APPALACHIAN

FANS —

OVERVIEW /

CLASSIFICATION

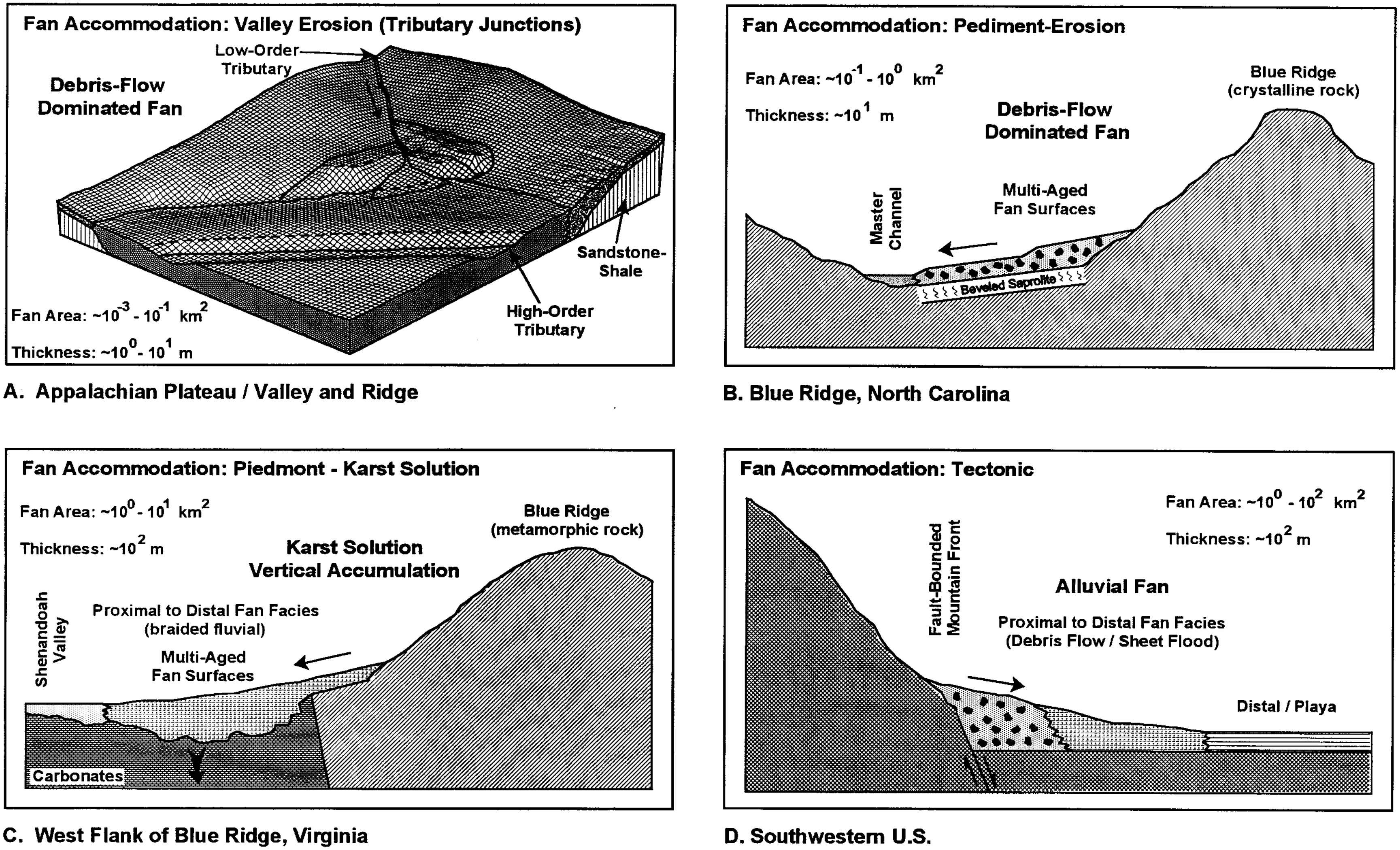
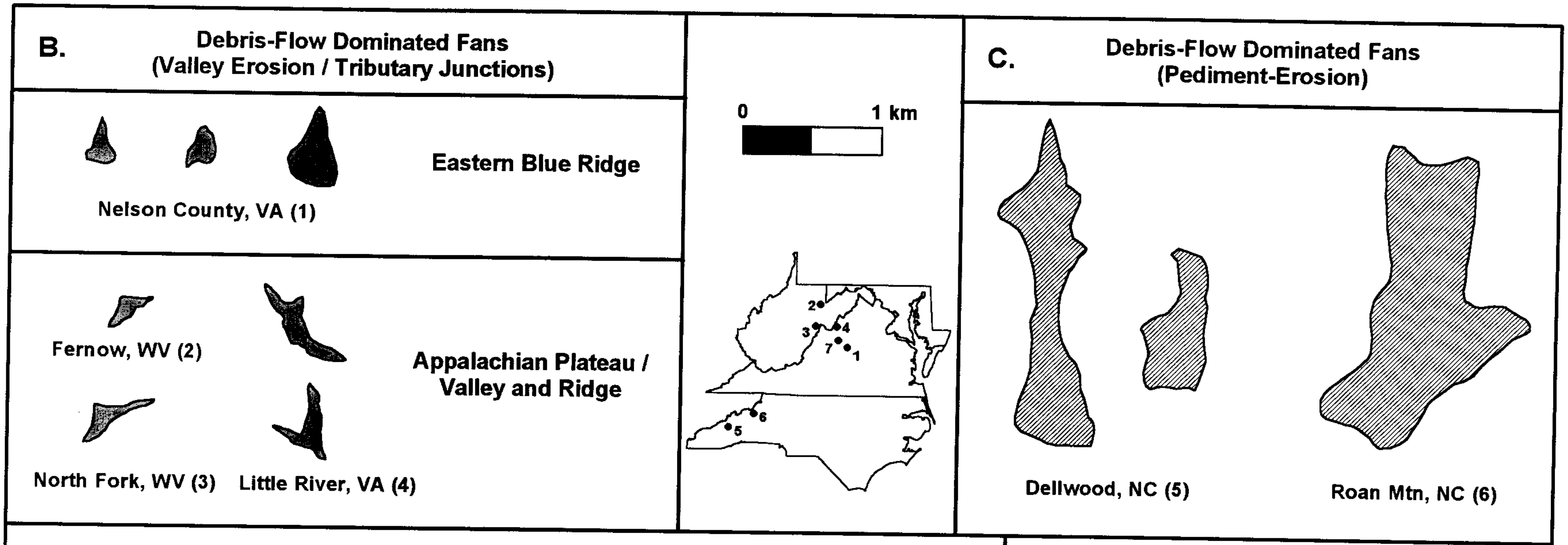


Figure 6-17. Diagrammatic illustration of the modes of fan accommodation recognized in this study (not to scale). Fan accommodation diagrams are arranged in increasing order of magnitude. Southwestern U.S. fans modeled after summary discussions provided by Ritter and others (1995) and Blair and McPherson (1994). Diagrams B and C for the Blue Ridge are derived from Kochel (1990), Whittecar and Duffy (1992), Mills (1983) and Mills and Allison (1995a,b,c).



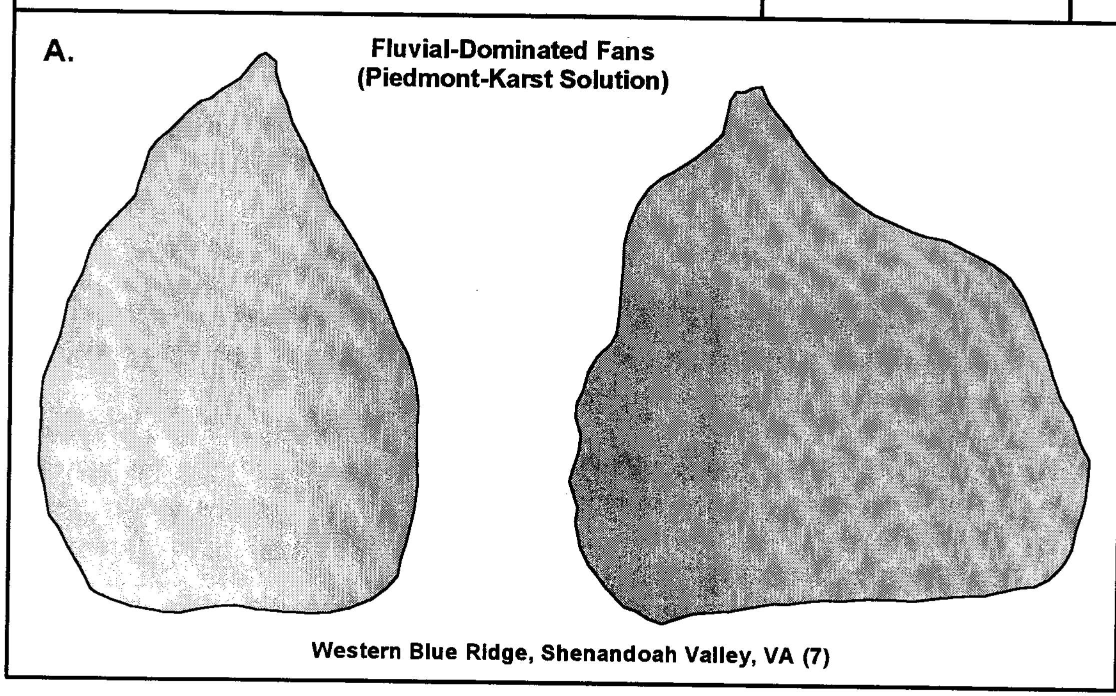


Figure 6-3. Scale comparison of fan types recognized in the central Appalachians (after Kochel, 1990). Source of fan accommodation listed in parentheses.
Fan shapes are derived from the following sources: Nelson County, VA - Kochel and Johnson (1984); Roan Mountain, NC - Mills (1983); Dellwood, NC (Mills, 1982); western Blue Ridge, VA (Kochel, 1990); Fernow, North Fork, Little River - this study. Refer to numbered site locations on base map. See text for discussion.

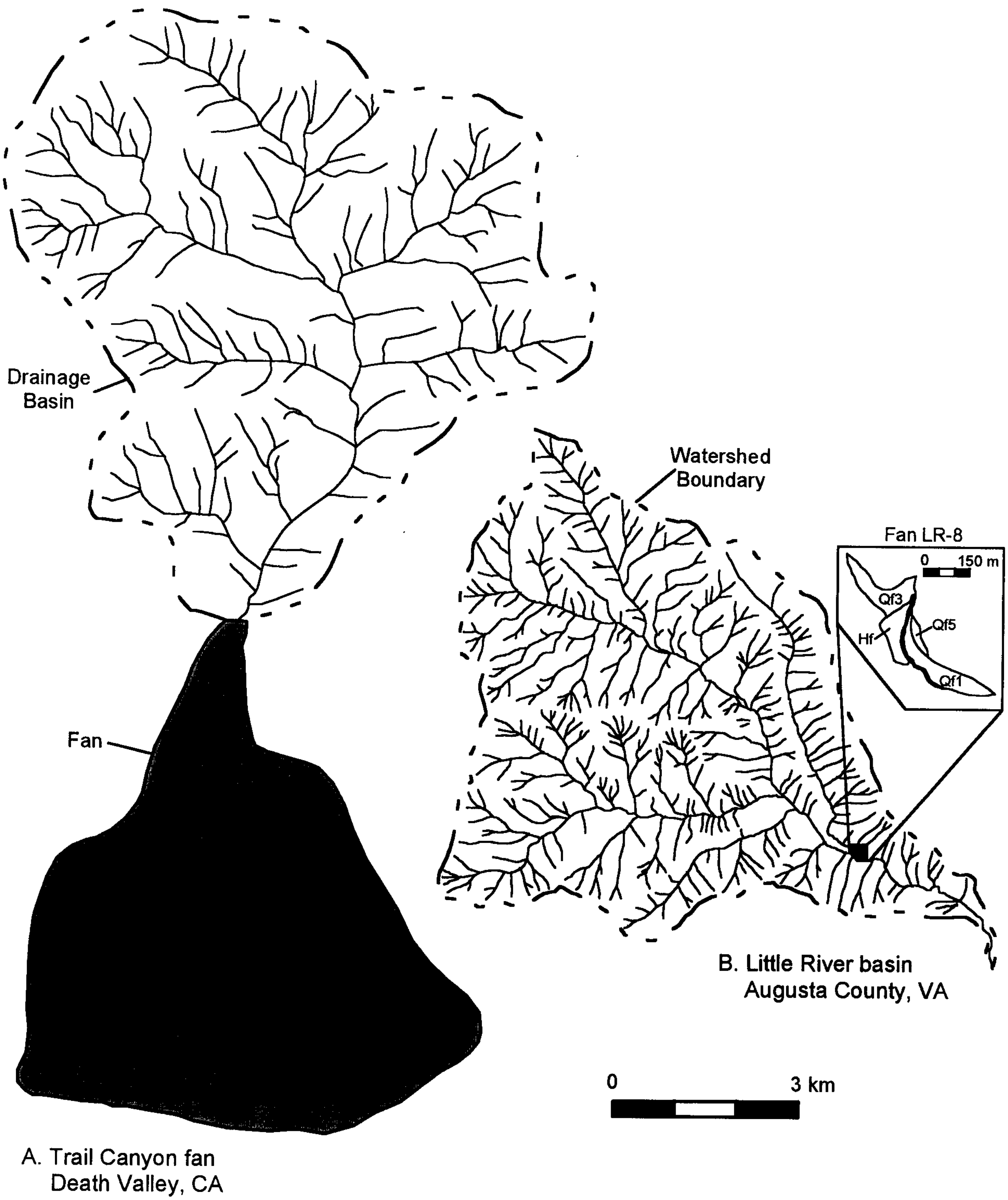


Figure 6-7. Scale comparison of debris fans at the Little River basin with an arid alluvial fan at Death Valley, California. The Trail Canyon fan map is from Blair and McPherson (1994).

