonics

Rock structure in the Fernow area consists of broad, open folds with axes that trend and plunge to the northeast (trend: N32°E, plunge: ~0.65° NE). The study area lies on the southeast dipping limb of the Deer Park anticline, with the axis of the North Potomac syncline to the southeast (Cardwell and others, 1968). Based on structure contour data, strata in the Fernow area strike N32°E and dip approximately 5-10° to the southeast (Figures 2-9 and 2-10; Plate 2-2; Reger, 1923; Cardwell and others, 1968). Direct field measurements by the author confirm these data. No evidence of faulting was observed in the study area; however this portion of the Appalachian Plateau is significantly affected by jointing. Two dominant sets of fractures are evident in this region: (1) systematic cross-fold joints oriented roughly orthogonal to fold axes (northwest strike), and (2) non-systematic strike joints oriented approximately parallel to fold axes (northeast strike; Evans, 1994). Bedrock exposures along the channel of Elklick Run readily display this fracture pattern.

Tectonically, the central Appalachians comprise the interior segment of the modern Atlantic passive margin. Four major tectonic events have impacted this region; these include: (1) the Middle Proterozoic Grenville orogeny, (2) the Lower and Middle Cambrian Iapetan rifting, (3) the Late Paleozoic Alleghanian orogeny, and (4) the Mesozoic Atlantic rifting (Shumaker and Wilson, 1996; Froelich and Robinson, 1988). Deformation near the study area is genetically related to the Alleghanian orogeny, in which the Appalachian structural province experienced crustal shortening and allochthonous detachment (Kulander and Dean, 1986). Neotectonic studies suggest that the central Appalachians are presently subjected to northeast-southwest horizontal compression (Gardner, 1989; Zoback and Zoback, 1989). Most of the long-term deformation on the central Atlantic margin is attributed to lithospheric flexure in response to shelf loading, and isostatic deformation in response to crustal denudation (Gardner, 1989). Thus, neotectonics and variable lithologic resistance to erosion are the primary factors controlling topography in the Appalachian Highlands (Hack, 1980; Mills and others, 1987).

SURFICIAL GEOLOGY

Methodology

The surficial geology at the Fernow Experimental Forest was mapped according to cartographic protocol developed by Kite (1994). These guidelines are designed to address the fluvial, colluvial, and karst features in the unglaciated Appalachians. The purpose of this map protocol is to: (1) provide an expanded, yet flexible, surficial map format for use in 7.5-minute quadrangle mapping, (2) provide a uniform approach to surficial mapping techniques in a field program that includes workers from various backgrounds, (3) provide a map-based data collection format that lends itself to geographic information systems, and (4) provide an approach to surficial mapping that is meaningful to planners, educators, consultants and other user groups.

Three types of surficial map criteria are recognized for the unglaciated humid-mountainous landscape of the central Appalachians (Taylor and others, 1996). These include: Type I - polygonal map units associated with landforms and surficial deposits; Type II - discrete surface features not associated with surficial deposits; and Type III - observational features associated with data collection and field mapping (Table 2-5). Type I units include landforms and deposits that result from *in-situ* weathering, mass wasting, fluvial processes, catastrophic slope failure, and ancient periglacial activity. Type II units include surface features associated with karst processes, slope failure, surface hydrology, and anthropogenic activity. Type III features include reference points defined for purposes of data collection. Type I mapping criteria employ a four-fold scheme in which units are delineated by age, origin, landform, and material. Unit polygons are coded with patterns or color, and labeled with an abbreviated four-part identifier. "Age" refers to the age of the material; "origin" refers to the primary surficial process responsible for deposition of the unit; "landform" refers to the topographic occurrence of the unit; and "material" refers to the texture of unconsolidated deposits or lithology of exposed bedrock. Type II and III criteria are mapped as two-dimensional surface features without reference to material or age.

Surficial mapping at Fernow Experimental Forest was conducted primarily in the Summer and Fall of 1995. The field and digitizing procedures were identical to those described for bedrock geology. The 1:4,800 base map and 10 ft contour intervals proved very effective for identification of mesoscale landforms in the study area (see Kite and others, 1998). Surficial data were compiled using the Tucker County soils survey (Losche and Beverage, 1967), natural exposures, topographic analysis, and air photo imaging. Final map coverages were transferred to the 1:9,600 base, and compiled in an AutoCAD 12.0 format (Plate 2-4, Figure 2-12).

Composition of surficial deposits at the Fernow was deduced solely on the basis of natural exposures, the county soil survey (Losche and Beverage, 1967), topographic analysis, and site reconnaissance. No excavations or laboratory particle-size analyses were utilized in the preparation of the accompanying surficial maps. Table 2-6 is modified from Table 2-2, showing a summary of soils mapping units (Losche and Beverage, 1967) and their interpretation as surficial units after Kite (1994). Preliminary conversion of the Tucker County soil survey was used as a general guide to delineate more detailed surficial units during field reconnaissance

Table 2-5. Surficial Map Criteria for the Central Appalachians (after Kite, 1994).

A. Type I Criteria: Age, Origin, Landform, Material.

1. Age of Surficial Material
- H = Holocene (< 10,000 years old)
- W = Wisconsin (ca. 89 to 10 ka)
- I = Illinoian
- P = Pleistocene Undifferentiated
- EP = Early Pleistocene
- MPl= Middle Pleistocene
- LP = Late Pleistocene
- Q = Quaternary Undifferentiated
- CZ = Cenozoic Undifferentiated

2. Origin / Surficial Process
- A. Hillslope
  - r = residuum (in situ regolith)
  - c = colluvium (mass wasting)
  - ds = debris slide
  - rf = rock fall or topple
- B. Valley Bottom
  - a = stream alluvium (normal flow)
  - hcf = hyperconcentrated flow
  - df = debris flow
  - sw = slackwater deposition
- C. Lacustrine
  - l = lacustrine deposit, undiff.
  - lb = lake-bottom deposit
  - ld = lacustrine deltaic
- D. Other
  - g = glaciofluvial, undifferentiated
  - go = glacial outwash
  - e = eolian
  - co = collapse (solution)
  - cr = cryoturbation
  - x = anthropogenic disturbance
  - f = artificial fill
  - rk = bedrock (process n/a)

3. Landform Units
- A. Hillslope
  - n = nose
  - sl = side slope
  - h = hollow
  - veneer = < 2m of regolith
  - blanket = > 2 m of regolith
  - bf = boulder field
  - bs = boulder stream
  - pg = patterned ground
  - tls = talus deposits

3. Landform Units (Cont.)
- B. Valley Bottom
  - ch = channel
  - fp = floodplain (RI </= 2-3 yr)
  - t = terrace (t1, t2 …tn; height AMRL)
  - f = fan
  - f-t = fan terrace (f1, f2 …fn; height AMRL)
  - a = apron (footslope deposit)
  - lo = lobe
  - lv = levee
  - ox = oxbow, abandoned channel
- C. Other
  - ft = flow track (debris flows)
  - hm = hummocky topography
  - rb = rock-block slide deposits
  - x = excavated, fill, disturbed ground
  - d = delta
  - du = dune

4. Material (Composition and Texture)
- b = boulders (>256 mm; clast supported)
- c = cobbles (64-256 mm; clast supported)
- p = pebbles (4-64 mm; clast supported)
- g = gravel (>2 mm; clast supported)
- sg = mixed sand and gravel
- s = sand (0.05-2.0 mm)
- st = silt (0.002-0.05 mm)
- cy = clay (<0.002 mm)
- l = loam (mix of sand, silt, clay)
- d = diamicton undifferentiated
- bbd = very bouldery diamicton
- bd = bouldery diamicton
- cd = cobbly diamicton
- pd = pebbly diamicton
- ds = sandy matrix diamicton
- dt = silty matrix diamicton
- dy = clayey-matrix diamicton
- rk = bedrock (modify with lithology)
- rs = rotten stone, saprolite
- tr = travertine
- tu = tufa
- ma = marl
- og = organic-rich sediment
- w = water
- u = unkown

B. Type II Criteria: 2-D Surface Features

1. Karst
   - bv = blind valley
   - ca = cave (human entry)
   - ═ Active cave passage
   - ╍ Abandoned cave passage
   - dv = dry valley
   - kw = karst window
   - sk = sinkhole (doline)
   - skst = sinking stream
   - ks = karst spring
2. Hillslope
   - hs = headscar
   - ds = debris-slide scar
   - ls = landslide scar undifferentiated
   - rs = rotational slide (slump) scar
   - ts = translational slide scar
   - rb = rock-block slide scar
   - tc = terracettes
3. Other
   - wf = water fall
   - w = water, lake, reservoir
   -  Spring
   - wt = wetland, undifferentiated
   - wh = wetland, heath
   - wm = wetland, marsh
   - ws = swamp
   - quarry (with highwall)
   - gravel pit
   - deep mine opening
   - strip mine (with highwall)
   - mine subsidence zone
   - rc = rock city
   -  Scarp
   -  Meander scroll on floodplain
   - -·- Lacustrine strandline

C. Type III Criteria: - Data Reference Points

- Sandwhich symbols showing stratigraphy
- Depth to bedrock (drilling or seismic data)
- Minimum depth to bedrock (log data)
- Test hole / boring
- Well
- RE = refusal (in test boring)
- Hand-auger hole, shovel hole,
- Fossil locality
- Paleocurrent direction
- Observation Point

