Excerpts from:

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ABSTRACT

A surficial map protocol was developed for the unglaciated, humid-mountainous region of the central Appalachians. The technique emphasizes the link between landforms, materials and processes in a landscape dominated by hillslopes, mass wasting and fluvial erosion.

Three types of surficial map criteria are recognized. 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. Type I units encompass landforms and deposits that result from in-situ weathering, mass wasting, fluvial processes, catastrophic slope failure and 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. Mapping of Type I criteria employs a four-fold scheme in which units are delineated on the basis of age, origin (process), landform, and material (texture). Type II and III criteria are mapped as two-dimensional surface features without reference to material or age.

Large-scale landform units in the central Appalachians are classified into hillslope and valley-bottom features. Hillslope landforms are subdivided into ridges, side slopes, hollows, and noses. Mappable hillslope variations include boulder streams, boulder fields, talus slopes, patterned ground, rock-block slides, debris slide scars, and debris flow tracks. Valley-bottoms are subdivided into channels, floodplains, terraces, fans and aprons. Type II karst features include cave openings, sinks, solution pinnacles, blind valleys, swallows and karst springs.

Colluvial diamicton is subdivided into side-slope facies, nose facies and hollow facies. Hillslope hollows represent a geomorphically significant element and special consideration is warranted. Channel gravel is typically clast-supported, moderately sorted and imbricated due to deposition by turbulent streamflow hydraulics. Fans in the central Appalachians are the product of a combination of debris-, hyperconcentrated- and stream-flow processes. Debris flows result in poorly-sorted diamictons with crude internal stratification. Dating of surficial deposits is problematic, hence

traditional stratigraphy-based techniques are largely not applicable. The four-fold mapping protocol circumvents the need for formal stratigraphic nomenclature.

The map technique was systematically applied to three study areas in the central Appalachians, one of which was subject to debris flow activity in June, 1949. Surficial mapping combined with slope analysis identifies gradients that are conducive to debris-slide failure. The example application suggests that a well-defined surficial map protocol combined with GIS analysis provides a potentially powerful tool for the design of hazards mitigation plans in flood and debris-flow prone regions. The technique offers a blueprint for design of surficial maps in other unglaciated, mountainous landscapes.

SURFICIAL MAP CRITERIA

Methodology

The mapping protocol is based on similar schemes employed by the Maine Geological Survey (1986) and Kite (1994). These guidelines are designed to address the fluvial, colluvial, and karst features of 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 useful and 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 5-2). Type I units include landforms and deposits that result from in-situ weathering, mass wasting, fluvial processes, catastrophic slope failure and 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. Mapping of Type I criteria employs a four-fold scheme in which units are delineated on the basis of age, origin, landform, and material. Unit polygons may be coded with labels, patterns or color to signify the four-fold designation. AAge@ refers to the age of the material, Aorigin@ refers to the primary surficial process responsible for deposition of the unit, Alandform@ refers to the topographic occurrence of the unit, and Amaterial@ 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.

The systematic nature of the map protocol is amenable to a flow-chart approach in recording field data. The map feature is first identified and recognized as a Type I, II or III element. A checklist format facilitates objective classification by the field worker. If a three-dimensional surfical deposit is encountered, then the Type I criteria are systematically examined, and the map feature is assigned age, origin, landform and material identifiers. Additional map data include heights of surfaces above channel grade, vegetative relations and relative age observations.

The optimum scale for surficial map preparation is largely determined by the intended use of the final product (Kite and others, 1998). Surficial geology maps can only be made for large areas in reasonable amounts of time if unit contacts can be derived from topographic and air photo interpretation, based on ground-truthing (Jacobson, unpublished report). A scale of 1:24,000 works well for large fluvial landforms, but is inadequate for portraying most landforms produced by small streams or colluvial processes. A 1:10,000 scale is optimal for mesoscale landforms such as point bars, floodplains, terraces, debris fans and boulder streams (Kite and others, 1998). Larger map scales are a prerequisite for detailed reconstruction of processes at flood and debris-flow impacted sites (Wells and Harvey, 1987; Ohmori and Shimazu, 1994; Cenderelli and Kite, 1998). The 1:24,000 scale is the preferred mode for many mapping projects at the state and federal level, however much process-oriented detail is lost due to generalization of map units. A 1:9,600 scale has proven quite effective for the delineation of process-landform associations in small (<60 km^2) mountain watersheds associated with this study (Taylor and Kite, 1997; 1998; 1999). The four-fold components of Type I criteria are discussed in detail below.