Table 6.1. Major historical appalachian debris-flows

Date	Location	Rainfall Data Amount (cm)	Duration (hrs)	Source*	Reference
8/4–5/38	Webb Mt., TN	28–38	4	T	Moneymaker, 1939
8/17–18/40	Watauga, TN	–	–	T–H	U.S.G.S., 1949
8/17–18/40	Grandfather Mt., NC	–	–	T–H	U.S.G.S., 1949
8/17–18/40	Radford, VA	–	–	T–H	U.S.G.S., 1949
6/17–18/42	Northcentral, PA	90	12	?	Eisenlohr, 1952
6/17–18/49	Little River, VA	24	3–4	T	Hack and Goodlett, 1960
6/17–18/49	Petersburg, WV	40	24	T	Stringfield and Smith, 1956
9/1/51	Smoky Mts., NC–TN	10–20	1	T	Bogucki, 1970; 1976
6/30/56	Cove Creek, NC	30	1	T	Bogucki, 1970
8/19–20/69	Nelson Co., VA	80	8	T–H	Williams and Guy, 1973
8/19–20/69	Spring Creek, WV	10–40	8	T–H	Schneider, 1973
8/10/76	Dorset Mt., VT	10	6	T–H	Ratte and Rhodes, 1977
6/19–20/77	Johnstown, PA	25–30	–	ET	Pomeroy, 1980
8/10–11/84	Smoky Mts., TN	10	24	?	this study
Various dates	Adirondack Mts., NY	–	–	–	Bogucki, 1977
Various dates	White Mts., NH	–	–	–	Flaccus, 1958

*T = demonstrable tropical air mass
T–H = hurricane
ET = extratropical cyclone
? = difficult to determine

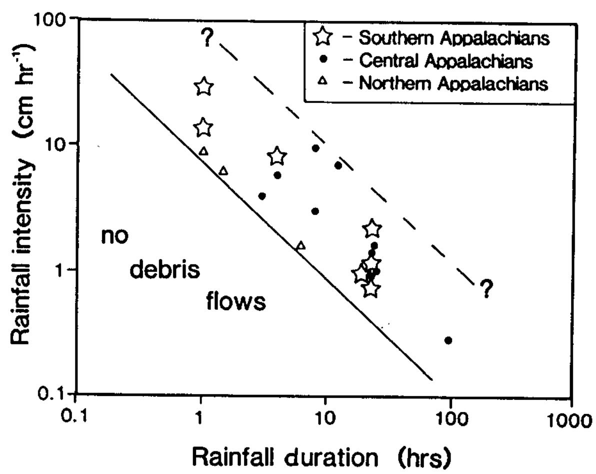


Figure 6.3. Intensity-duration relation for major debris-flow producing storms in the Appalachians. Debris-flows occur at lower rainfall intensities as the duration of the storm increases. See discussion in text. Data were compiled from the following sources: Bogucki, 1970, 1976, 1977; Costa, unpublished; Eisenlohr, 1952; Eschner and Patric, 1982; Hack and Goodlett, 1960; Moneymaker, 1939; Neary and Swift, 1984; Patric, 1981; Pomeroy, 1980; Ratte and Rhodes, 1977; Schneider, 1973; Stringfield and Smith, 1956; Williams and Guy, 1973

Blue Ridge-Fluvial-Dominated Fans

BR FAN – AT SHENANDOAH VALLEY

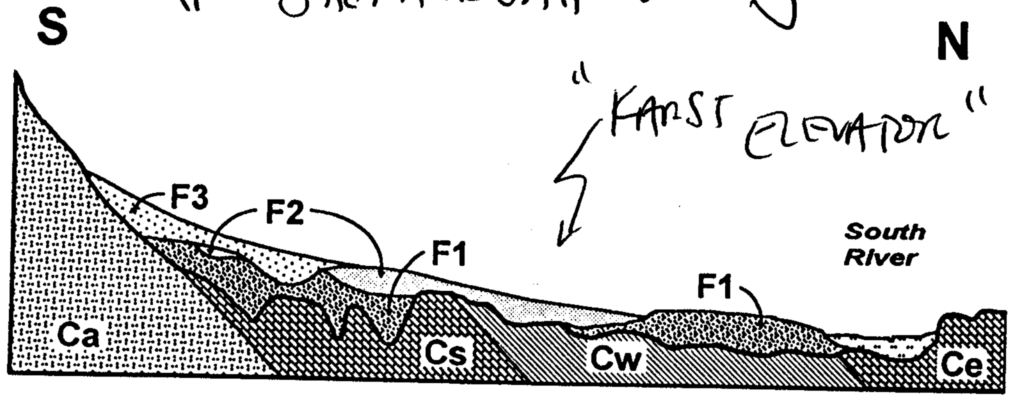


Figure 7. Schematic cross-section of bedrock geology and relative thicknesses of fan deposits. Fan sediments (F1, F2, and F3) are thickest over the Shady Formation (Cs) and thinnest over the Waynesboro (Rome) (Cr). The Antietam (Ca) and the Elbrook (Ce) formations are also shown.

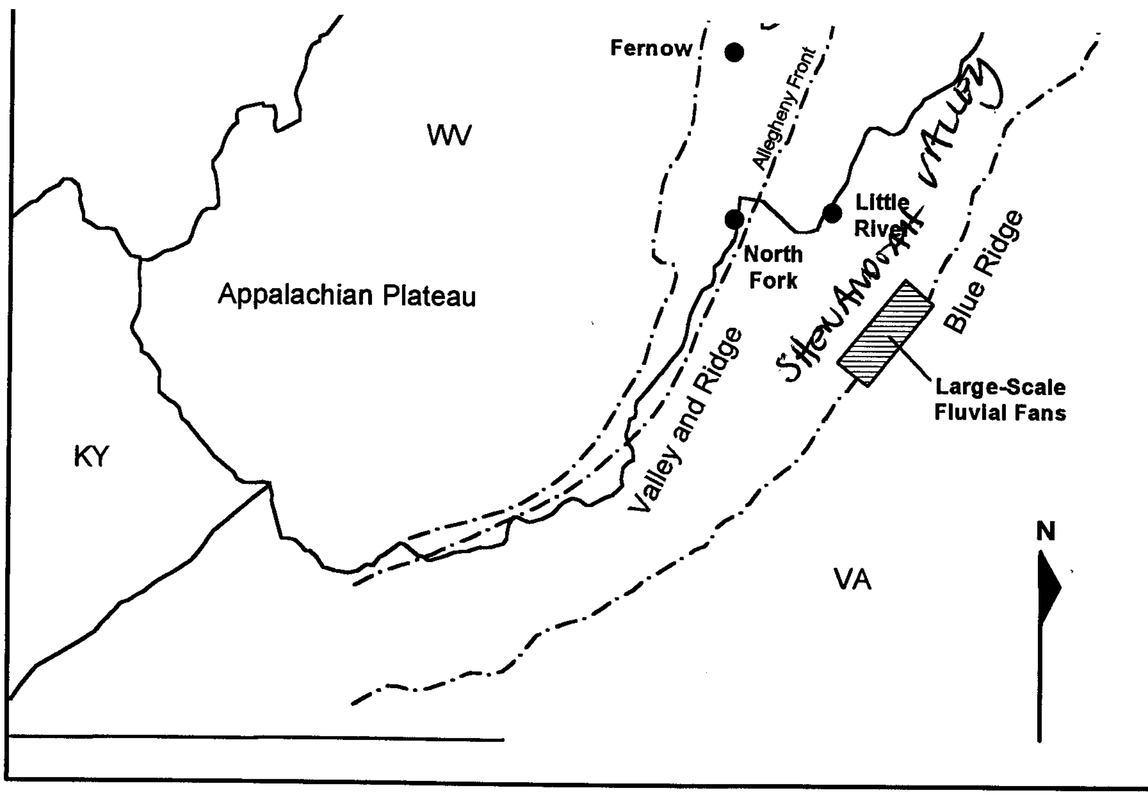


Figure 6-1. Physiographic map of the central Appalachians. Locations include: "Fernow" - Fernow Experimental Forest, Tucker County, West Virginia; "North Fork" - North Fork basin, Pocahontas County, West Virginia; and "Little River" - Little River basin, Augusta County, Virginia. Physiographic base map from Kulander and Dean (1986). Hatched box shows location of large-scale fluvial fans as described by Kochel (1990). See text for discussion.

Blue Ridge Fans

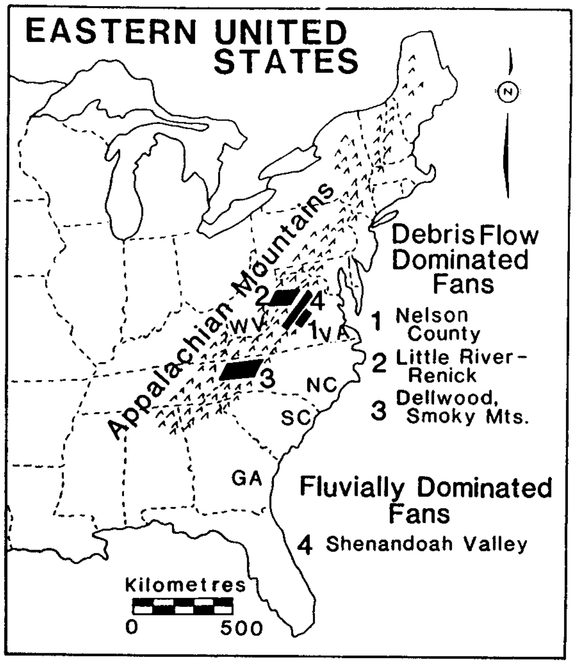


Figure 6.1. Map of the eastern United States showing the location of the major Appalachian Mountain study areas discussed in the text