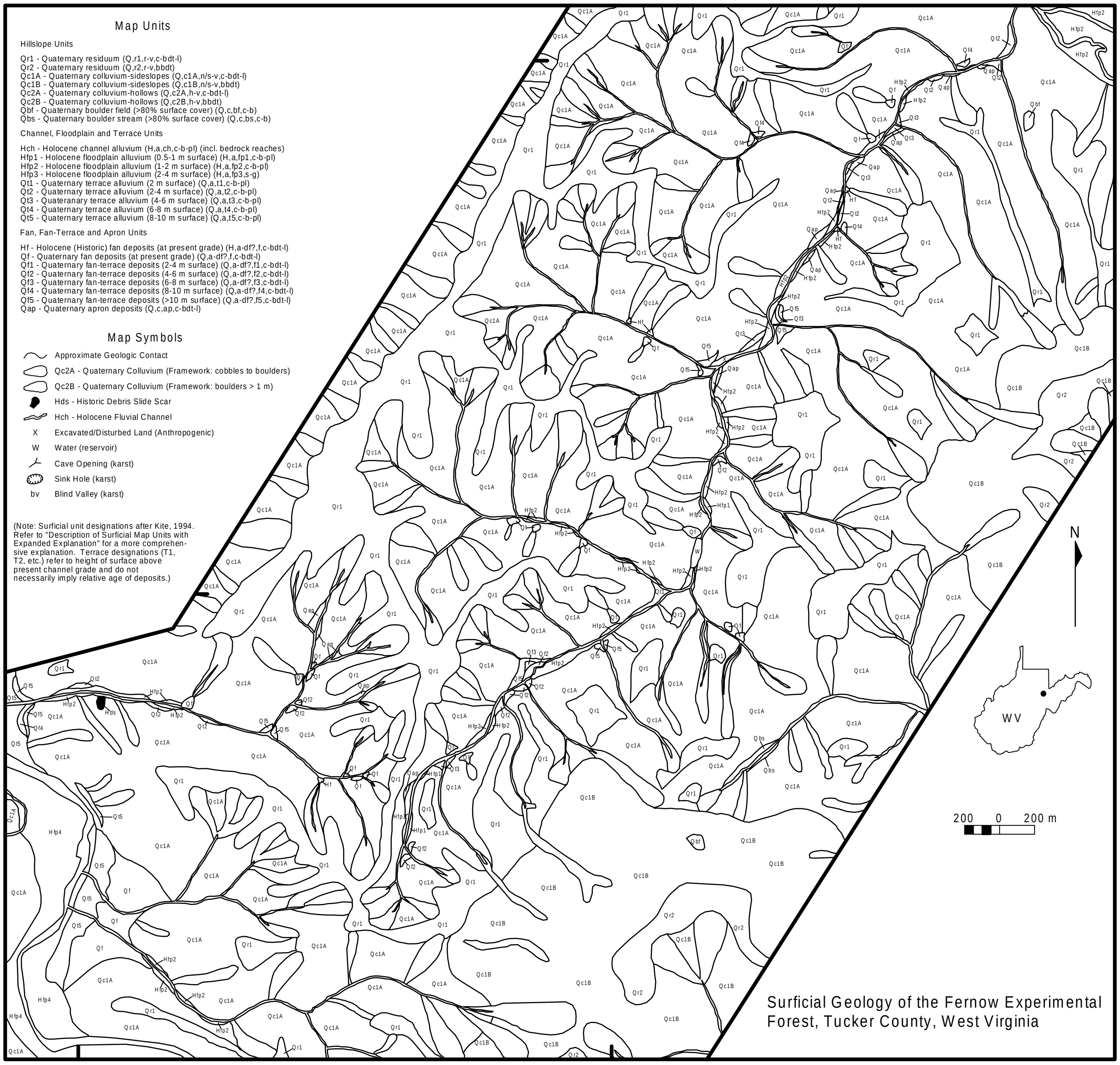


Figure 2-12. Surficial geology of the Fernow Experimental Forest. Refer to Plate 2-4 for the 1:9,600 scale version.

Table 2-6. Conversion of Soils Units in Table 2 to Equivalent Surficial Map Units (after Kite, 1994).

Soil Survey Data						Equivalent Surficial Geology					
Soils Unit	**Soil Series**	**Slope**	**Soil Texture**	**Depth to Bedrock**	**Topographic Occurrence**	**Age**	**Landform**	**Materials**	**Origin**	**Surficial Map Unit**	**Physiographic Occurrence**
AbC	Albrights	8-15%	Silt Loam	38 + in	drainages	Quaternary	veneer-apron	silt loam	colluvial?	Q,v-a,st-l,c	E. Side McGowan Mtn
Al	Alluvial Land	level	gravel, sand, silt	??	streams	Holocene	chann.-floodpl.	gravel-sand-silt	alluvial	H,ch-fp,g-s-st,a	stream channels
At	Atkins	level	Silt Loam	33 in	floodplain	Holocene	floodplain	silt loam	alluvial	H,fp,st-l,a	Shavers Fork Lowland
Ba	Barbour-Pope	level	fine sandy loam	40 in	floodplain	Holocene	floodplain	sand loam	alluvial	H,fp,s-l,a	Shavers Fork Lowland
Bb	Barbour-Pope	level	fine sandy loam	40 in	floodplain	Holocene	floodplain	sand loam	alluvial	H,fp,s-l,a	Shavers Fork Lowland
Bc	Barbour-Pope	level	gravelly sandy loam	40 in	floodplain	Holocene	floodplain	gravel-sand-loam	alluvial	h,fp,gs-l,a	Shavers Fork Lowland
BmB	Belmont	3-10%	Silt Loam	20-50 in	gentle slopes	Quaternary	veneer	silt loam	residual	Q-CZ,v,st-l,r	W. Side McGowan Mtn
BmC	Belmont	10-20%	Silt Loam	20-50 in		Quaternary	veneer	silt loam	residual	Q-CZ,v,st-l,r	W. Side McGowan Mtn
BmD	Belmont	20-30%	Silt Loam	20-50 in		Quaternary	veneer	silt loam	residual	Q-CZ,v,st-l,r	W. Side McGowan Mtn
BmE	Belmont	30-40%	Silt Loam	20-50 in	hillslopes	Quaternary	veneer	silt loam	residual	Q-CZ,v,st-l,r	W. Side McGowan Mtn
BnE	Belmont	30-40%	Very Stony Silt Loam	20-50 in		Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
BnF	Belmont	40-70%	Very Stony Silt Loam	20-50 in		Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
BrC	Brinkerton	8-15%	Silt Loam	up to 88	drainages	Quaternary	veneer	silt loam	colluvial?	Q,v,st-l,c	Shavers Fork Lowland
CaB	Calvin	3-10%	Channery Silt Loam	22-48 in	uplands	Quaternary	veneer	diamicton undiff.	resid.-colluvial	Q-CZ,v,d,r-c	Elklick Run Side Slopes
CaC	Calvin	10-20%	Channery Silt Loam	22-48 in	uplands	Quaternary	veneer	diamicton undiff.	resid.-colluvial	Q-CZ,v,d,r-c	Elklick Run Side Slopes
CaD	Calvin	20-30%	Channery Silt Loam	22-48 in	uplands	Quaternary	veneer	diamicton undiff.	resid.-colluvial	Q-CZ,v,d,r-c	Elklick Run Side Slopes
CaE	Calvin	30-40%	Channery Silt Loam	22-48 in	uplands	Quaternary	veneer	diamicton undiff.	resid.-colluvial	Q-CZ,v,d,r-c	Elklick Run Side Slopes
CaF	Calvin	40-65%	Channery Silt Loam	22-48 in	uplands	Quaternary	veneer	diamicton undiff.	resid.-colluvial	Q-CZ,v,d,r-c	Elklick Run Side Slopes
ChB	Calvin	3-10%	Channery Silt Loam	22-48 in	ridges, benches	Quaternary	veneer	grav.-cobb. diamict	resid.-colluvial	Q-CZ,v,g-c d,r-c	W. Side McGowan Mtn
ChC	Calvin	10-20%	Channery Silt Loam	22-48 in	ridges, benches	Quaternary	veneer	grav.-cobb. diamict	resid.-colluvial	Q-CZ,v,g-c d,r-c	W. Side McGowan Mtn
ChD	Calvin	20-30%	Channery Silt Loam	22-48 in	convex slopes	Quaternary	veneer	grav.-cobb. diamict	resid.-colluvial	Q-CZ,v,g-c d,r-c	W. Side McGowan Mtn
ChE	Calvin	30-40%	Channery Silt Loam	22-48 in	concave slopes	Quaternary	veneer	grav.-cobb. diamict	resid.-colluvial	Q-CZ,v,g-c d,r-c	W. Side McGowan Mtn
ChF	Calvin	40-60%	Channery Silt Loam	22-48 in	steep slopes	Quaternary	veneer	grav.-cobb. diamict	resid.-colluvial	Q-CZ,v,g-c d,r-c	W. Side McGowan Mtn
CnC	Calvin	3-20%	Ext. Stony Silt Loam	22-48 in	benches	Quaternary	veneer	cob-bldr diamicton	resid.-colluvial	Q-CZ,v,c-b d,r-c	Upper McGowan Mtn
CnE	Calvin	20-40%	Ext. Stony Silt Loam	22-48 in	steep slopes	Quaternary	veneer	cob-bldr diamicton	resid.-colluvial	Q-CZ,v,c-b d,r-c	Upper McGowan Mtn
CnF	Calvin	40-65%	Ext. Stony Silt Loam	22-48 in	steep slopes	Quaternary	veneer	cob-bldr diamicton	resid.-colluvial	Q-CZ,v,c-b d,r-c	Upper McGowan Mtn
CoB	Cookport	2-10%	Silt Loam	> 40 in	ridgetops	Quaternary	veneer	silt loam	residual	Q-CZ,v,st-l,r	W. Side McGowan Mtn
DaB	Dekalb	3-10%	Channery Loam	20-48 in	convex slopes	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	Elklick Run Side Slopes
DaC	Dekalb	10-20%	Channery Loam	20-48 in	benches, ridges	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	Elklick Run Side Slopes
DaD	Dekalb	20-30%	Channery Loam	20-48 in	side slopes	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	Elklick Run Side Slopes
DaF	Dekalb	40-65%	Channery Loam	20-48 in	side slopes	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	Elklick Run Side Slopes

Table 2-6 (Cont.).