Landform

The erosional, mountainous landscape of the central Appalachians is characterized by large-scale, bedrock-dominated landforms. Hack (1960, 1975) emphasized the importance of dynamic equilibrium in this region, where fluvial-dominated surface processes are in delicate equilibrium with bedrock structure and resistance to erosion. Large-scale, bedrock-dominated landforms are generally evident from topographic maps, but the geometry of the overlying surficial deposit is not (Kite, 1994). The landform component presented in Table 5-2 addresses both the large-scale landscape feature (e.g. ridge) and the overlying deposit geometry (e.g. residual veneer, <2 m thick).

Large-scale landform units in the central Appalachians are classified into hillslope and valley-bottom features. Hillslopes are characterized by gradients contoured to valley-bottom areas, servicing drainage and transport of surficial materials. These larger-scale landform units are comprised of smaller, mesoscale features that are delineated at the outcrop-level and from contour patterns. The following is a description of landform features recognized in this study.

Hillslope Regime

Hack and Goodlett (1960) provided a framework for classification of hillslope elements in the central Appalachians. This seminal work has been recognized by numerous researchers outside of the region (Marcus, 1980; Pierson, 1980; Dietrich and Dorn, 1984; Dietrich and others, 1986; Reneau and others, 1989; Montgomery and Dietrich, 1989). Following Hack and Goodlett's (1960) approach, hillslope landforms are subdivided into ridges, side slopes, hollows, and noses (Table 5-2, Figure 5-1, Figure 5-2). Ridges are defined as upper elevation areas in which contours are closed, acting as the primary divides between high-order drainages. Side slopes represent open hillslope areas with approximately straight contour patterns. Hollows are defined as upland stream heads in which contours are concave outward in a down-slope direction. Hollows were also termed "zero-order basins" by Tsukamoto (1973) to signify convergent slopes located above a perennial first-order stream. For expediency during a topographic-based reconnaissance, hollows as defined here include the zero-order portion of the hillslope, as well as part of the first-order tributary with open-channel flow (after Mills, 1981). Hollows serve as the primary conduits for routing runoff and colluvium to higher order tributaries, and can occupy greater than 50% of total watershed area (Marcus, 1980). Noses represent hollow divides in which contours are convex outward in a down-slope direction. Hack and Goodlett (1960) originally defined footslopes as a transitional area between the side slope and valley-bottom channel. For purposes of organization, the footslope environment is included with the discussion of valley-bottom landforms below.

Deposit Geometry

The geometry of hillslope regolith is an important consideration with respect to the style and magnitude of processes that operate. Dietrich and Dunne (1978) noted the importance of colluvial thickness and root penetration depth in determining the stability of hillslopes. As such, there is a strong tendency for regolith to thin on noses and thicken in convergent hollows (Reneau and Dietrich, 1987). Jacobson (unpublished report) suggested that these landform-thickness relationships are prevalent in the central Appalachians and topographic form is a guiding factor in determining depth to bedrock.

The map protocol outlined in Table 5-2 includes criteria for recognizing the thickness of regolith on larger-scale, hillslope landforms. The terms "veneer" and "blanket" are applied to regolith less than and greater than 2 m thick, respectively. Landforms with no regolith cover are accordingly mapped as "bedrock". Thus hillslope landforms are combined with deposit geometry to provide a three-dimensional characterization of the surficial environment. Using the landform-thickness relations discussed above, example Type I hillslope elements may include "nose veneer", "side-slope veneer", "hollow blanket", or "nose bedrock".

Valley Bottom Regime

Valley-bottoms represent lower elevation areas that lie adjacent to stream channels. This zone is further subdivided into channels, floodplains, terraces, fans and aprons (Figure 5-2; Figure 5-3). The channel is the area occupied by open stream flow and includes the channel bed, depositional bars, and active-channel bank (Osterkamp and Hupp, 1984). Alluvium in the channel is subject to active reworking by open fluvial flow for significant periods of the year, with negligible vegetative occupation.

The floodplain is defined as a low-lying surface adjacent to the channel that is inundated once every 1 to 3 years (Osterkamp and Hupp, 1984; Wolman and Leopold, 1957). In the central Appalachians, heights of the floodplain surface can range from less than 1 m (Taylor and Kite, 1999) to greater than 10 m (Schultz and others, 1990) above channel grade, depending on the scale of the watershed.