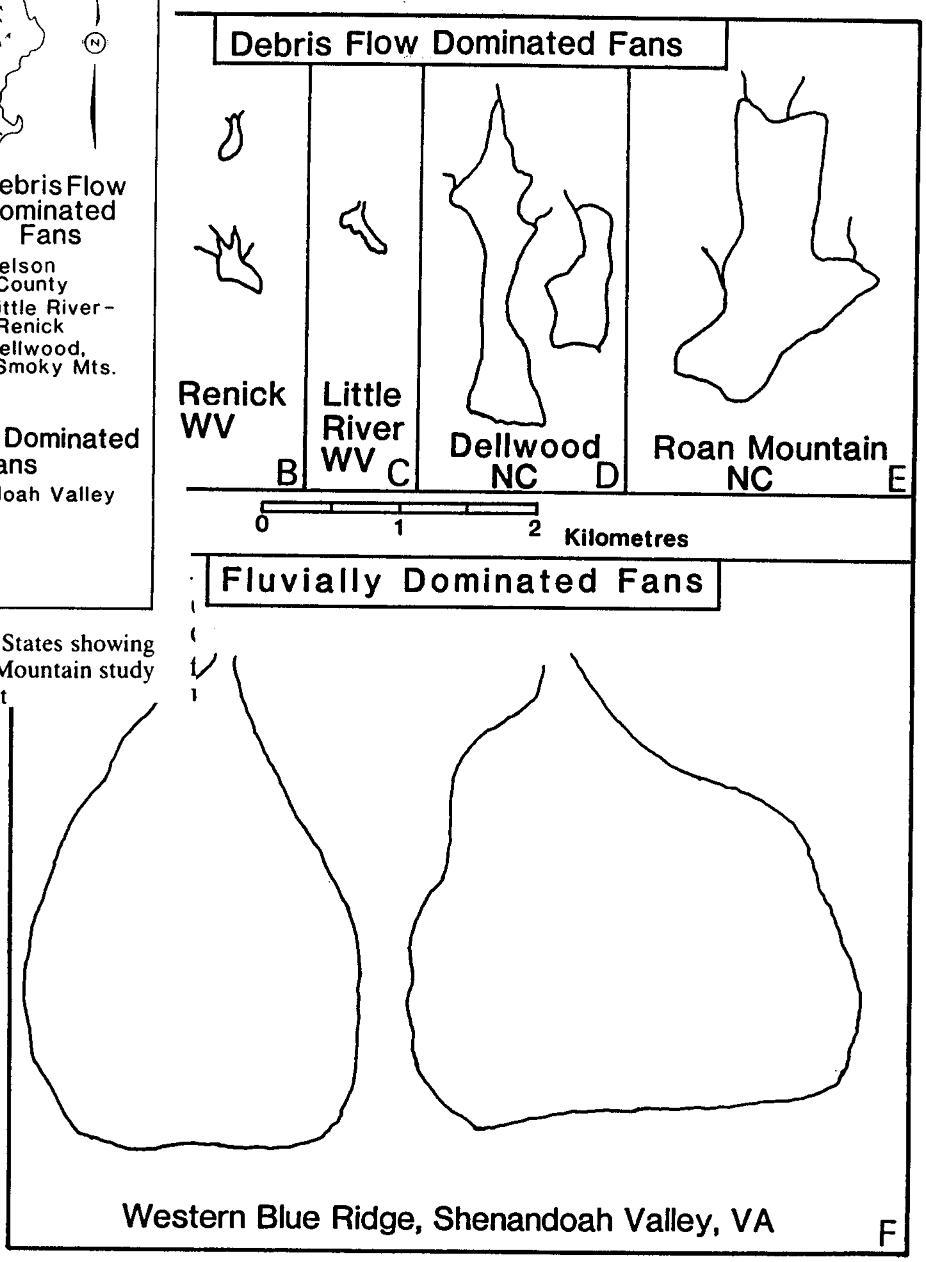


Figure 6.5. Comparative maps of debris-flow dominated fans and fluvially dominated fans. Debris fans are extremely irregular and variable in size, but considerably smaller than the fluvial fans in the eastern Shenandoah Valley. (A) Fans in Davis Creek and Ginseng Hollow, Nelson County, Virginia (from Kochel and Johnson, 1984, and this study; (B) Fans in the vicinity of Renick, West Virginia (from Wilson, 1987); (C) Fan 770 in Little River, Virginia (from Hack and Goodlett, 1960); (D) Examples of fans near Dellwood, North Carolina (from Mills, 1982b); (E) Typical fan at Roan Mountain, North Carolina (from Mills, 1983); (F) Two examples of unconfined, fluvially dominated fans near Waynesboro, Virginia, in the Shenandoah Valley

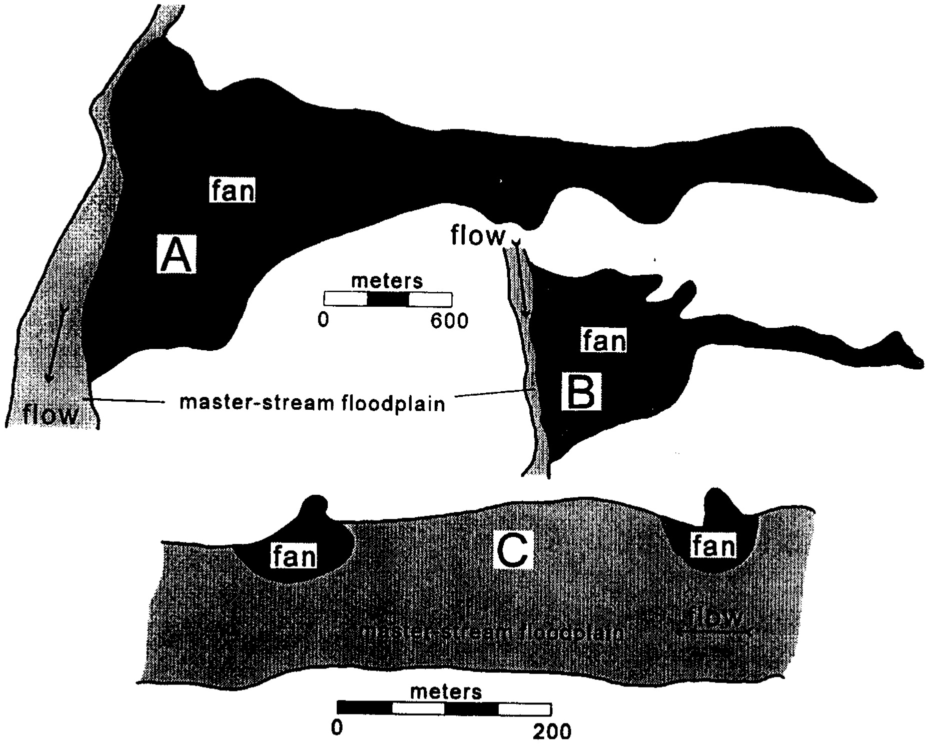


Figure 2. Plan view diagrams of fans at tributary-master stream junctions (C, from Hack and Goodlett 1960, Fig. 26, Reddish Knob quadrangle) vs. intrabasinal fans (A, from Bakersville quadrangle, North Carolina; B, from Dellwood quadrangle, North Carolina).

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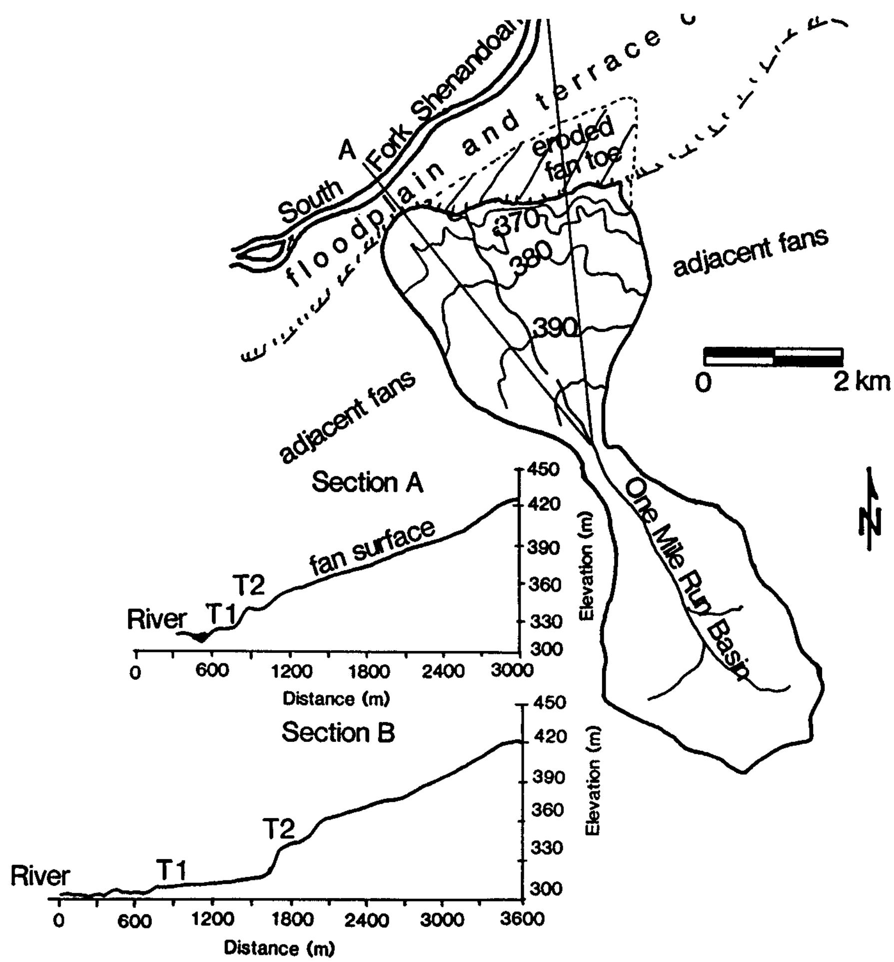
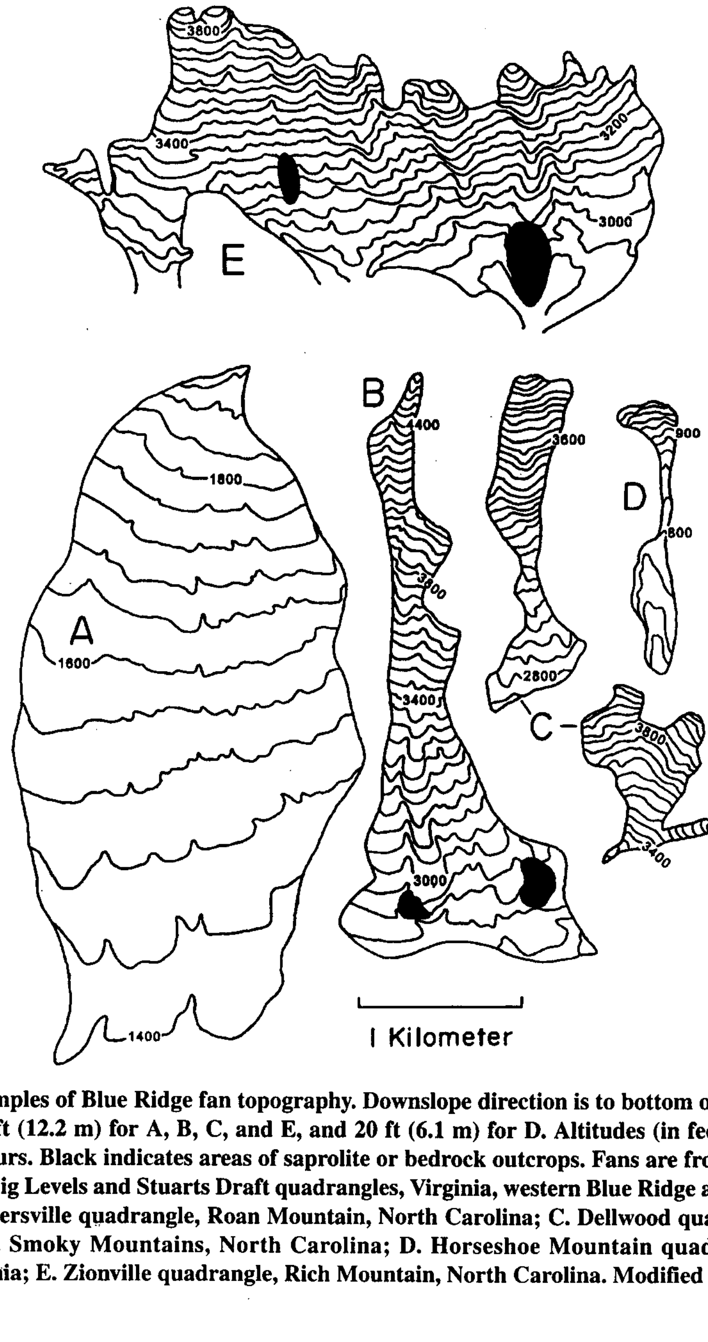


Figure 6.10. Topographic sketch map and longitudinal cross-sections of a fan in the Shenandoah Valley between Waynesboro and Elkton. Evidence of the old age of this fan includes its being graded to a high terrace level and post-depositional dissection. Erosion by the South Fork of the Shenandoah River has removed a significant portion of the northern toe of this fan. This can be seen clearly by comparing the two fan profiles. Fans appear to be of varying ages along the eastern Shenandoah Valley because others are graded to lower terrace levels



BR
FAN
SHAPES

Figure 4. Examples of Blue Ridge fan topography. Downslope direction is to bottom of page. Contour interval is 40 ft (12.2 m) for A, B, C, and E, and 20 ft (6.1 m) for D. Altitudes (in feet) are given for selected contours. Black indicates areas of saprolite or bedrock outcrops. Fans are from the following locations: A. Big Levels and Stuarts Draft quadrangles, Virginia, western Blue Ridge and Shenandoah Valley; B. Bakersville quadrangle, Roan Mountain, North Carolina; C. Dellwood quadrangle, southeastern Great Smoky Mountains, North Carolina; D. Horseshoe Mountain quadrangle, Nelson County, Virginia; E. Zionville quadrangle, Rich Mountain, North Carolina. Modified from Mills *et al.* 1987.