Soil Survey Data						**Equivalent Surficial Geology**					
Soils Unit	**Soil Series**	**Slope**	**Soil Texture**	**Depth to Bedrock**	**Topographic Occurrence**	**Age**	**Landform**	**Materials**	**Origin**	**Surficial Map Unit**	**Physiographic Occurrence**
DkB	Dekalb	3-10%	Loam	20-48 in	benches, ridges	Quaternary	veneer	loam	residual	Q-CZ,v,l,r	W. Side McGowan Mtn
DkC	Dekalb	10-20%	Loam	20-48 in	benches, ridges	Quaternary	veneer	loam	residual	Q-CZ,v,l,r	Upper Fork Mtn
DmC	Dekalb	3-20%	Ext. Stony Loam	20-48 in	benches, ridges	Quaternary	veneer	cob-bldr diamicton	residual	Q-CZ,v,c-b d,r	Upper Fork Mtn
DmE	Dekalb	20-40%	Ext. Stony Loam	20-48 in	side slopes	Quaternary	veneer	cob-bldr diamicton	residual	Q-CZ,v,c-b d,r	Upper Fork Mtn
DmF	Dekalb	40-70%	Ext. Stony Loam	20-48 in	side slopes	Quaternary	veneer	cob-bldr diamicton	residual	Q-CZ,v,c-b d,r	Upper Fork Mtn
EnB	Ernest	3-8%	Silt Loam	to 72 in	drainages	Quaternary	veneer-apron	silt loam	colluvial?	Q,v-a,st-l,c	Shavers Fork Lowland
EnC	Ernest	8-15%	Silt Loam	to 72 in	footslopes	Quaternary	veneer-apron	silt loam	colluvial?	Q,v-a,st-l,c	W. Side McGowan Mtn
EnD	Ernest	15-25%	Silt Loam	to 72 in	footslopes	Quaternary	veneer-apron	silt loam	colluvial?	Q,v-a,st-l,c	Shavers Fork Lowland
ErC	Ernest	3-15%	Ext. Stony Silt Loam	to 72 in	drainages	Quaternary	veneer-apron	cob-bldr diamicton	colluvial?	Q,v-a,c-b d,c	W. Side McGowan Mtn
ErD	Ernest	15-35%	Ext. Stony Silt Loam	to 72 in	drainages	Quaternary	veneer-apron	cob-bldr diamicton	colluvial?	Q,v-a,c-b d,c	Elk Lick Run
GcC	Gilpin	10-20%	Channery Silt Loam	20-36 in	ridgetops	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
GcD	Gilpin	20-30%	Channery Silt Loam	20-36 in	sideslope	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
GcE	Gilpin	30-40%	Channery Silt Loam	20-36 in	sideslope	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
GcF	Gilpin	40-70%	Channery Silt Loam	20-36 in	hillslopes	Quaternary	veneer	diamicton undiff.	residual	Q-CZ,v,d,r	W. Side McGowan Mtn
McC	Meckesville	8-15%	Silt Loam	44 + in	dissected slopes	Quaternary	veneer-apron	silt loam	colluvial?	Q,v-a,st-l,c	Upper McGowan Mtn
MkD	Meckesville	15-30%	Very Stony Silt Loam	44 + in	dissected slopes	Quaternary	veneer-apron	cob-bldr diamicton	colluvial?	Q,v-a,c-b d,c	Upper McGowan Mtn
MoB	Monongahela	3-8%	Silt Loam	>36 in	terraces	Pleistocene	terrace (high)	loam	alluvial	P,t,l,a	Shavers Fork Lowland
Ph	Philo	level	Silt Loam	> 38 in	drainages	Holocene	chann.-floodpl.	silt loam	alluvial	H,fp-ch,st-l,a	Shavers Fork Lowland
Sa	SS Rubble	??	Cobbles, boulders		slopes, ridges	Quaternary	blockfield	boulders-cobbles	resid.-colluvial	Q,bk-bs,b,r-c	Upper McGowan Mtn
Sl	Alluvial Land	??	gravel, cobbles		channel ways	Holocene	channel	gravel-cobbles	alluvial	H,ch,g-c,a	Shavers Fork Lowland
VdE	V. Stony Land	20-40%	cobbles, boulders		steep sideslopes	Quaternary	veneer	cob-bldr diamicton	resid.-colluvial	Q,v,c-bd,r-c	Upper McGowan Mtn
VdF	V. Stony Land	40-80%	cobbles, boulders		steep sideslopes	Quaternary	veneer	cob-bldr diamicton	resid.-colluvial	Q,v,c-bd,r-c	Upper McGowan Mtn

(Plate 2-4, Figure 2-12). Map units are grouped into the following categories: (1) hillslope units (Type I: residuum and colluvium), (2) channel-floodplain-terrace units (Type I), and (3) fan-fan terrace-apron units (Type I). Refer to Table 2-7 for an expanded explanation of surficial map units used in this study.

Landforms

Several types of large-scale landforms are recognized at the Fernow area; these include hillslope, valley-bottom, and karst features. These larger-scale landform units are comprised of smaller, mesoscale features delineated at the outcrop level and from contour patterns. Hillslopes feed into valley-bottom areas, conveying runoff and transporting sediment. Karst features are related to dissolution processes in limestones of the Mississippian Greenbrier Group, a well-known cave-former throughout West Virginia (Davies, 1958; Springer and others, 1997).

Hillslope Regime

Hillslopes at Fernow Experimental Forest consist of ridges, side slopes, hollows, noses, and footslopes (Hack and Goodlett, 1960; Figure 2-13). Ridges are upper elevation areas in which contours are closed, acting as the primary divides between drainage basins. Side slopes represent open hillslope areas with approximately straight contour patterns. Hollows are defined as zero-order upland stream heads in which contours are concave outward in a down-slope direction. Hollows serve as valley-head conduits for the transport of runoff and surficial materials to higher order drainages. Noses represent hollow divides in which contours are convex outward in a down-slope direction. Footslopes generally lie at the base of hillslopes and represent a transitional zone between side slopes and the valley-bottom channel. Footslopes typically display a gentler gradient than the adjacent side slopes and are commonly underlain by mass-wasting deposits.

Valley-Bottom Regime

Valley-bottoms represent lower elevation areas adjacent to stream channels. This zone is further subdivided into channels, floodplains, and stream terraces (Figure 2-14). The channel is

Table 2-7. Expanded Explanation of Surficial Map Units Recognized at the Fernow Experimental Forest (refer to Plate 2-4).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
Qr1	Quaternary Residuum (Hampshire / Price Parent)	Quaternary (Undiff.)	Residuum	Ridge-Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,r1,r-v,c-bdt-l)	Predominantly associated with ridge crests supported by the Hampshire and Price formations.
Qr2	Quaternary Residuum (Pottsville Parent)	Quaternary (Undiff.)	Residuum	Ridge-Veneer	Very Bouldery Diamicton with Silty Matrix	(Q,r2,r-v,bbdt)	Associated with ridge crests supported by the Pottsville Group. Large-diameter (> 1m) surface boulders common.
Qc1A	Quaternary Colluvium (Side Slopes)	Quaternary (Undiff.)	Colluvium	Nose-Side Slope Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,c1A,n/s-v,c-bdt-l)	Associated with side slopes underlain by the Hampshire, Price, Greenbrier and Mauch Chunk lithostratigraphic units.
Qc1B	Quaternary Colluvium (Side Slopes - Pottsville Parent)	Quaternary (Undiff.)	Colluvium	Nose-Side Slope Veneer	Very Bouldery Diamicton with Silty Matrix	(Q,c1B,n/s-v,bbdt)	Associated with side-slope colluvium derived from Pottsville Group sandstones. Large-diameter (> 1m) surface boulders common.
Qc2A	Quaternary Colluvium (Hollows)	Quaternary (Undiff.)	Colluvium	Hollow Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,c2A,h-v,c-bdt-l)	Predominantly associated with zero- to first-order hollows underlain by the Price, Greenbrier and Mauch Chunk lithostratigraphic units.
Qc2B	Quaternary Colluvium (Hollows - Pottsville Parent)	Quaternary (Undiff.)	Colluvium	Hollow Veneer	Very Bouldery Diamicton with Silty Matrix	(Q,c2B,h-v,bbdt)	Associated with hollow colluvium derived from Pottsville Group sandstones. Large-diameter (> 1m) surface boulders common.
Qbf	Quaternary Boulder Field	Quaternary (Undiff.)	Colluvium (periglacial?)	Boulder Field	Cobbles and Boulders	(Q,c,bf,c-b)	Equant to irregularly shaped side slopes covered by greater than 80% cobbles and boulders. Commonly interpreted as the product of Pleistocene periglacial slope processes.
Qbs	Quaternary Boulder Stream	Quaternary (Undiff.)	Colluvium (periglacial?)	Boulder Stream	Cobbles and Boulders	(Q,c,bs,c-b)	Elongate valley-bottom areas covered by greater than 80% cobbles and boulders. Commonly interpreted as the product of Pleistocene periglacial slope processes.
Hch	Holocene Channel Alluvium	Holocene	Alluvium	Channel and Narrow Floodplain	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(H,a,ch,c-b-pl)	Fluvial channel deposits associated with first- to fifth order streams. Unit includes channel alluvium and portions of adjacent floodplain too small to map at the given scale. Unit also includes bedrock channel reaches.