Terraces are defined as elevated alluvial surfaces that are inundated by flood waters at a frequency less than that of the floodplain. The higher the elevation of the terrace above the channel, the less likely the occurrence of inundation. Elongate terrace treads are commonly disconnected and unpaired, characterized by areas of anomalously flat topography. Low-level terraces are common in small Appalachian watersheds (<60 km^2) and range in heights from 2.0 to 8.0 m above channel grade (Taylor and Kite, 1998). Strath terraces on larger drainage systems range up to 100 m above mean river level (Mills, 1986; Jacobson and others, 1988; Schultz and others, 1990; Erikson and Harbor, 1998). The terrace map designations presented in Table 5-2 are labeled with a modifier to signify the height of the surface above active channel grade (e.g. T1 = 2-4 m, T2 = 6-8 m, etc.). The height identification method precludes the need for obtaining chronologies prior to mapping terrace surfaces, however flexibility in the protocol permits precise age assignment if the data become available (see "Age" discussion below).

Although not as dramatic as in the southwestern United States, fan deposits are a common occurrence in the central Appalachians (see Kochel, 1990 for a review). In smaller-scale watersheds, poorly-sorted debris fans occur at the junctions of lower and higher order tributaries (Taylor, 1998). Similar types of deposits are described as "debris cones" elsewhere in the literature (Wells and Harvey, 1987; Kellerhals and Church, 1990). Larger-scale, more complexly organized fans are found in piedmont areas of the Blue Ridge, where lateral erosion provides greater accommodation space for fan growth and preservation (Kochel, 1990; Whittecar and Duffy, 1992; Mills and Allison, 1995b). Fans may become laterally and vertically incised to form abandoned fan-terraces, with surfaces elevated well above the active channel floor (Mills, 1983; Whittecar and Duffy, 1992). Fan terrace surfaces range in height from 3-15 m AMRL in small watersheds (Taylor, 1998), and greater than 20 m in larger-scale fan environments of the Blue Ridge (Mills and Allison, 1995a). Similar to terrace levels described above, fan surfaces are mapped according to height above channel grade (e.g. F = at grade, F1 = 2-4 m, F2 = 4-6 m, *etc*.; Figure 5-3). Large fans may coalesce to form bajadas on the western slopes of the Blue Ridge (Whittecar and Duffy, 1992).

Colluvial aprons lie at the base of the hillslope and represent a transitional zone between the hillslope and valley-bottom regimes ("footslope" deposits of Hack and Goodlett, 1960). Aprons typically display a gentler gradient than the adjacent side slopes and are commonly underlain by mass-wasting deposits. Lateral erosion of aprons by valley-bottom channels can result in development of a steep scarp, with the apron surface appearing as an irregular, unpaired terrace along the drainageway.

Miscellaneous Landforms

Several Appalachian landforms represent mappable variations of the primary hillslope and valley-bottom features described above (Table 5-2). Miscellaneous hillslope features include boulder streams (Potter and Moss, 1968), boulder fields (Clark and Torbett, 1987), talus slopes (Whittecar and Ryter, 1992), patterned ground (Clark, 1968; Clark and Ciolkosz, 1988); rock-block slides (Schultz and Southworth, 1989), debris slide scars (Clark, 1984; Mills and others, 1987), and debris flow tracks (Clark, 1984; Mills and others, 1987). Miscellaneous valley-bottom landforms include lobes (Cenderelli and Kite, 1998), levees (Hack and Goodlett, 1960), oxbows, hummocky topography, and deltas. Type II karst features include cave openings, sinks, solution pinnacles, blind valleys, swallows and karst springs (Davies, 1958; Schultz and others, 1990; Kite and others, 1995). Anthropogenically disturbed lands are mapped as "excavated", "fill" or "disturbed ground".

Materials and Origin (Process)

The materials and origin criteria are summarized in Table 5-2. Material refers primarily to the texture of surficial deposits overlying bedrock. Kite (1994) recommended use of the USDA soils textural classification for grain sizes less than 2 mm, since soils surveys are a common starting point for most surficial geologists. The Wentworth scale is recommended for clasts larger than 2 mm as the USDA designations lack geomorphically significant detail. Bedrock exposure on the landscape is an important component of the geomorphic system and is included as a materials unit. The origin criteria refers to the dominant process resulting in the surficial deposit. Process interpretations are based largely on facies and landform analysis, and by comparison with deposits of a known origin. The process identifiers are not applied to bedrock map polygons.