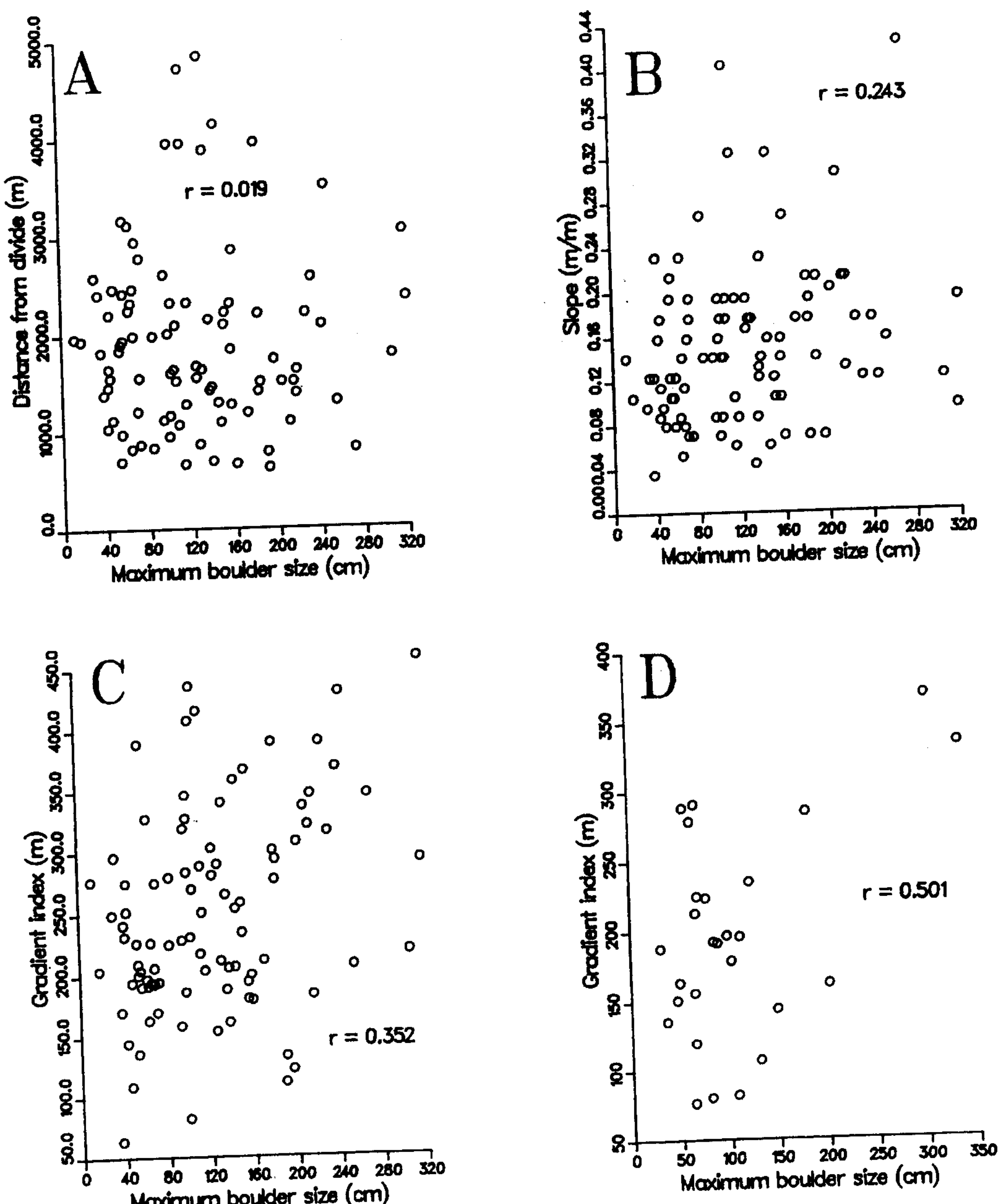


Figure 11. Plots of maximum boulder sizes on mountain piedmonts of the North Carolina Blue Ridge. A. Distance from divide vs. maximum boulder size for young and intermediate-age fan surfaces. B. Local slope vs. maximum boulder size for young and intermediate fan surfaces. C. Gradient index (SL; defined for a given point on a stream as the local slope times the horizontal distance from the point to the most distant point on the basin divide) vs. maximum boulder size for young and intermediate fan surfaces. D. Gradient index (SL) for footslope streams, including areas with and without fans. All correlations are significant ($p \leq 0.05$) except for A.

BLUE RIDGE FAN AGES / EVOLUTION

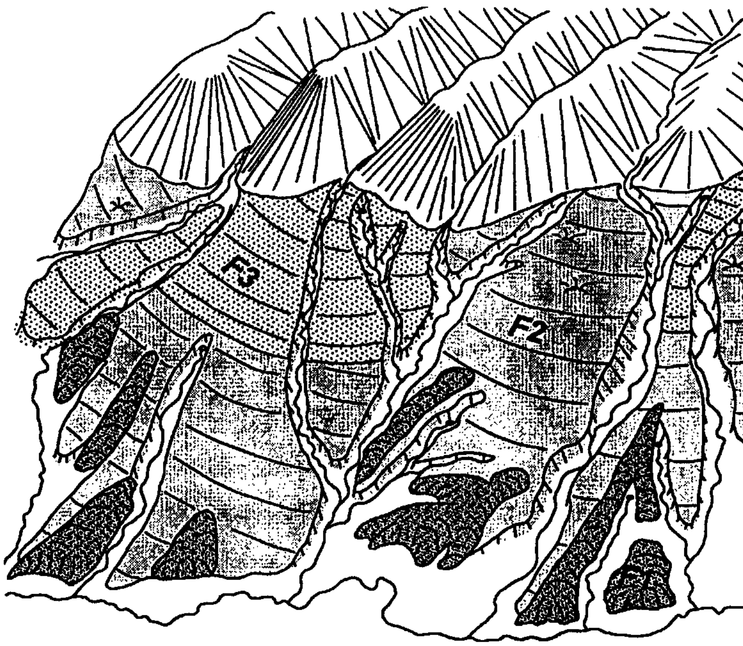


Figure 4. Generalized physiographic sketch showing geomorphic relationships between fan surfaces within the study area. View is to the southeast from the South River towards the Blue Ridge mountains. Oldest (F1) features are deeply dissected remnants that contain highly weathered gravels; the youngest (F3) fans have few incised valleys and contain weakly weathered sediments. The intermediate (F2) fans contain a range of moderately weathered gravels, some dissection, and numerous sinkholes where they overlie carbonate rocks.

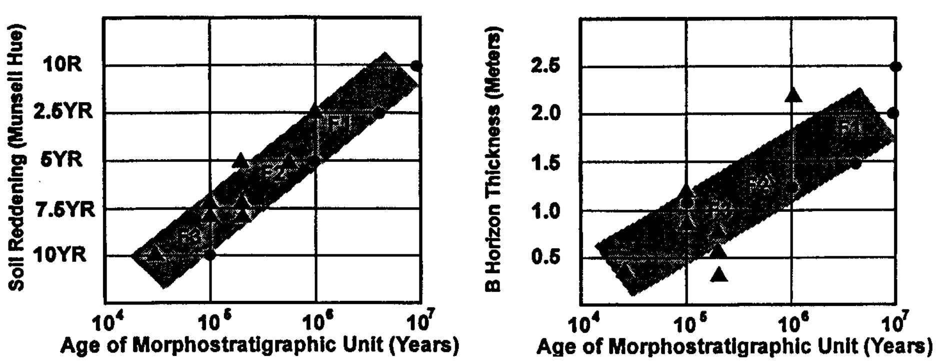


Figure 6. Soil hue and B horizon thickness versus age of unit. Data from Markewich et al. (1987; circles) and Howard et al. (1993; triangles). Trends of least squares regression lines marked by shaded zones (a: y = 1.55x – 5.92, R^2 = 0.87; b: y = 0.68x – 2.63, R^2 = 0.69). Average values for F1 (oldest), F2 (intermediate), and F3 (youngest) map units are placed along the midpoints of these trends to provide an estimate of the age of the units.

Blue Ridge Fan Evolution

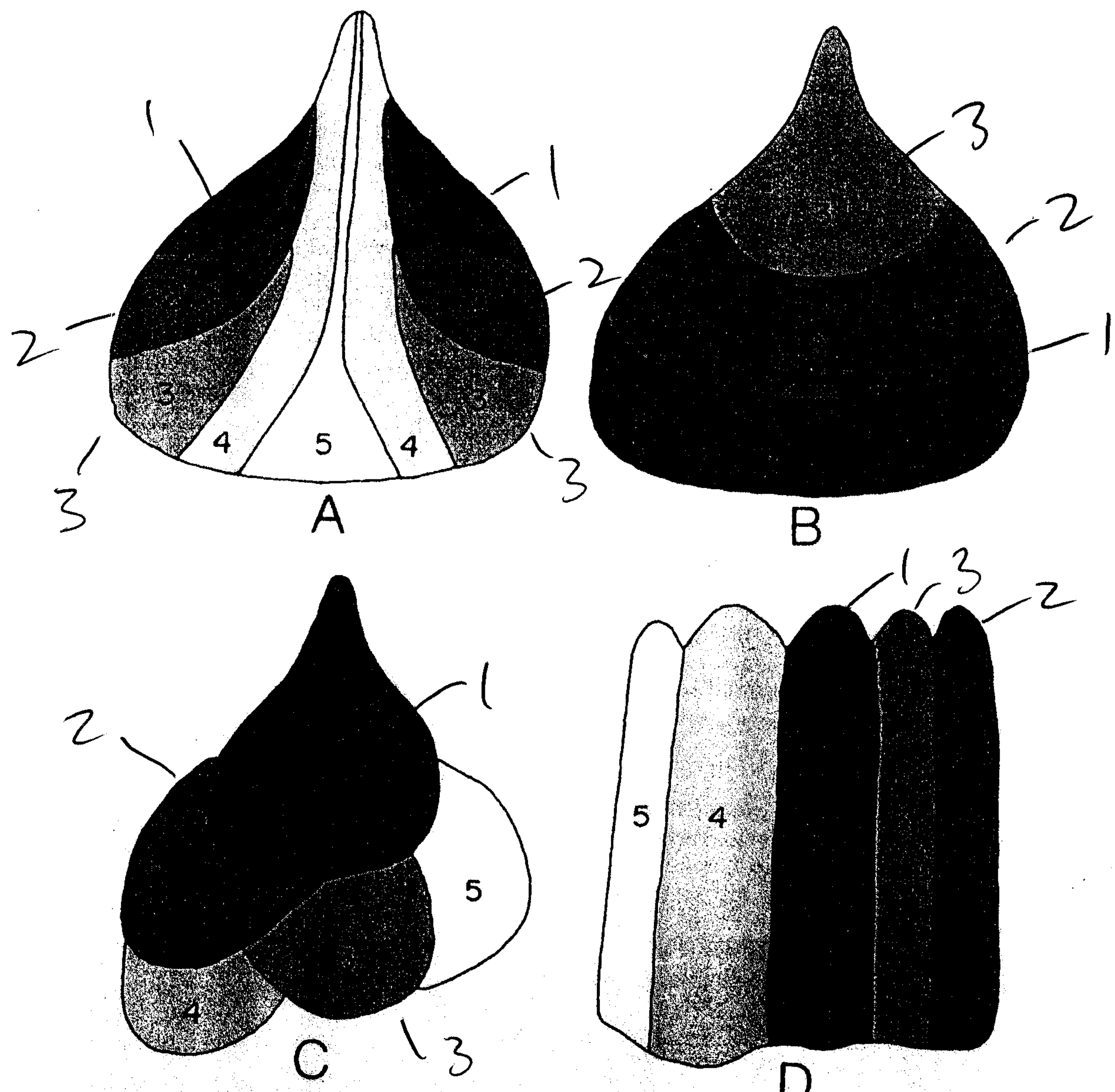


Figure 13. Four hypothetical map patterns produced by different fan development scenarios. Fan surfaces labeled 1 are the oldest in each case. A. "Telescopic" fan pattern produced by fanhead incision and unidirectional fan progradation. B. Concentric pattern with decreasing surface age toward apex. C. Random fan pattern produced by piedmont stream capture. D. Pattern produced by lateral stream migration. Scenarios are discussed in text.