Table 2-7 (Cont.).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
Hfp1	Holocene Floodplain Alluvium (0.5 to 1.0 m surface)	Holocene	Alluvium	Floodplain	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(H,a,fp1,c-b-pl)	Floodplain alluvium associated with third- to fifth-order streams. Unit includes low-lying surfaces 0.5 to 1.0 m above present channel grade with a flood recurrence interval of approximately 3 to 5 years.
Hfp2	Holocene Floodplain Alluvium (1.0 to 2.0 m surface)	Holocene	Alluvium	Floodplain	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(H,a,fp2,c-b-pl)	Floodplain alluvium associated with third- to fifth-order streams. Unit includes low-lying surfaces 1.0 to 2.0 m above present channel grade with a flood recurrence interval of approximately 3 to 5 years.
Hfp3	Holocene Floodplain Alluvium (2.0 to 4.0 m surface)	Holocene	Alluvium	Floodplain	Sandy Gravel	(H,a,fp3,s-g)	Wide floodplain surfaces associated with Shaver's Fork on the southwestern boundary of the study site.
Qt1	Quaternary Low-Terrace Alluvium (2.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t1,c-b-pl)	Low-terrace deposits associated with third- to fifth-order streams. Unit includes low terrace surfaces 2.0 m above present channel grade with a flood recurrence interval greater than 5 years.
Qt2	Quaternary Terrace Alluvium (2.0 to 4.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t2,c-b-pl)	Terrace deposits associated with third- to fifth-order streams. Unit includes terrace surfaces 2.0 to 4.0 m above present channel grade.
Qt3	Quaternary Terrace Alluvium (4.0 to 6.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t3,c-b-pl)	Terrace deposits associated with third- to fifth-order streams. Unit includes terrace surfaces 4.0 to 6.0 m above present channel grade.
Qt4	Quaternary Terrace Alluvium (6.0 to 8.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t4,c-b-pl)	Terrace deposits associated with third- to fifth-order streams. Unit includes terrace surfaces 4.0 to 6.0 m above present channel grade.
Qt5	Quaternary Terrace Alluvium (8.0 to 10.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t5,c-b-pl)	High terraces and Monongahela soils associated with Shaver's Fork on the southwestern boundary of the study site.
Hf	Holocene (Historic) Fan Deposits (undissected)	Holocene	Alluvium - Debris Flow(?)	Fan	Cobbles and Boulders, Gravel Diamicton	(H,a-df?,f,c-bdt-l)	Historic fan deposits commonly associated with first to second-order hollows at stream-tributary junctions. Identified by fresh deposits, disturbed and buried vegetation.

Table 2-7 (Cont.).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
Qf	Quaternary Fan Deposits (undissected)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f,c-bdt-l)	Fan deposits commonly associated with first-order hollows at stream-tributary junctions. Identified by older tree stands and lack of fresh appearance.
Qf1	Quaternary Fan-Terrace Deposits (2.0 to 4.0 m surface)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f1,c-bdt-l)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.
Qf2	Quaternary Fan-Terrace Deposits (4.0 to 6.0 m surface)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f2,c-bdt-l)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.
Qf3	Quaternary Fan-Terrace Deposits (6.0 to 8.0 m surface)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f3,c-bdt-l)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.
Qf4	Quaternary Fan-Terrace Deposits (8.0 to 10.0 m surface)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f4,c-bdt-l)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.
Qf5	Quaternary Fan-Terrace Deposits (>10.0 m surface)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	(Q,a-df?,f5,c-bdt-l)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.
Qap	Quaternary Apron Deposits	Quaternary (Undiff.)	Colluvium	Apron	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,c,ap,c-bdt-l)	Footslope deposits > 2.0 m in thickness. Commonly located at break in gradient between steeper side slopes and valley-bottoms.
Hds	Holocene (Historic) Debris Slide Scar	Holocene (Historic)	Debris Slide	Scar	N/A	N/A	Historic slide scars. Identified by youthful and disturbed vegetation.

**Heights of terrace and fan surfaces are relative to active channel grade of nearest stream tributary.

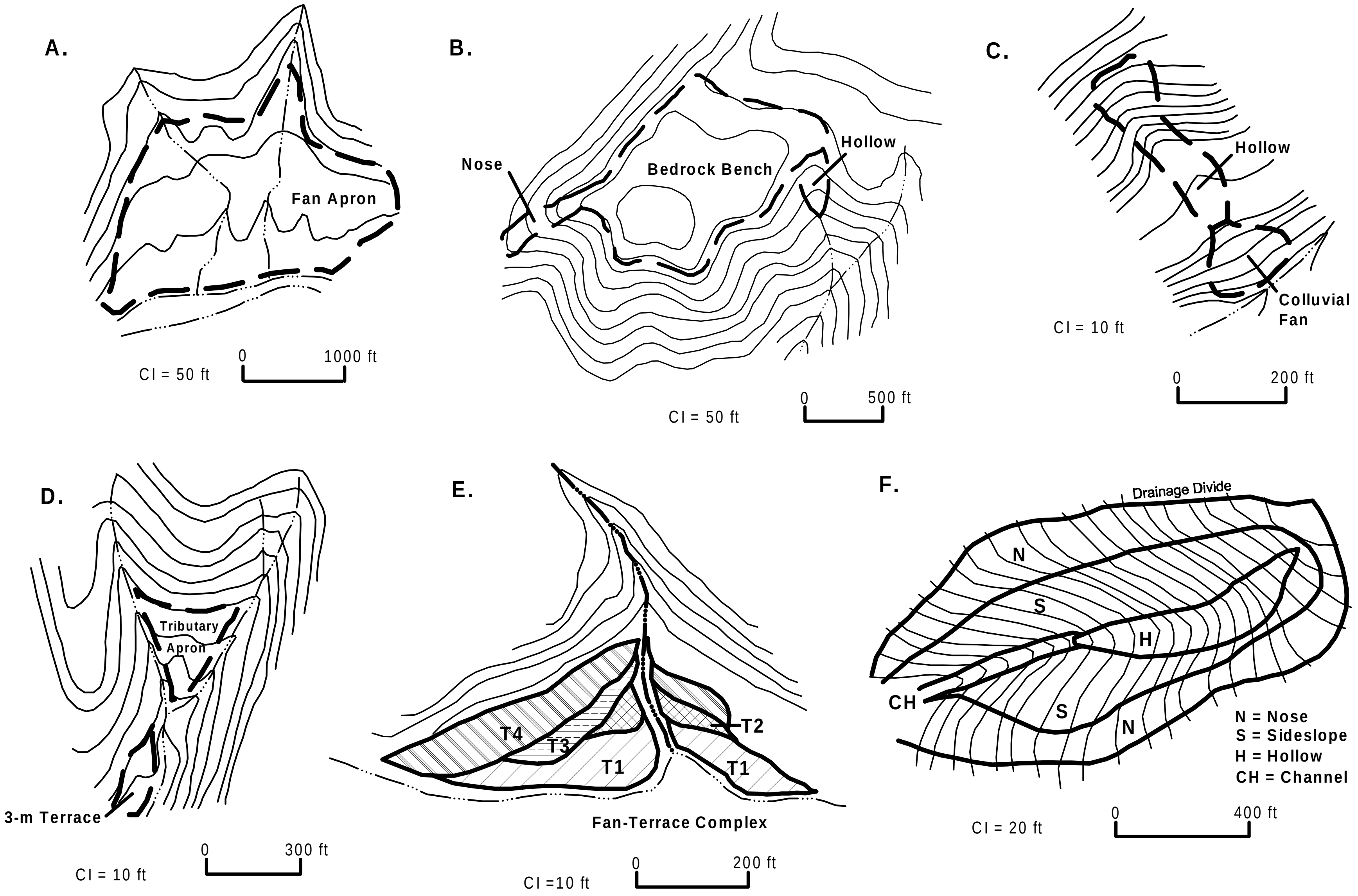


Figure 2-13. Examples of hillslope-regime landform units recognized in the central Appalachians. Diagram F is from Hack and Goodlett (1960). See text for discussion.