Similar to landforms, surficial material is 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, fan deposits and apron deposits.

Hillslope Deposits

Colluvium and residuum are the most widespread surficial deposits in the central Appalachian region (Mills and Delcourt, 1991). Both of these facies are comprised primarily of gravel diamicton in which boulders and cobbles are set in a matrix of loamy sand, silt, and clay. Clast composition and texture of these deposits are controlled primarily by the lithology of the bedrock from which they are derived. The term "regolith" is defined as all weathered and transported unconsolidated sediment at the earth's surface. "Colluvium" is applied to regolith that has been transported and deposited by diffusive mass wasting processes (Mills and Delcourt, 1991). These processes are gravity driven and include slope wash, creep, slide, frost heave, tree throw and faunal turbation. Under conditions of significant down-slope transport, the clast composition of the colluvial sediments may differ significantly from that of the underlying bedrock (Mills, 1981). "Residuum" is comprised of the in-situ products of bedrock weathering. Clast composition is representative of the underlying bedrock, with little or no transport (after Mills, 1988). Hillslope colluvium and residuum most commonly form veneers on top of bedrock, with thicknesses less than 2 m. Residual veneers develop on ridge crests and noses with gentle slope gradients. Colluvial veneers occur on steeper side slopes.

Based on landform-deposit relations, hillslope colluvium is subdivided into side-slope / nose facies (Qc1) and hollow facies (Qc2). Many researchers have recognized the importance of hollows with respect to hillslope sediment routing and hydrologic processes (Hack and Goodlett, 1960; Williams and Guy, 1973; Dietrich and Dunne, 1978; Anderson and Burt, 1978; Pierson, 1980; Dietrich and Dorn, 1984; Marron, 1985; Hayes, 1985; Reneau and Dietrich, 1987; Tsukamoto and Minematsu, 1987; Crozier and others, 1990; Dietrich and others, 1995). Local contour curvature determines whether material transport follows flow paths that are divergent (noses), convergent (hollows) or parallel (side slopes) (Hack and Goodlett, 1960; Reneau and others, 1989). Reneau and others (1984) concluded that thick deposits of hollow colluvium are important sources of debris flow and constitute a mappable geologic hazard. Hollow colluvium accumulates by diffusive mass-wasting processes. Debris slides are initiated during high-intensity precipitation events, in which positive pore pressures develop and the critical threshold of shear strength is exceeded (Anderson and Burt, 1978; Pierson, 1980). The lower the bedrock conductivity compared to that of hollow colluvium, the less stable the hillslope (Dietrich and others, 1995). Debris slides are rapidly transformed into debris flows as they are mobilized into higher-order tributaries (Costa, 1984). Dietrich and Dunne (1978) noted the importance of regolith thickness with respect to slope failure, as thicker colluvium reduces the probability of root penetration to bedrock, lowering net effective shear strength. Hence the recurrence interval for episodic debris flow events are a function of the rate of colluviation in lower order hollows, and the return time for triggering rainfall events (Costa and Jarrett, 1981). The rate of colluvial transport in turn, is directly proportional to the slope gradient (Dietrich and others, 1995). These hollow models are partially validated by flood-damage assessments in the central Appalachians. Williams and Guy (1971) noted that during the 1969 Nelson County debris flow event in Virginia, 85% of debris slides originated in previously existing hillslope depressions. Hack and Goodlett (1960) made a similar observation for 1949 slope failures in the Little River basin of Augusta County, VA. Thus, hillslope hollows represent a geomorphically significant element of the Appalachian landscape and special consideration is warranted in any surficial mapping scheme.