SMALL-SCALE DEBRIS FANS:

SANDSTONE LANDSCAPES OF CENTRAL APPALACHIANS

Table 6-2. Explanation of Fan-Related Map Units Recognized at the Study Sites (from Taylor and Kite, 1997; 1998; and 1999).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Comments
Hch	Holocene Channel Alluvium	Holocene	Alluvium	Channel and Narrow Floodplain	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	Fluvial channel deposits associated with first- to sixth-order streams. Unit includes channel alluvium and portions of adjacent floodplain too small to map at the given scale.
Hf	Holocene (Historic) Fan Deposits (undissected)	Holocene	Alluvium - Debris Flow(?)	Fan	Cobbles and Boulders, Gravel Diamicton	Historic fan deposits commonly associated with first- to second-order hollows at stream-tributary junctions. Identified by fresh deposits, disturbed and buried vegetation.
Qf	Quaternary Fan Deposits (undissected)	Quaternary (Undiff.)	Alluvium - Debris Flow(?)	Fan	Cobble- to Boulder-Diamicton with Silty Loam Matrix (subangular to rounded)	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)	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)	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)	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)	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)	Entrenched fan surfaces commonly located at stream tributary junctions. Diamicton may be crudely stratified with imbricated gravely-loam facies.

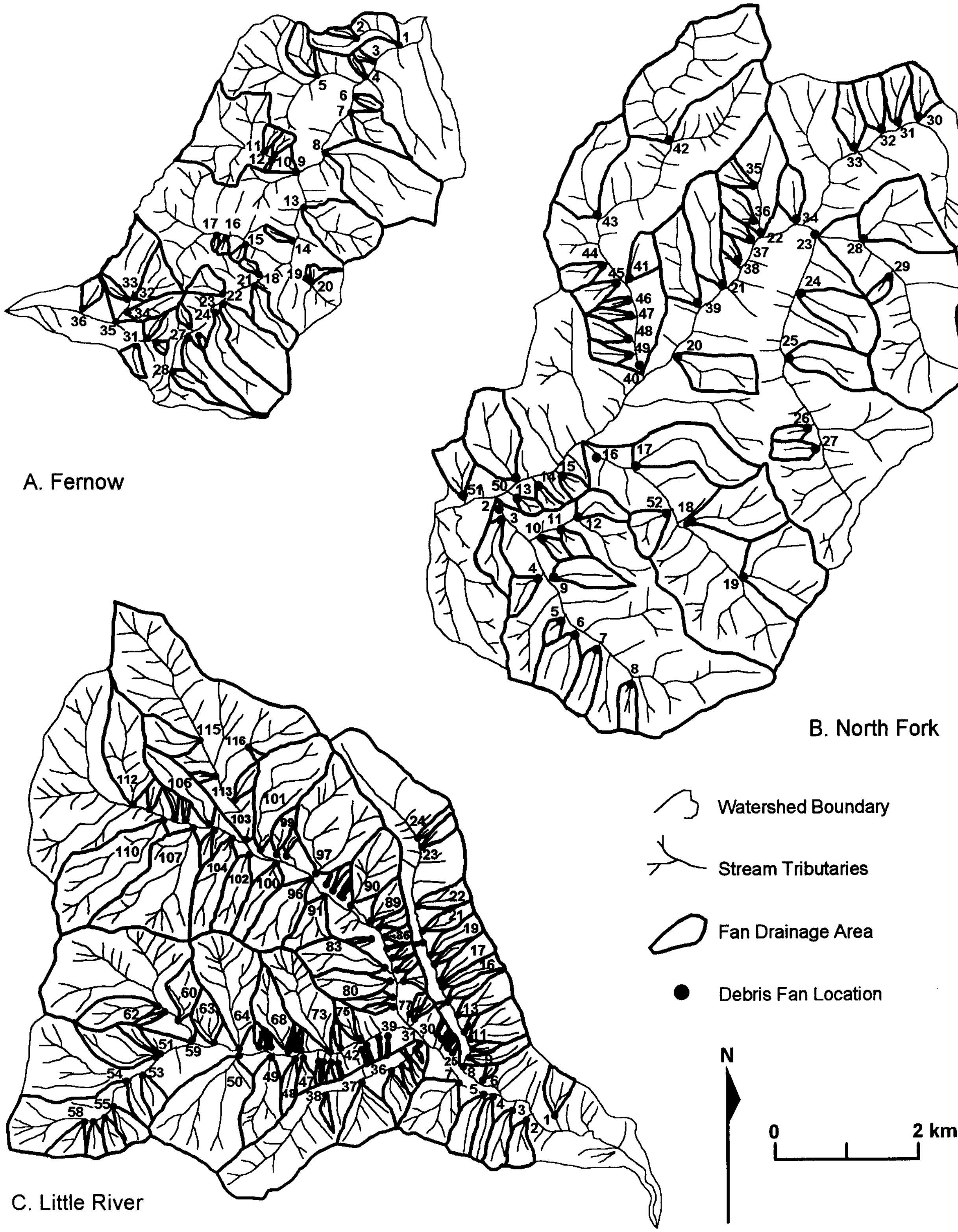


Figure 6-8. Map showing debris fan locations and fan drainage areas; Fernow, North Fork, and Little River study areas.

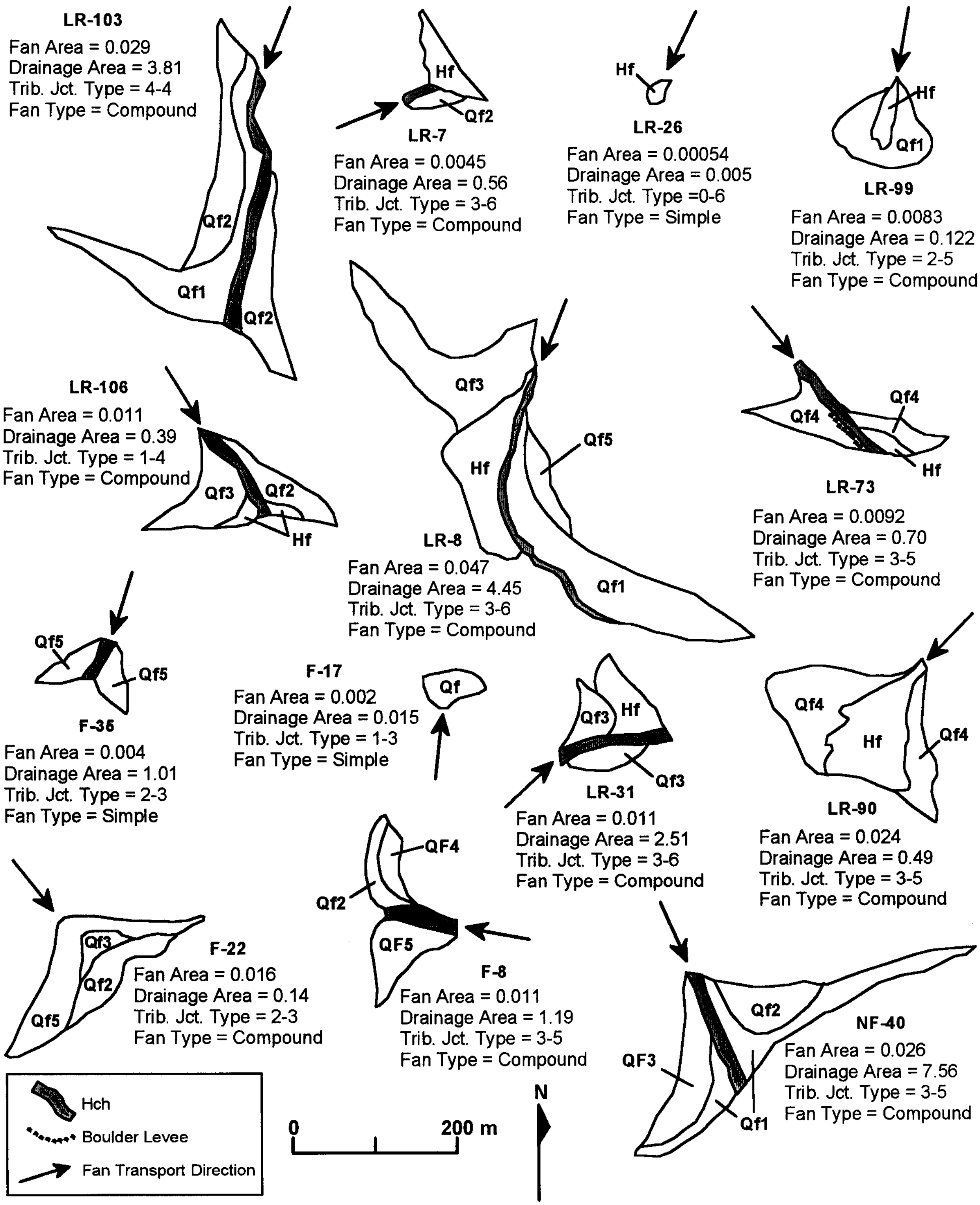


Figure 6-9. Examples of debris fan morphology recognized in this study. Surficial map units are as follows: Hch = Late Holocene channel alluvium, Hf = historic fan deposits (at grade), Qf = Quaternary fan deposits (at grade), Qf1 = Quaternary fan-terrace deposits (2-5 m surface), Qf2 = Quaternary fan-terrace (4-6 m), Qf3 = Quaternary fan-terrace (6-8 m), Qf4 = Quaternary fan-terrace (8-10 m), Qf5 = Quaternary fan-terrace (>10 - 15 m). Areas are listed in sq. km. Other codes include: F = Fernow, NF = North Fork, LR = Little River; Trib. Jct. Type = tributary junction according to Strahler stream order (e.g., 1-3 = 1st order-3rd order tributary junction). Refer to Figure 6-8 for fan locations.