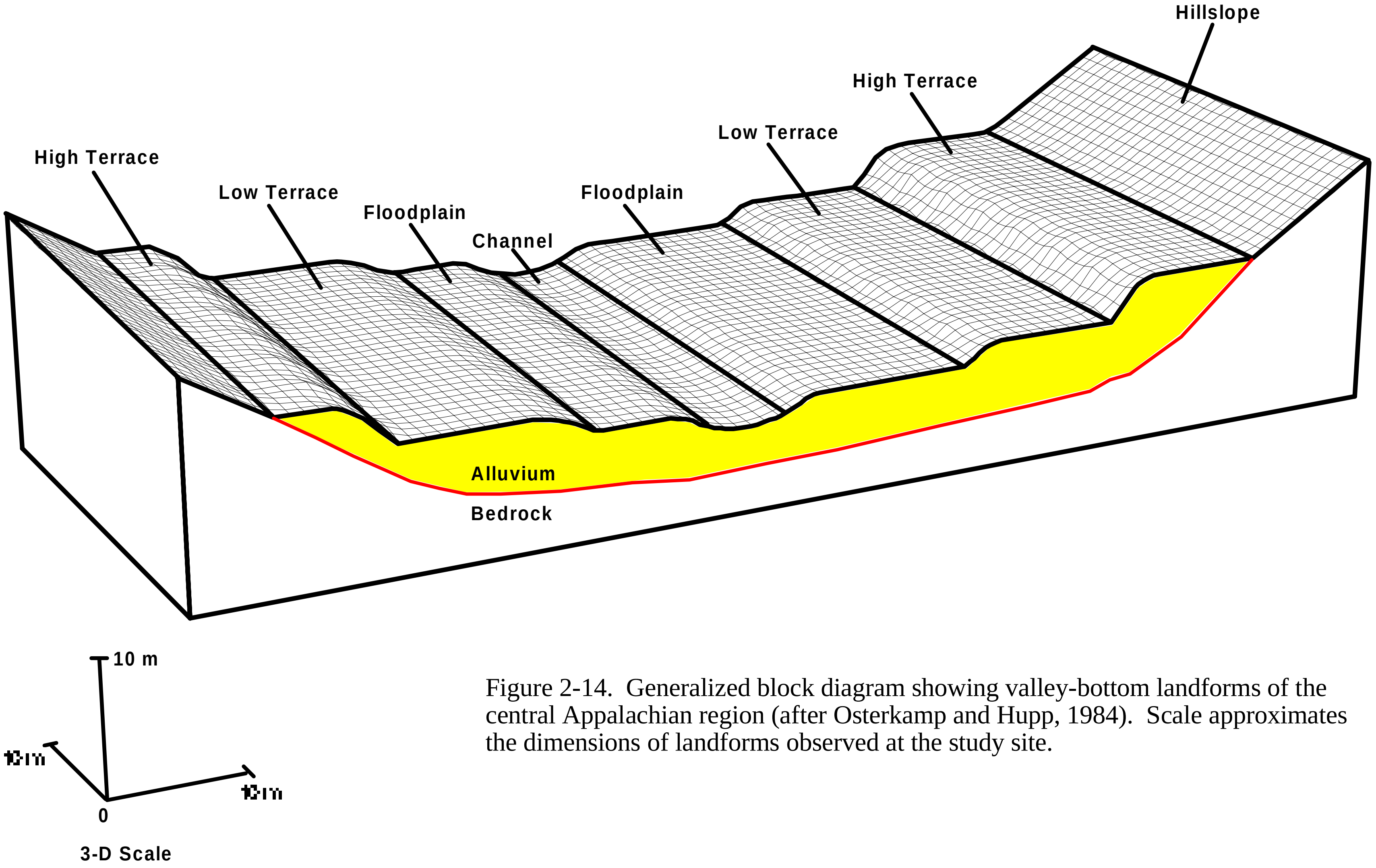


Figure 2-14. Generalized block diagram showing valley-bottom landforms of the central Appalachian region (after Osterkamp and Hupp, 1984). Scale approximates the dimensions of landforms observed at the study site.

the zone occupied by open streamflow and includes the channel bed, depositional bar, active-channel bank, and active-channel shelf (terminology after Osterkamp and Hupp, 1984). Alluvium in the channel is subject to active reworking by streamflow for significant periods of the year. The highest order channels at the Fernow, fifth order of Strahler (1952), are located along the lower reaches of Elklick Run and Stonelick Run (Figure 2-12, Plate 2-1).

The floodplain is a low-lying surface adjacent to the channel that is inundated once every one to three years (Osterkamp and Hupp, 1984; Wolman and Leopold, 1957). Based on surface morphology at the Fernow, it appears that floodplains are delineated by planar surfaces 0.5 to 1.0 meters above the active channel (Figure 2-12. Plate 2-4).

Stream terraces are defined as elevated alluvial surfaces that are inundated less frequently than the floodplain. The higher the elevation of the terrace above the channel, the less likely the occurrence of inundation, with the highest surfaces abandoned completely. Terraces at the Fernow are of two different geometries: (1) elongate terraces that are generally parallel to the channel, and (2) dissected, fan-shaped terraces that occur at the mouths of tributary junctions (Figures 2-13 and 2-14). Terrace segments are commonly disconnected and characterized by areas of anomalously flat topography. Low-level terraces are common along drainages in the Fernow and range in heights from 2.0 to 6.0 meters above the channel (Figure 2-15). Fan terraces represent preserved segments of alluvial fans that have been otherwise dissected by tributary channels following deposition (Figure 2-16). Fan terraces are less common than the elongate low-level terraces, although fan surfaces may lie up to 15 meters above the active channel floor (Figure 2-12, Plate 2-4). Unit designations "Hf" and "Qf" are applied to undissected fans graded to present channel elevations.

Karst Features

Karst landforms are moderately well developed in portions of the Greenbrier Group. Landforms include sinkholes, karst springs, pocket valleys, and cave openings. Karst features are most common toward the base of the Greenbrier section, within 20 meters of the underlying Price (Pocono) contact. The most notable occurrence is near Big Springs Gap (Figures 2-9 and 2-12; Plate 2).

Figure 2-15. Photo of elongate stream terrace (Qt3) along Stonelick Run. Terrace surface lies 6 m above active channel grade. Note man for scale.

Figure 2-16. Photo showing example of a fan terrace (Qf2) from Pocahontas County, WV. The fan surface lies 5 m above active channel grade. Note car for scale.

Sinkholes occur as small, shallow, circular to oval closed depressions up to 5 meters in diameter, and 1 to 2 meters in depth. These features form by downward solution of limestone from the surface or by roof collapse of a solution cavity. Sinks are most commonly found on topographic noses to the southeast of Elklick Run, immediately above the Price bedrock benches (Figure 2-12, Plate 2).

Well-developed karst springs occur in the Big Springs Gap area, near the base of the Greenbrier Group. Groundwater hydraulics are controlled by secondary fracture porosity in the limestone lithofacies. These springs commonly form pocket valleys in which streams emerge from hillslopes along headless solution hollows. Karst spring discharge likely has a significant effect on the stream water chemistry of upper Elklick Run and its tributaries.

Caves are defined as those openings large enough for human entry into the immediate near-surface passage way (Kite, 1994; Figure 2-17). Although cave passage morphology was not considered in this study, it is likely that Fernow forms are similar to those of other Greenbrier caves in the region (Springer, 1994). Regional fracture patterns and bedding provide the primary control on groundwater flow paths and associated passage geometries (Palmer, 1991).

Geologic Controls on Topography

Hack (1960, 1980) emphasized the relationships between bedrock geology, lithologic resistance to erosion, and topography in the central Appalachians. Bedrock geology is the dominant factor controlling the large-scale configuration of the Fernow landscape (Figures 2-3 and 2-4).

In terms of structural-geomorphic relationships, hillslopes with gradients to the southeast represent dip-slopes, and those to the northwest, anti-dip slopes ("scarp face" of Easterbrook, 1993). In general, the first-order streams northwest of Elklick Run lie in a dip-slope orientation, whereas those to the southeast are anti-dip. Morphometric analysis indicates that anti-dip, first-order streams are steeper than those on dip slopes, with average stream gradients of 0.33 and 0.29, respectively (Figure 2-18). Dip-slope morphometry likely has a significant influence on hillslope processes, stream discharge, and surficial materials. For example, Graham (1996) determined that steep anti-dip slopes on North Fork Mountain, Pendleton County, West Virginia, are more prone to slope failure than gentler dip slopes.