Surficial Map Units

Qc1 - Quaternary colluvium (side-slope veneer, cobble- to boulder-diamicton)

Hch - Holocene channel deposits (alluvium; cobbles and boulders)

Hfp1 - Holocene floodplain alluvium (1-2 m above channel grade, loamy gravel)

Qt1 - Quaternary terrace deposits (2-4 m above channel grade; alluvium; gravelly loam)

Hf - Holocene (historic) fan deposits (debris flow, cobble- to boulder-diamicton)

Qf1 - Quaternary fan-terrace deposits (fan surface 2-4 m above active channel grade; debris flow?-alluvium; cobble- to boulder-diamicton)

Qf4 - Quaternary fan-terrace deposits (fan surface 8-10 m above active channel grade; debris-flow?-alluvium, cobble- to boulder-diamicton)

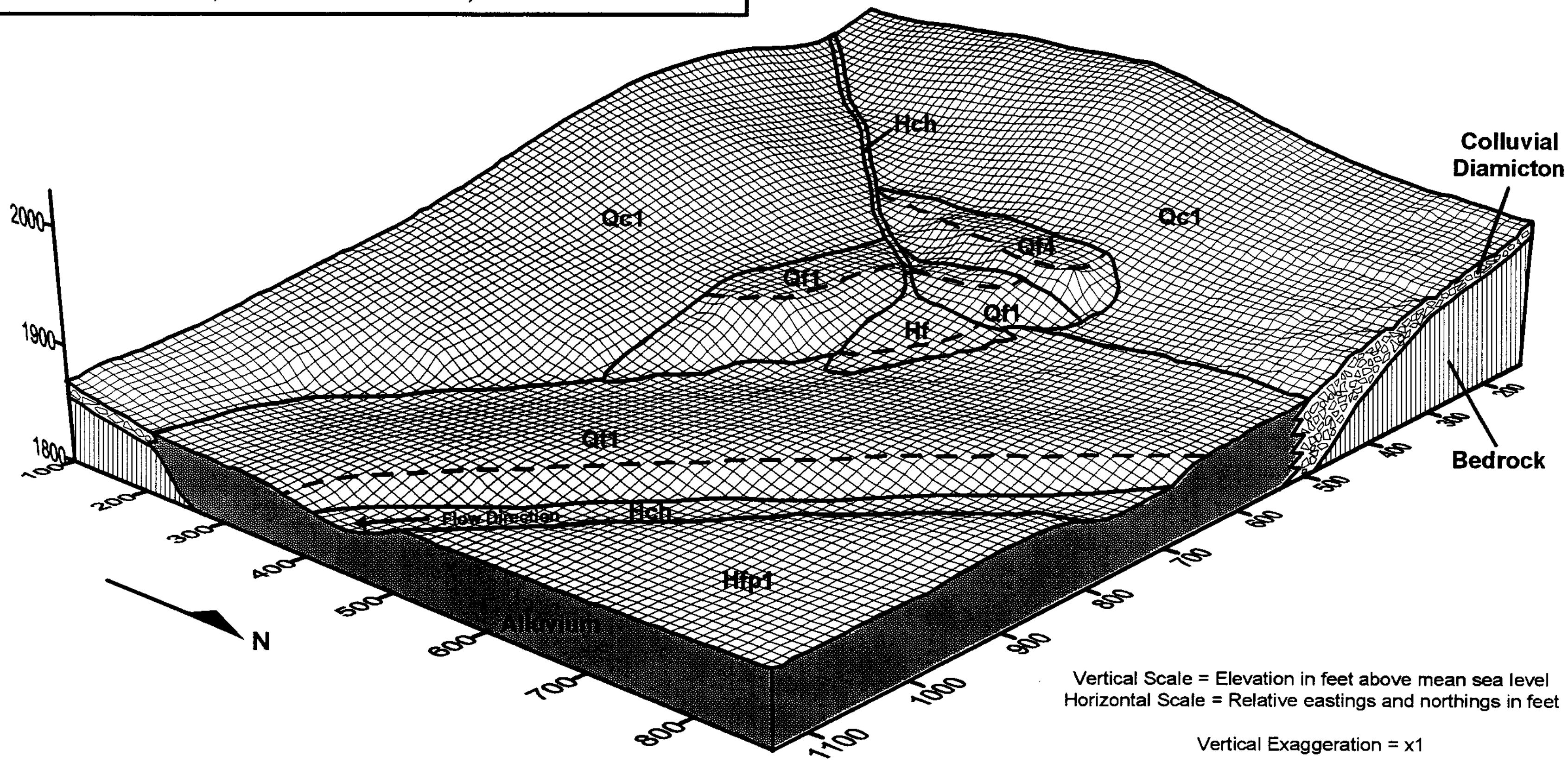


Figure 6-6. Generalized block diagram illustrating inset fan-terrace relationships in the central Appalachians.

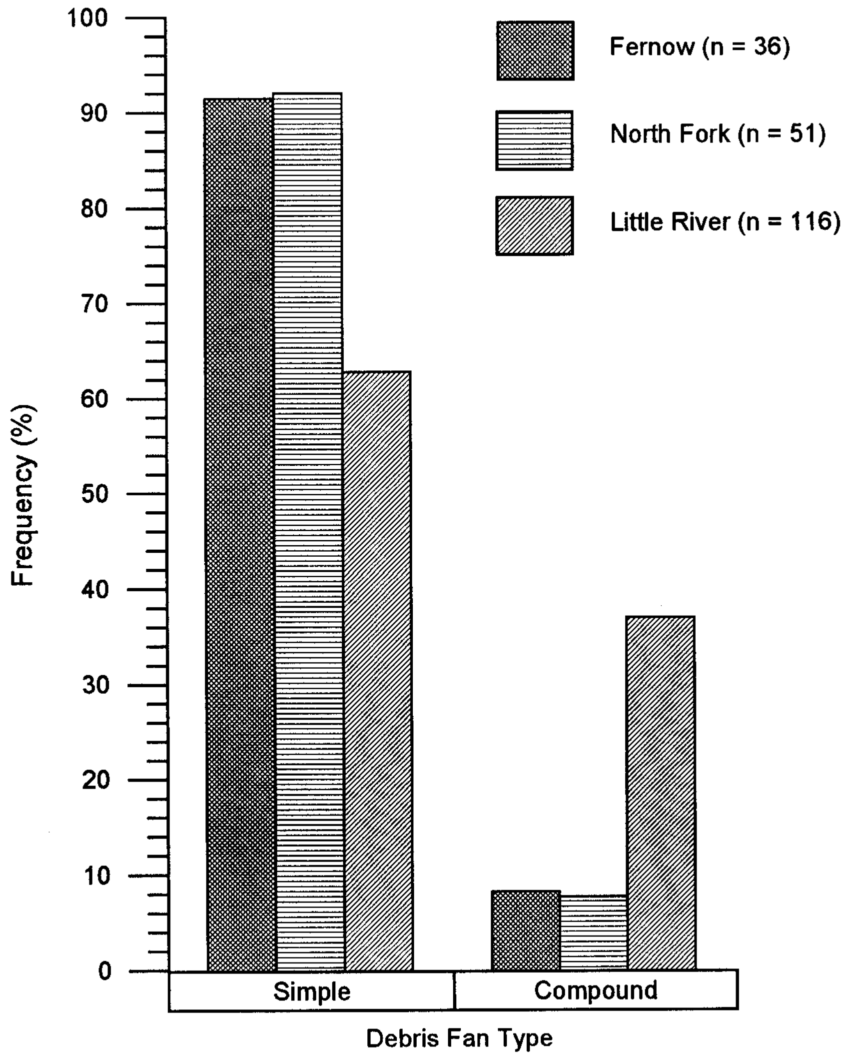


Figure 6-11. Percent frequency distribution of fan type (simple vs. compound) at the Fernow, North Fork and Little River areas.

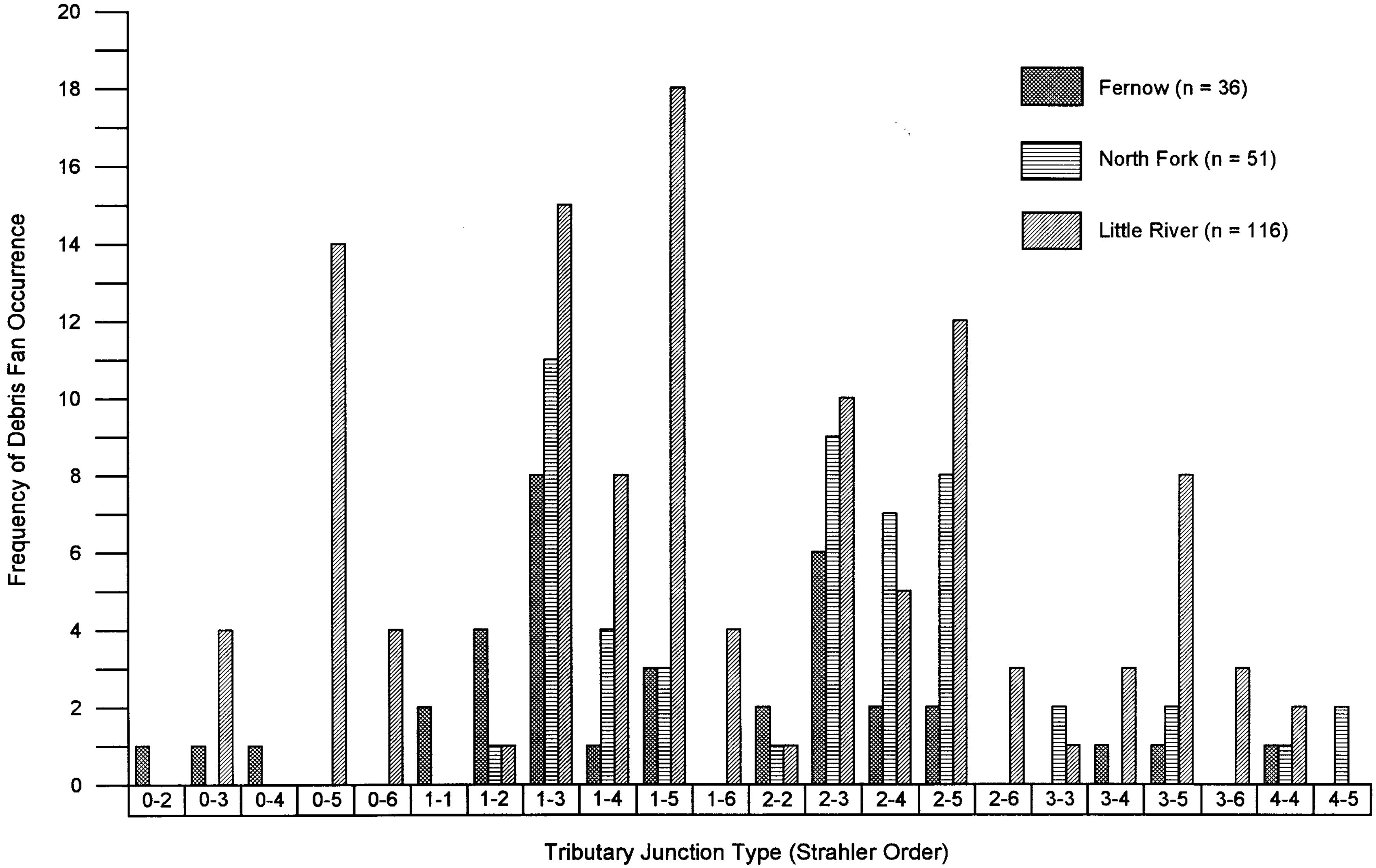


Figure 6-10. Frequency distribution of debris-fan occurrence at a given stream tributary junction type (Strahler order) for the study areas. The junction type code refers to Strahler stream order intersections (e.g. 1-4 = 1st order - 4th order intersection). Zero-order tributaries are hollows (*sensu* Hack and Goodlett, 1960) without well-defined channels.

APPALACITIAN

FAN

MORPHOMATRY

Table 6-3. Summary of Morphometric Data for Watersheds, Valley Bottoms, and Debris Fans at the Fernow, North Fork, and Little River Areas.

	Ref. I.D.[1]	Morphometric Parameter	Fernow[2]	North Fork	Little River
Watershed Morphometry	a	Drainage Order (Strahler)	5	5	6
	b	Basin Area (km^2)	17.62	49.27	41.48
	c	Drainage Density (km^{-1})	4.24	3.26	4.66
	d	Basin Relief (km)	0.586	0.533	0.828
	e	Ruggedness **(c*d)**	2.486	1.737	3.856
	f	Total No. of First-Order Tributaries (Shreve Magnitude)	139	287	380
	g	Total No. of Stream Segment Intersections	158	284	377
	h	Tributary Junction Frequency (km^{-2}) **(g/b)**	8.97	5.76	9.09
	I	Stream Frequency (km^{-2})	12.14	7.79	12.08
Valley Bottom Statistics	j	Maximum Valley Width (m)	120	180	290
	k	Total Valley Bottom Area (km^2)	0.76	1.86	3.09
Fan Morphometry	l	Total No. of Fans	36	51	116
	m	Total Fan Area (km^2)	0.113	0.165	0.486
	n	Total Fan Drainage Area (km^2)	8.24	30.51	35.42
	o	Average Fan Area (m^2)	3203.0	4165.0	4378.0
	p	Average Fan Drainage Area (km^2)	0.229	0.819	0.305
	q	Average Fan Basin Slope (m/m)	0.30	0.28	0.37
	r	Ratio: Slope of Fan Tributary / Slope of Receiving Tributary	5.20	7.40	9.90
	s	% Total Basin Area Occupied by Valley Bottom **(k/b)**	4.31	3.78	7.45
	t	% Valley Bottom Occupied by Fans **(m/k)**	14.87	8.87	15.73
	u	Ratio: Total Fan Area / Total Basin Area **(m/b)**	0.006	0.003	0.012
	v	Fan Frequency (km^{-2}) **(l/b)**	2.04	1.04	2.80
	w	Ratio: Total Fan Area / Fan Drainage Area **(m/n)**	0.014	0.005	0.014
	x	Ratio: Fan Drainage Area / Total Basin Area **(n/b)**	0.468	0.619	0.854

1. Ref. I.D. = reference letter used in text discussions and parameter derivations (in parentheses).

2. The Fernow site includes both the Elklick Run and Stonelick Run sub-basins.

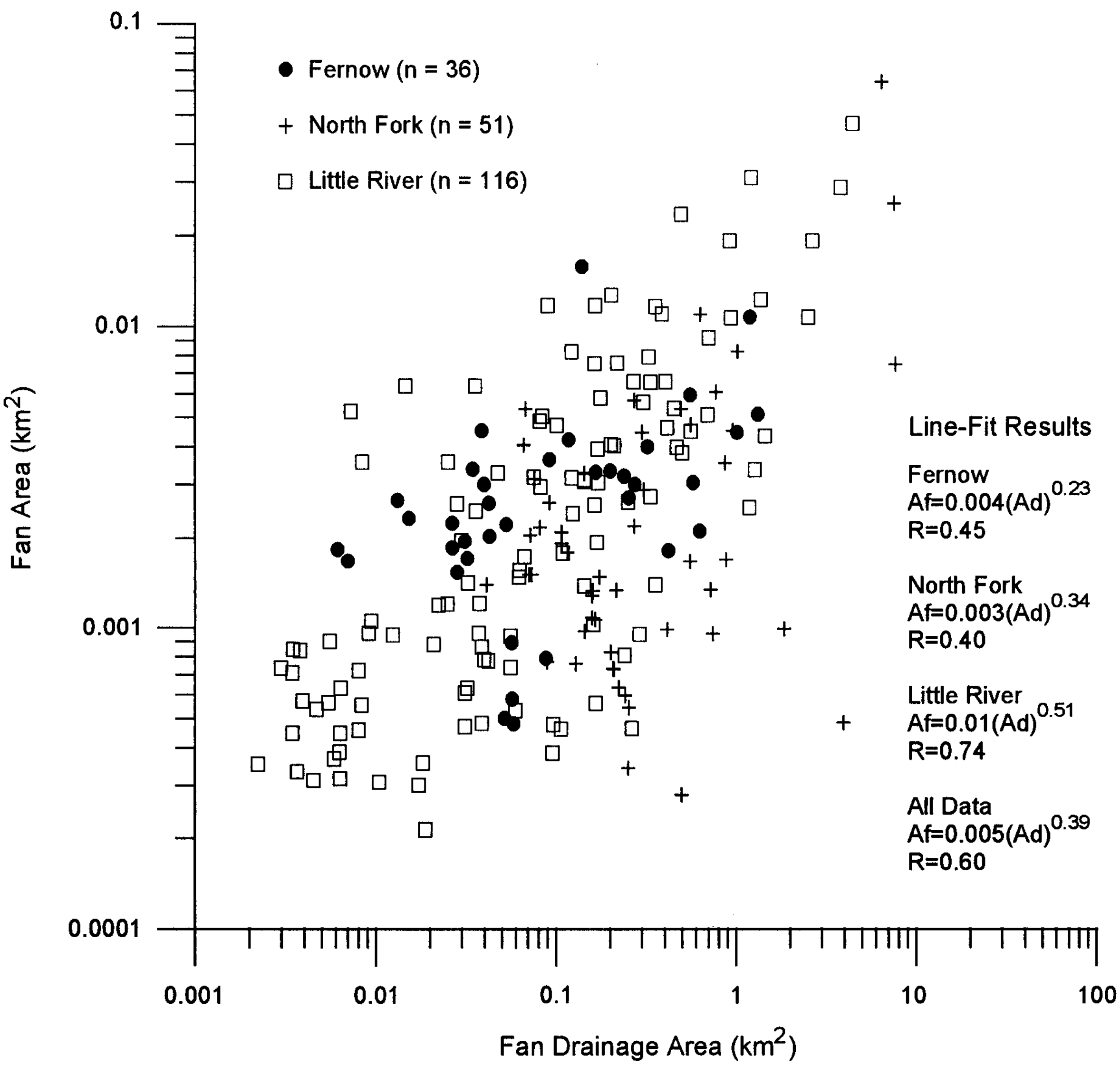


Figure 6-12. Log-log plot of fan drainage area (km^2) vs. fan area (km^2) for small-scale debris fans at the Fernow, North Fork and Little River areas. Power-function fits for the data are shown at lower right. Greater values for drainage-area exponent and correlation coefficient at the Little River result from increased valley-bottom width and erosional accommodation space.

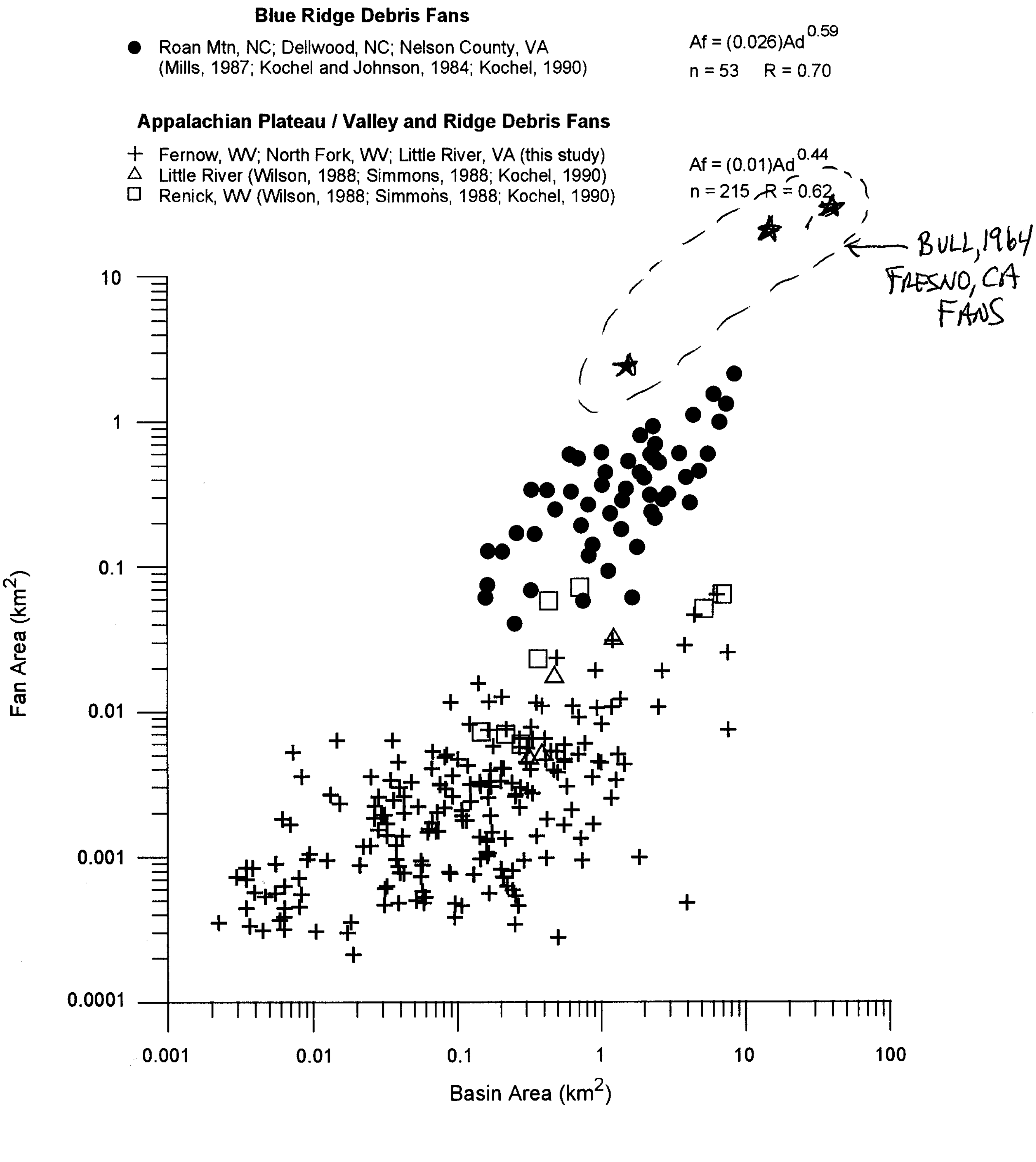
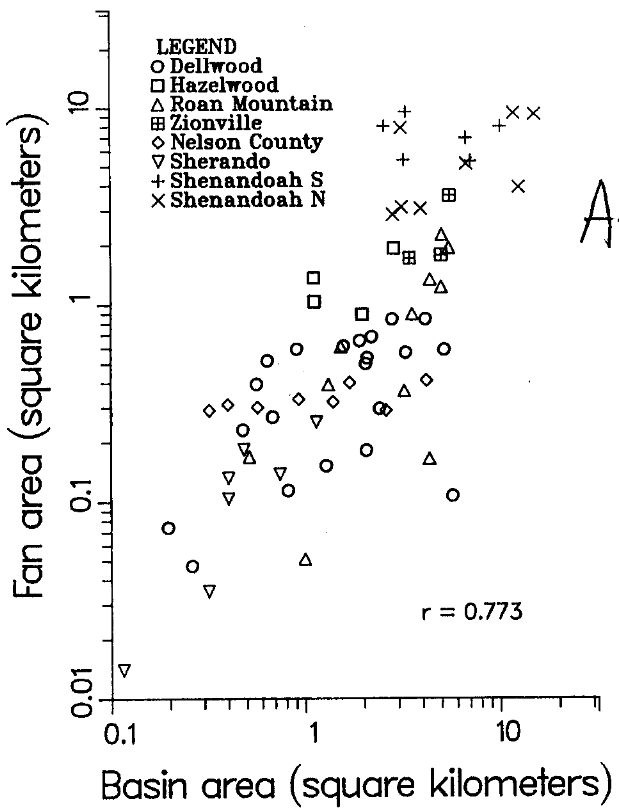


Figure 6-16. Comparison of fan area - drainage area relationships between crystalline bedrock landscapes of the Blue Ridge and sandstone terrain of the Appalachian Plateau and Valley and Ridge. Note larger fan sizes in the Blue Ridge, see text for discussion (after Kochel, 1990).



$Af = 0.23 A_d^{1.08}$

Figure 6. Plot of fan area versus basin area for Blue Ridge fans. Note that within some individual areas, such as Nelson County, there is little or no correlation.

1994a), and in many cases the log-log correlations are fairly high. In the Blue Ridge province, fan-basin area correlations have been found to be very low for some areas (e.g., Kochel and Johnson, 1984; Simmons, 1988), apparently owing to 1) the topographic constraint of fans, and 2) the small range of fan size in some areas. A plot of data for fans throughout the Blue Ridge area, however, shows a fairly good relation (Fig. 6), with a log-log correlation (*r*) of 0.773. For the plot in Figure 6, an equation of $A_f = 0.229 A_d^{1.08}$ is found. The values of c and n are thus within the ranges reported for the southwestern United States. The low value of c (0.229) indicates that in the Blue Ridge province the ratio of fan area to basin area is small relative to ratios usually seen in the Southwest. This could result from the low rate of sediment production in the Appalachians relative to tectonically active areas, but it probably also reflects the topographic constraint that limits the size of fans. These two factors are closely related, for if the volume of sediment in small, deposits will be thin and thus more affected by topography.