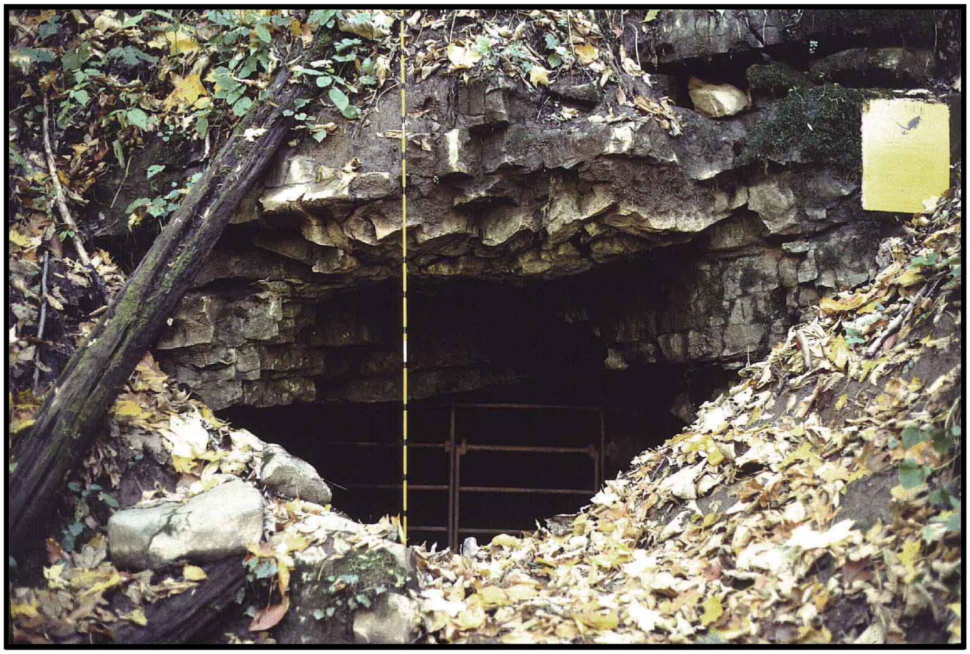


Figure 2-17. Photo of cave opening near the base of the Greenbrier Group, Big Springs Gap. Field of view is 2 m.

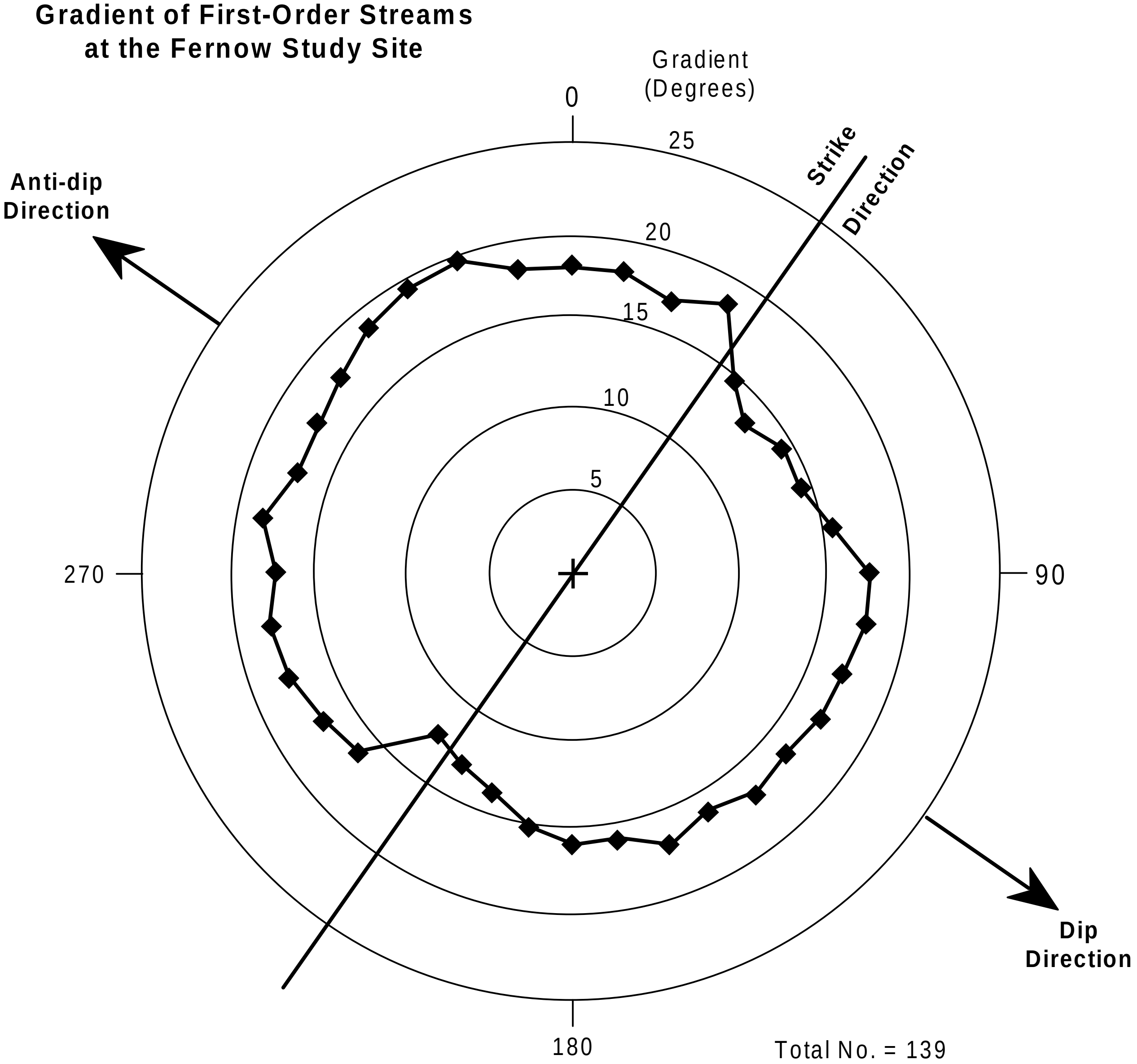


Figure 2-18. Azimuthal distribution of mean gradient (degrees) for first-order tributaries at the Fernow Experimental Forest. Azimuth direction refers to the direction of stream flow. The plot has been smoothed by averaging the values of all slopes that are within +/- 20 degrees of the azimuth point shown (method from Hack and Goodlett, 1960, p. 36).

Casual comparison of regional fracture orientations and stream-course azimuths suggest that drainage orientation at the study area is largely controlled by structurally-induced weaknesses. The northeast course of Elklick Run follows regional strike (Figure 2-9). Lower-order tributaries are predominantly oriented northwest-southeast, subparallel to the regional systematic fracture set (Kulander and others, 1980). Similarity of drainage and fracture orientations strongly suggests that bedrock structure has played an integral role in landscape evolution. The trellis-like drainage pattern displayed at the Fernow is more reminiscent of the Valley and Ridge province than the Appalachian Plateau.

In terms of erosional resistance, pebbly sandstones of the Price (Pocono) Formation and Pottsville Group serve as the dominant ridge formers. The upper Price contact forms prominent bedrock benches on the southeastern slopes of Elklick Run, while Pottsville strata support McGowan Mountain (Figures 2-9 and 2-10; Plate 2-3). Thickly-bedded sandstones of the Canon Hill Member also appear resistant to erosion, forming the spine of Fork Mountain. By comparison, interbedded shales and sandstones of the Rowlesburg Member are relatively non-resistant, forming rather subdued topography on the northwest side of Elklick Run. However, Hampshire sandstone interbeds locally form resistant stream knick-points, rapids, and slope breaks (Figure 2-19).

Topographic associations were extremely useful in delineating lithostratigraphic contacts in the study area. Changes in slope gradient, morphology, and regolith composition were readily recognizable during reconnaissance traverses, particularly along nose crests. Table 2-8 is a summary of the observed geomorphic associations; Figure 2-20 is a graphical representation of those relationships. The contact between the Hampshire and Price units is typically marked by an increase in slope gradient above the interface, coupled with regolith transition from disk-shaped ("flaggy") red sandstone clasts to equant brown sandstone clasts. Contact between the Price and Greenbrier units is delineated by an abrupt break in gradient from gently-inclined Price benches to the more steeply inclined Greenbrier scarp slopes (Figure 2-20). Morphologic changes above this contact are characterized by the appearance of irregularly-shaped limestone boulders, and the occurrence of small-scale karst features. The interface between the Greenbrier and Mauch Chunk groups is delineated by a notable increase in slope gradient with transition from limestone to red sandstone regolith. The Mauch Chunk-Pottsville contact is poorly

Figure 2-19. Photo showing slope break associated with a resistant sandstone interbed of the Hampshire Formation (Rowlesburg Member). Vertical field of view is 2.5 m.

Table 2-8. Summary of Lithostratigraphic Units, Geomorphic Associations and Surficial Properties.

Lithostratigraphic Unit	Slope Gradient*	Landform Association	Regolith Characterics (Cobble-Boulder Fraction)			
			Clast Compostion	Clast Color	Clast Shape	B-Axis Diameter*
Foreknobs Fm (Chemung)	0.45-0.60	Anti-dip slopes on western flank of Fork Mountain	Medium-grained sandstone	Light Olive Gray (5Y 5/2)	Equant, blocky	Avg: 40-60 cm
Hampshire Fm (Rowlesburg Mmbr)	0.15-0.35	Dip slopes on northwestern side of Elklick Run	Fine- to medium-grained sandstone, "flaggy", micaceous.	Grayish Red (10R 4/2)	Disk-shaped	Range: up to 60-70 cm Avg: 30-40 cm
Price Fm (Pocono)	0.40-0.45	Anti-dip slopes on southeastern side of Elklick Run. Top of unit marked by resistant dip-slope benches.	**Medium- to coarse-grained sandstone, ##pebbly coarse-grained sandstone near top of unit.	**Pale Yellowish Brown (10YR 6/2); ## Light Gray (N7)	Equant, blocky	Range: up to 80 cm Avg: 50-60 cm
Greenbrier Gp	0.30-0.35	Anti-dip slopes on southeastern side of Elklick Run. Localized karst features (cave openings, sinks, springs)	Crystalline limestone, arenaceous limestone.	Greenish Gray (%GY 6/1), Medium Gray (N5)	Equant-blocky to irregular	Range: up to 100 cm Avg: 30-50 cm
Mauch Chunk Gp	0.35-0.40	Anti-dip slopes on southeastern side of Elklick Run.	Medium-grained sandstone	Grayish Red (5R 4/2)	Equant-blocky	Avg: 40-50 cm
Pottsville Gp	0.40-0.50	Anti-dip slopes on southeastern side of Elklick Run. Resistant ridge-former on McGowan Mountain.	Medium- to coarse-grained sandstone, and pebbly sandstone.	Medium Light Gray (N6)	Equant-blocky	Range: 50-300 cm Avg: 100-200 cm

* Generalized and approximate. Data not subject to rigorous statistical analysis.

Table 2-8 (Cont.).

Lithostratigraphic Unit	**Primary Soil Association**	**Comments**
Foreknobs Fm (Chemung)	Dekalb; stony loam; yellowish brown (10YR 3/4) to dark brown (7.5YR 4/4)	Outcrops on southwestern corner of Fernow Forest. Sandstone interbeds resistant to erosion, forms the spine of Fork Mountain.
Hampshire Fm (Rowlesburg Mmbr)	Calvin; channery silt loam to stony silt loam; reddish brown (2.5YR)	Contact of Hampshire Group with Price Formation marked by change from red sandstone regolith to brown sandstone regolith. Upper contact may also be associated with subtle slope increase into overlying Price strata.
Price Fm (Pocono)	Dekalb; channery loam to stony loam; yellowish brown (10YR 3/4) to dark brown (7.5YR 4/4)	Top of Price Formation forms resistant bedrock benches on otherwise steep anti-dip slope topography (southeast of Elklick Run). Break in slope (> gradient) above benches mark contact with overlying Greenbrier strata.
Greenbrier Gp	Belmont; silt loam to very stony silt loam; dark brown to brown (7.5YR 4/2)	Irregular clast shape reflects susceptibility to near-surface dissolution. Lower 20 m of unit commonly associated with sinks and karst microtopography. Upper contact marked by distinct slope break (> gradient) into overlying Mauch Chunk strata.
Mauch Chunk Gp	Calvin; channery silt loam to stony silt loam; reddish brown (2.5YR)	Similar in appearance to Hampshire regolith. Mauch Chunk interval commonly covered by Pottsville boulder colluvium from upper section.
Pottsville Gp	Very stony land-Dekalb complex; stony land - stony loam; yellowish brown (10YR 3/4) to dark brown (7.5YR 4/4)	Forms prominent rock-cities along uppermost elevations of McGowan Mountain. Conspicuous meter-scale boulder colluvium and block fields common. Forms an extensive colluvial apron on the northwest flank of McGowan Mountain, at the drainage divide of Elklick Run.

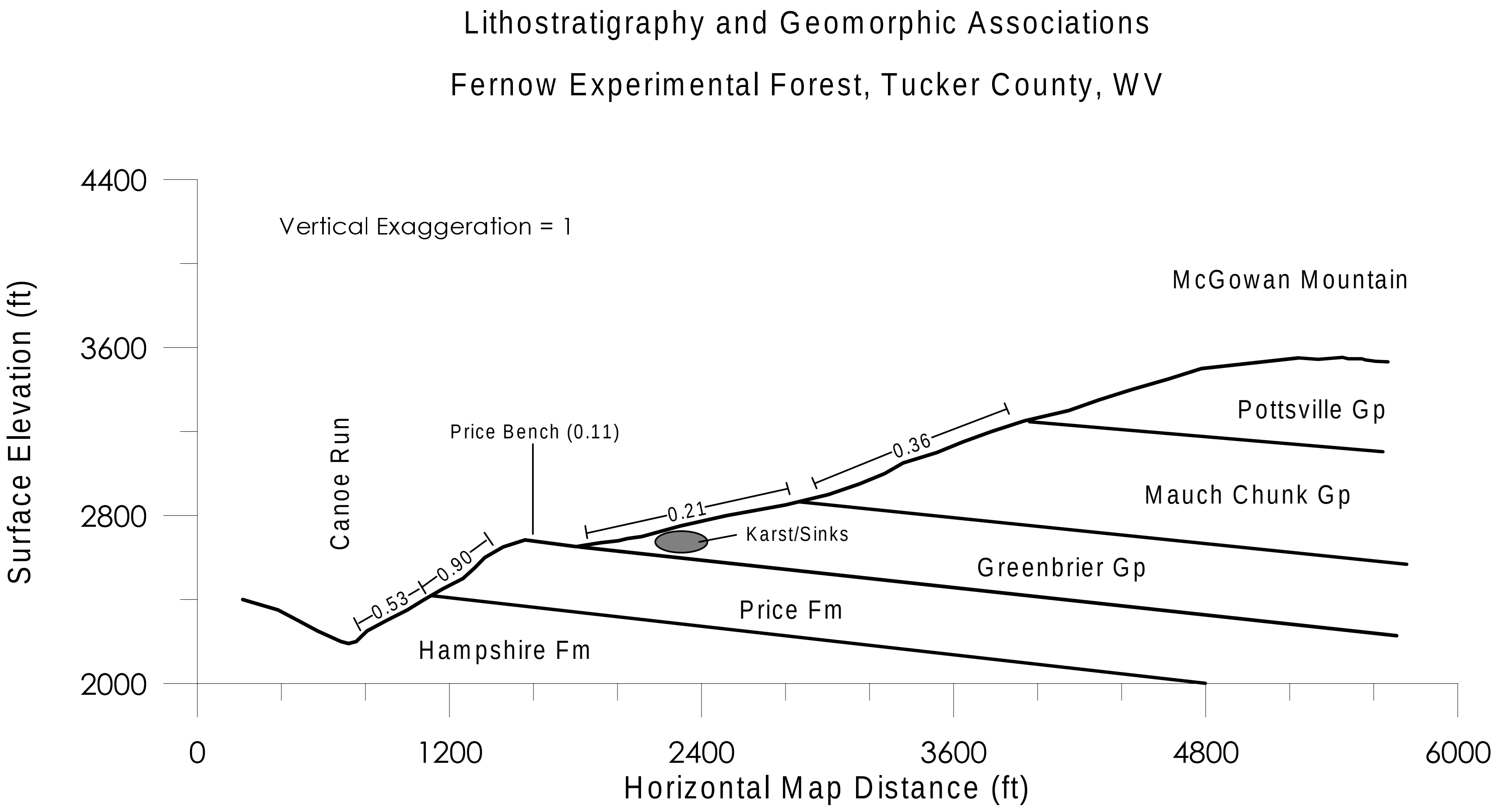


Figure 2-20. Generalized cross-section illustrating the relationship between lithostratigraphy and hillslope morphology at the Fernow Experimental Forest. See text for discussion. Decimal fractions represent mean slope gradients.

reflected by hillslope morphology (Figure 2-20); however, the occurrence of large-diameter (> 2 m) boulders is diagnostic for Pottsville colluvium (Figure 2-21).

Surficial Deposits (Materials and Origin)

Similar to landforms, surficial materials are also divided into hillslope and valley-bottom facies. Hillslope deposits include colluvium and residuum, while valley-bottom deposits include channel alluvium, floodplain alluvium, terrace sediments, fans, and aprons.

Hillslope Deposits

Colluvium and residuum are the most widespread surficial deposits at the Fernow Experimental Forest (Figure 2-12, Plate 2-4). Both facies are comprised primarily of cobble-boulder diamicton in which gravel clasts are set in a matrix of loamy sand, silt, and clay ("channery silt loams" and "stoney soils" of Losche and Beverage, 1967). Parent lithology is the primary influence on clast composition and texture. The term "regolith" encompasses all weathered and transported sediment at the earth's surface. "Colluvium" is applied to regolith that has been transported and deposited by mass-wasting processes. These processes are gravity driven and include slope wash, creep, slide, frost heave, tree throw, and other bioturbation. Tree-throw processes are locally important in the Fernow Forest, especially on Hampshire dip-slopes northwest of Elklick Run (Figure 2-22). Under conditions of significant down-slope transport, the clast composition of colluvial sediments may differ significantly from that of the underlying bedrock lithology. "Residuum" by definition contains the *in-situ* products of bedrock weathering. Clast composition represents parent bedrock lithology, with little or no transport (Mills, 1988). Hillslope colluvium and residuum most commonly form depositional veneers on bedrock, with thicknesses generally less than two meters. Residual veneers develop on ridge crests and noses with gentle slope gradients, less than 0.15. Colluvial veneers occur on side slopes with gradients greater than 0.15.

Hillslope colluvium is subdivided on Plate 2-4 into side-slope facies (Qc1) and hollow facies (Qc2). This distinction is important with respect to slope process, in that hollow colluvium is commonly associated with debris-slide failure during high-intensity precipitation events (Hack and Goodlett, 1960; Reneau and Dietrich, 1987). Some low-order hollows are

Figure 2-21. Photo showing a large-diameter boulder clast in Pottsville colluvium. Horizontal field of view is approximately 4 m.