A question addressed by many authors is the effect of drainage-basin lithology on the size and form of alluvial fans. Bull (1962) and Hooke (1968) reported that drainage basins underlain by rock types which are less resistant to erosion tend to produce alluvial fans larger in area than do basins with more-resistant rock types, the idea being that basins with less-resistant rocks produce more sediment per unit area. In contrast, in the White Mountains of eastern California, Lecce (1991) found that larger fans are produced by basins underlain by more resistant rocks. His explanation involved the valleys associated with rock type. In basins underlain by resistant rock types, trunk streams flow in

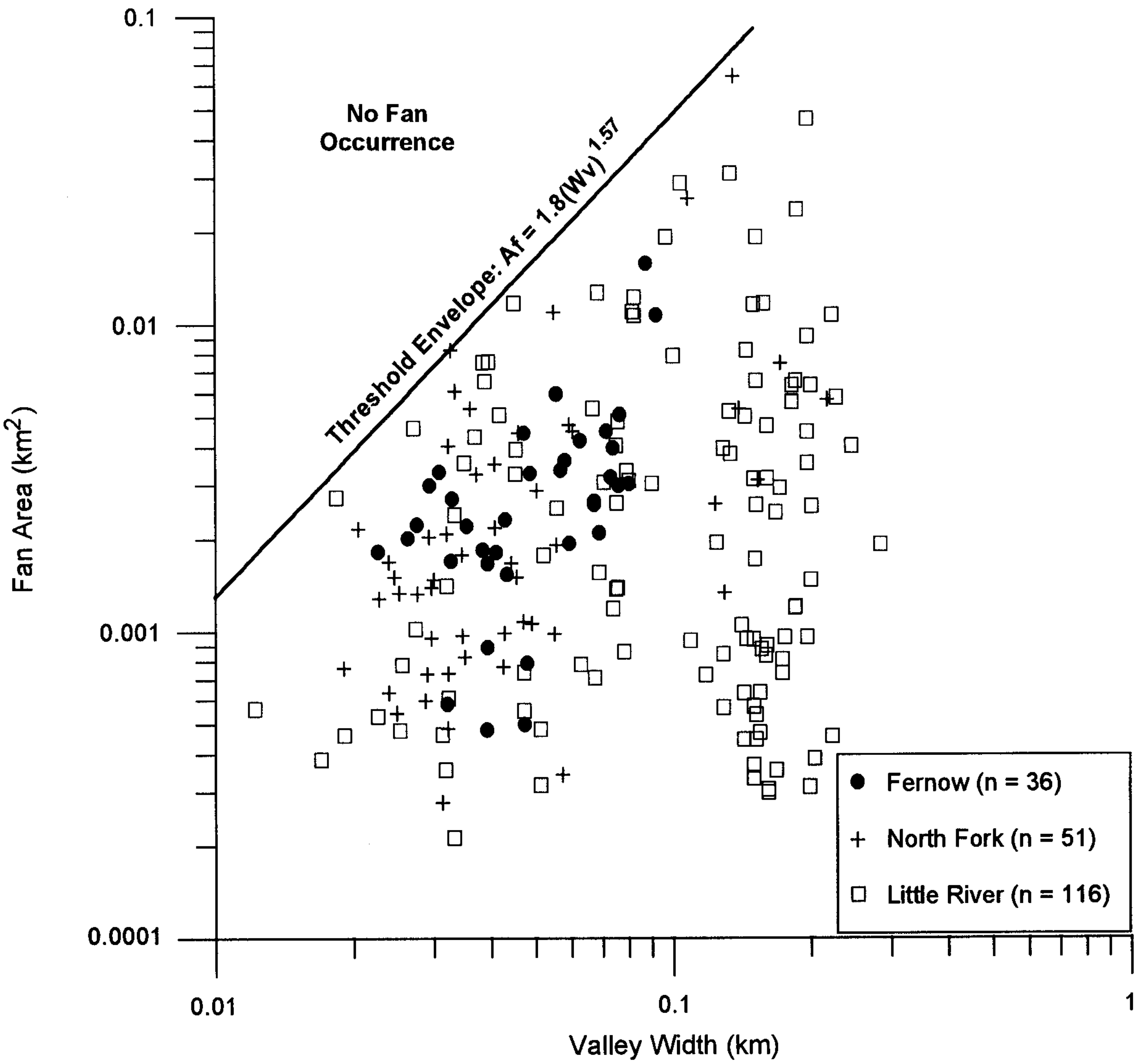


Figure 6-14. Log-log plot of valley width (km) vs. fan area (km^2) for the Fernow, North Fork and Little River areas. The threshold envelope suggests that for a given fan area greater than 0.001 km^2, there is a critical valley width, below which, fans are not preserved.

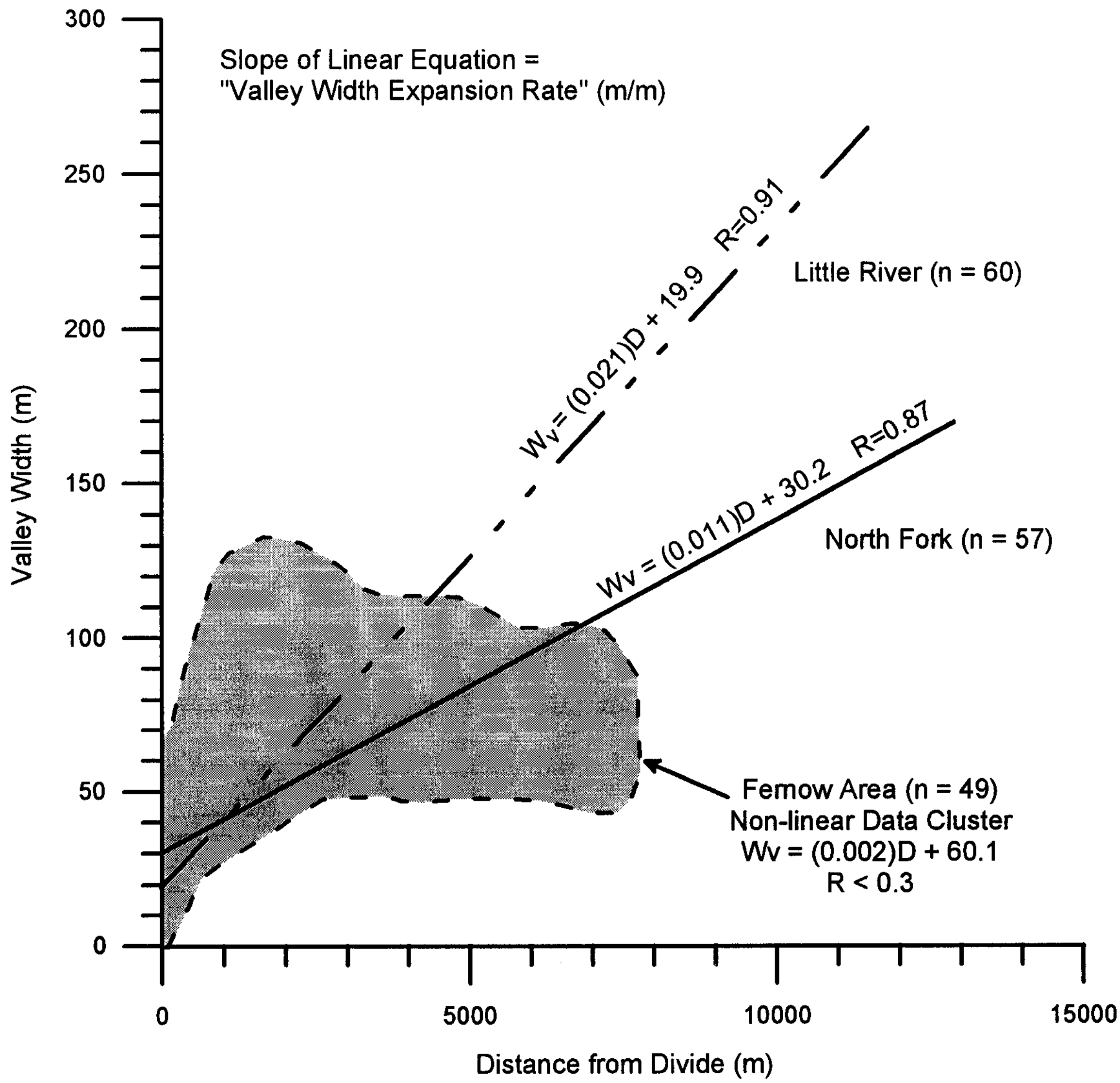
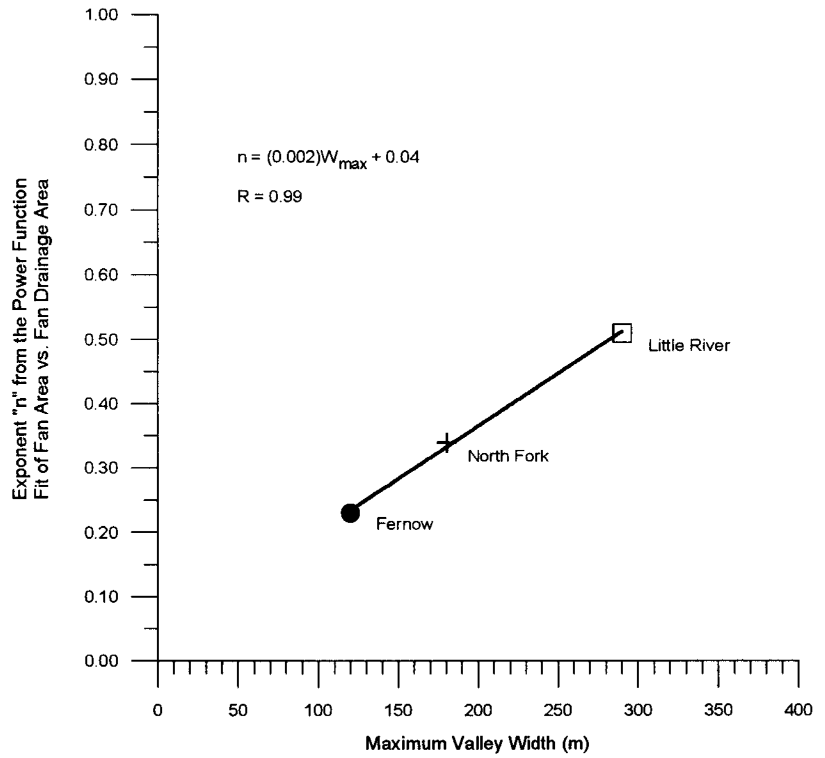


Figure 6-13. Linear regression summary from scatter plot of longest channel distance from divide (m) vs. valley width (m). Note the constricted valley width trend at the Fernow area and the relatively high rate of valley-width expansion at Little River.



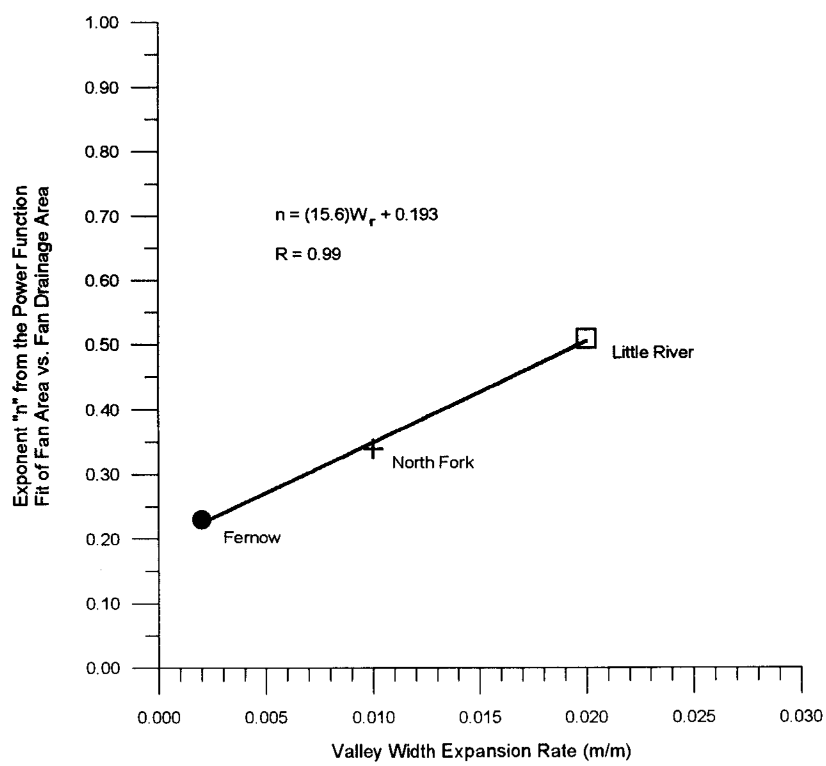


Figure 6-15. Plots of exponent "n" from the relation $A_f = c(A_d)^n$ vs. maximum valley width (m) and valley-width expansion rate (m/m), respectively. Exponent "n" values are derived from Figure 6-12. The plots suggest that valley width is the primary factor controlling growth of debris fans.