Figure 2-22. Photo illustrating tree-throw processes at the Fernow Experimental Forest. Vertical field of view is 2.5 m.

choked with colluvial fan deposits in which a thickened mantle fill has accumulated (Plate 2-4: unit Qf). These deposits are recognized by the inversion of concave-out to convex-out contours at the base of the hollow (refer to Figure 2-13C). Preservation of these deposits suggests that stream power has not been sufficient to remove the material by normal streamflow processes. An extensive veneer of Pottsville boulder colluvium is located on the western flank of McGowan Mountain near the headwaters of Elklick Run (Plate 2-4, map unit Qc1B). This coarse colluvial veneer completely covers the Greenbrier and Mauch Chunk outcrop belt, significantly influencing local soil composition.

Boulder streams and boulder fields occur locally along some hillslopes (Plate 2-4: units Qbs, Qbf). These units represent a mappable subset of colluvium. Boulder streams display elongate geometry and tend to armor low-order hollows. They are recognized by a prominent bouldery surface cover, with negligible amounts of finer-grained, interstitial sediment. Boulder fields are similar in character, but occur along straight side slopes and display an equant or irregular shape. Small-scale colluvial block fields are commonly located downslope of resistant sandstone outcrops in the Hampshire, Pocono (Price), and Pottsville formations (Plate 2-4). Boulder streams and fields likely form by a combination of sliding, creep, and slopewash winnowing. It is plausible that better developed boulder streams in the central Appalachians are the products of periglacial processes during Pleistocene glacial climates (Mills, 1988; Mills and Delcourt, 1991). Biogeomorphic analysis of modern forest cover in Virginia suggests that some boulder fields are active under present-day climate conditions (Hupp, 1983).

Valley-Bottom Deposits

Valley-bottom facies are comprised primarily of pebbles, cobbles, and boulders with various admixtures of loam, sand, and silt. Large clasts are composed of resistant sandstone lithologies. These deposits are associated with channels, floodplains, terraces, fans, and aprons (Plate 2-4). Fernow channels are gravel rich and relatively free of finer-grained sediments (Figure 2-23). Gravel clast diameters average 19 centimeters along the intermediate axis, with larger Pottsville boulders ranging up to 3.2 meters. Channel alluvium is commonly clast-supported, moderately- to poorly-sorted, and imbricated as a result of normal streamflow hydraulics. The channel along the main tributary of Elklick Run averages approximately 10

Figure 2-23. Photo showing the active channel of Elklick Run (Hch). Note cobbly to bouldery alluvium and coarse woody debris. Horizontal field of view is approximately 4.5 m.

Figure 24. Photo showing example of floodplain deposit along Elklick Run (Hfp2). Floodplain surface is 1.5 m above present channel grade, current direction is to the left. Vertical field of view is 2 m.

meters in width. Elklick Run becomes more deeply incised along its lower reaches, near its confluence with Black Fork. The lower end of the drainage is also characterized by a predominance of bedrock along the channel floor, with decreased amounts of alluvium.

Floodplains and low-level terraces are similarly comprised of coarse cobble-boulder deposits with loamy interbeds. Fabrics range from matrix- to clast-supported. Deposits exposed in several stream cuts along Elklick Run reveal crude internal stratification and imbrication (Figure 2-24). Floodplain surfaces range from 0.5 to 2 meters above the active channel floor. Evidence for frequent inundation includes scour-and-chute topography, disturbed vegetation, and fresh slackwater deposits. Low terraces range from 3 to 6 meters above active channel grade. Terrace surfaces commonly support growth of *Rhododendron maximum* and may be covered by colluvial aprons delivered from adjacent side slopes. In general, Stonelick Run displays a greater amount of bouldery debris in storage compared to Elklick Run. The lower reaches of Stonelick Run are debris-choked with notable preservation of low terraces (Plate 2-4).

Footslopes represent a transitional environment between hillslope colluviation and valley-bottom channel transport. The two most common types of footslope deposits at the Fernow are fans and aprons (Figure 2-13). Fan-shaped deposits typically occur at the mouths of tributaries, or tributary junctions. The fan geometry results from flow expansion as sediment exits the confines of a channel. Fan deposits in the study area are cobble- to boulder-rich, massive to crudely-stratified, with matrix-supported diamicton fabrics (Figure 2-25). Matrix fractions are in the silty loam class. Footslope aprons are similar in texture and occurrence; however, they lack a well-defined point source and fan-like geometry. Aprons occur at the base of straight side slopes and are identified by a distinct change in gradient (Plate 2-4; unit Qap). Fan and apron deposits are found adjacent to the present-day valley floor, and also form high terrace surfaces up to 15 meters above channel grade. The confluence between Canoe Run and Shavers Fork is associated with a notable fan-terrace assemblage on the southwestern margin of the study area (Figure 2-12, Plate 2-4). Most of the higher fan-terraces are dissected and covered with colluvial veneer. Fans and aprons in the central Appalachians are the products of a combination of debris-slide, debris-flow, and streamflow processes (Kite, 1987; Kochel and Johnson, 1984; Kochel, 1987; Mills, 1982). Although geochronologic data are lacking, it is likely that many fan deposits in the central Appalachians record multiple prehistoric debris-flow events (Kochel, 1987; Eaton and

Figure 2-25. Photo showing example of fan-terrace deposit at mouth of Wilson Hollow (Qf5). Fan surface is 15 m above present channel grade. Note predominance of matrix-supported diamicton. Vertical field of view is 3 m.

McGeehin, 1997). The relatively small volume of fan deposits at the Fernow area suggests that such deposits have a low preservation potential in this setting (Taylor, 1998).

Valley-bottom sediments are transported by a spectrum of channel processes ranging from normal streamflow to hyperconcentrated flow to viscous slurry flow (terminology after Pierson and Costa, 1987). Each of these processes mobilizes sediment into and out of storage in the valley-bottom setting. The relative significance of each process in the geomorphic history of Fernow Experimental Forest can not be adequately deciphered from the present data set.

Age of Surficial Deposits

Dating of surficial deposits in the Appalachians is problematic, and persists as an elusive facet of geomorphic study. Radiocarbon techniques are of limited value due to poor preservation of organic matter (Mills and Delcourt, 1991). Thermoluminescence (Shafer, 1988), magnetostratigraphic (Jacobson and others, 1988; Springer and others, 1997), and cosmogenic isotope (Pavich and others, 1985; Granger and others, 1997) techniques provide results holding some promise; however, they have not been widely applied in the Appalachians. Relative-age dating techniques were utilized in several studies (Mills, 1988; Engel and others, 1996), although the discontinuous nature of surficial deposits makes stratigraphic correlation difficult.

Given the preliminary nature of the present study, it is only possible to speculate on the age of surficial deposits at the Fernow study area. Several models have been proposed suggesting that colluvium in the central Appalachians dates to the last glacial maximum. Behling and others (1993) obtained radiocarbon dates from a surficial sequence in the Pendleton Creek basin of northern West Virginia. They found that hillslope colluvium is between 17,000 and 22,000 years old, while the floodplain alluvium is entirely Holocene in age (<10 Ka). Jacobson and others (1989b) found a similar chronology for colluvial and alluvial deposits in the South Branch of the Potomac. Eaton and others (1997) presented dates for prehistoric debris flows in the Virginia Blue Ridge with radiocarbon ages of 2,200, 22,430-34,770 and 50,800 years. Given the proximity of these dated sites to the Fernow, it is anticipated that similar chronologies exist. Additional work is required to definitively establish the age of surficial deposits.

SUMMARY AND CONCLUSION

Detailed bedrock and surficial geology maps are presented for the Fernow Experimental Forest. The study area is underlain by upper Paleozoic sedimentary strata that gently dip to the southeast. Lithostratigraphic units include the Devonian Foreknobs Formation (Greenland Gap Group), the Devonian Hampshire Formation (Canon Hill and Rowlesburg members), the Mississippian Price (Pocono) Formation, the Mississippian Greenbrier Group, the Mississippian Mauch Chunk Group, the Pennsylvanian Pottsville Group and the Pennsylvanian Allegheny Formation. Coarse sandstone lithofacies of the Price and Pottsville units form prominent bedrock ridges on the southeastern side of Elklick Run. Sandstones of the Canon Hill Member support the resistant crest of Fork Mountain. Interbedded sandstones and shales of the Rowlesburg Member are relatively nonresistant and form gentle dip-slopes on the northwestern side of Elklick Run.

Several types of large-scale landforms are recognized at the Fernow Experimental Forest; these include hillslope, valley-bottom, and karst features. Hillslopes are further subdivided into ridges, noses, side slopes, hollows, and footslopes. Mesoscale valley-bottom landforms include channels, floodplains, and terraces. Karst features are common in the lower 20 meters of Greenbrier Group; landforms include sinkholes, karst springs, pocket valleys, and cave openings. Hillslope deposits are comprised primarily of colluvial and residual diamicton. Boulder fields and boulder streams occur locally within the area. Footslope areas are commonly associated with fan and apron deposits. Valley-bottom sequences are composed largely of imbricated coarse-grained facies with various admixtures of loam, sand and silt. The ages of surficial deposits at Fernow Experimental Forest are unknown; however comparison with regional chronosequences suggests that hillslope colluvium may be Late Pleistocene in age, and valley alluvium Holocene.

Ecosystem management and global change are at the forefront of public discourse and policy making. The understanding of geomorphic processes is critical for deciphering complex interactions between forest biota, hydrologic systems, and site geology. The long history of research at Fernow Experimental Forest provides a valuable scientific resource from which to expand our understanding of central Appalachian geomorphology. The work described herein represents an important step toward an interdisciplinary approach to forest ecosystem management.

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