Boulder streams and boulder fields are a common occurrence in the central Appalachians, and represent a mappable subset of colluvium. Boulder streams are elongate in the down slope direction and tend to armor low-order tributaries. They are recognized by a clast-supported surface covering of bouldery debris with a paucity of interstitial sediment (Mills and Delcourt, 1991). Boulder fields are similar in character but occur along straight side slopes and display a more equant or irregular shape. Boulder streams and fields likely form by a combination of sliding, creep, and slopewash winnowing. It is plausible that more well-developed boulder streams are the result of periglacial processes that operated during Pleistocene glacial climates (Clark and Torbett, 1987; Mills, 1988; Mills and Delcourt, 1991; Whittecar and Ryter, 1992). Supporting evidence is provided by numerous occurrences of patterned ground throughout the central Appalachians, documenting the widespread nature of periglacial conditions south of the glacial limit (Clark and Ciolkosz, 1988). The minimum elevation of patterned ground increases with decreasing latitude, from 600 m along the glacial border to 1500 m in the southern latitudes (~35^{o} N; Mills and Delcourt, 1991). Geo-botanical 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 coarse gravel with varying admixtures of loam, sand and silt. These deposits are associated with channels, floodplains, terraces, fans and aprons. Cobble- to boulder-dominated channels are common in steep mountain watersheds. Channel alluvium is typically clast-supported, moderately sorted and imbricated due to deposition by turbulent streamflow hydraulics.

Floodplains and terraces are likewise comprised of coarse gravel deposits with loamy interbeds. Fabrics range from matrix- to clast-supported. Evidence for frequent inundation of floodplains includes scour-and-chute topography, disturbed vegetation and fresh slackwater deposits. Higher terrace surfaces display stabilized vegetation and are elevated well above flood-discharge level. Distinguishing between low terrace and floodplain is problematic as both surfaces are irregular in appearance (Leopold and others, 1964). Osterkamp and Hupp (1984) argue that vegetative patterns are the only reliable criteria that can be used to distinguish between the two. Floodplains and terraces are the product of fluvial incision, lateral channel migration and overbank aggradation (Leopold and others, 1964; Nanson, 1986).

Fan deposits in sandstone landscapes of the central Appalachians are cobble- to boulder-rich, massive to crudely-stratified, with either matrix- or clast-supported fabrics. Matrix fractions are in the silty to sandy loam class. Debris-fan deposits occur at tributary junctions as a result of flow expansion and decreased stream power. More sand-dominated, braided-fluvial fans are located on the western flanks of the Blue Ridge in Virginia (Kochel and Johnson, 1984). Debris fan exposures reveal a complex internal stratigraphy with inset facies relations (Kite, 1987; Tharp, unpublished data; Figure 5-4). Most of the higher fan-terraces are erosionally dissected and covered with a colluvial veneer. Fans in the central Appalachians are the product of a combination of debris-, hyperconcentrated- and stream-flow processes (Mills, 1982; Kochel, 1990). The debris flows derived from sandstone regolith are non-cohesive, resulting in poorly-sorted diamictons with crude internal stratification. Clast-supported and imbricated gravels are the product of fully turbulent streamflow (after Smith, 1986). Footslope aprons are similar in texture and occurrence, but they lack a well-defined point source. Aprons are the result of mass wasting processes such as slide, creep and slope wash.

Age

Dating of surficial deposits in the Appalachians is problematic, and persists as an elusive facet of geomorphic study. Geo-botanical evidence provides an important dating tool for historic deposits (Osterkamp and others, 1995), however the ages of older landforms are poorly constrained. Radiocarbon techniques are of limited value due to poor preservation of organic matter and many of the older deposits are well beyond the range of application (Mills, 1986; 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; Ries and others, 1998) techniques provide results holding some promise; they have not yet been widely applied in the Appalachians. In addition, costly absolute dating techniques add greatly to mapping budgets, which are chronically underfunded and typically limited to field expenses. Relative-age dating techniques were utilized in several studies (Mills, 1988; Whittecar and Duffy, 1992; Mills and Allison, 1995b), although the discontinuous nature of surficial deposits makes stratigraphic correlation difficult. Pollen stratigraphy is applicable in upland bogs and on the coastal plain (Delcourt and Delcourt, 1986), but application in colluvial environments has not been tested. Mills (1988) concluded that a continuum of relative ages exists for many deposits with no discrete mappable groups. Hence, a traditional stratigraphy-based mapping scheme is largely not applicable due to poor resolution of surficial chronologies (Kite, 1994).

Table 5-2 provides criteria for assigning ages to surficial map units. Grouping deposits by age is often arbitrary and speculative at best. Historic channel and debris flow deposits are mapped with a high degree of certainty as "Late Holocene", however many older deposits are typically assigned an age of "Quaternary-undifferentiated". Despite the problematic uncertainties of surficial chronologies in the central Appalachians, the map protocol is flexible and offers precise age identification when data permit. Since the mapping scheme incorporates the four-fold criteria system described above, the need for formal stratigraphic nomenclature is largely unnecessary.

Table 5-2. 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

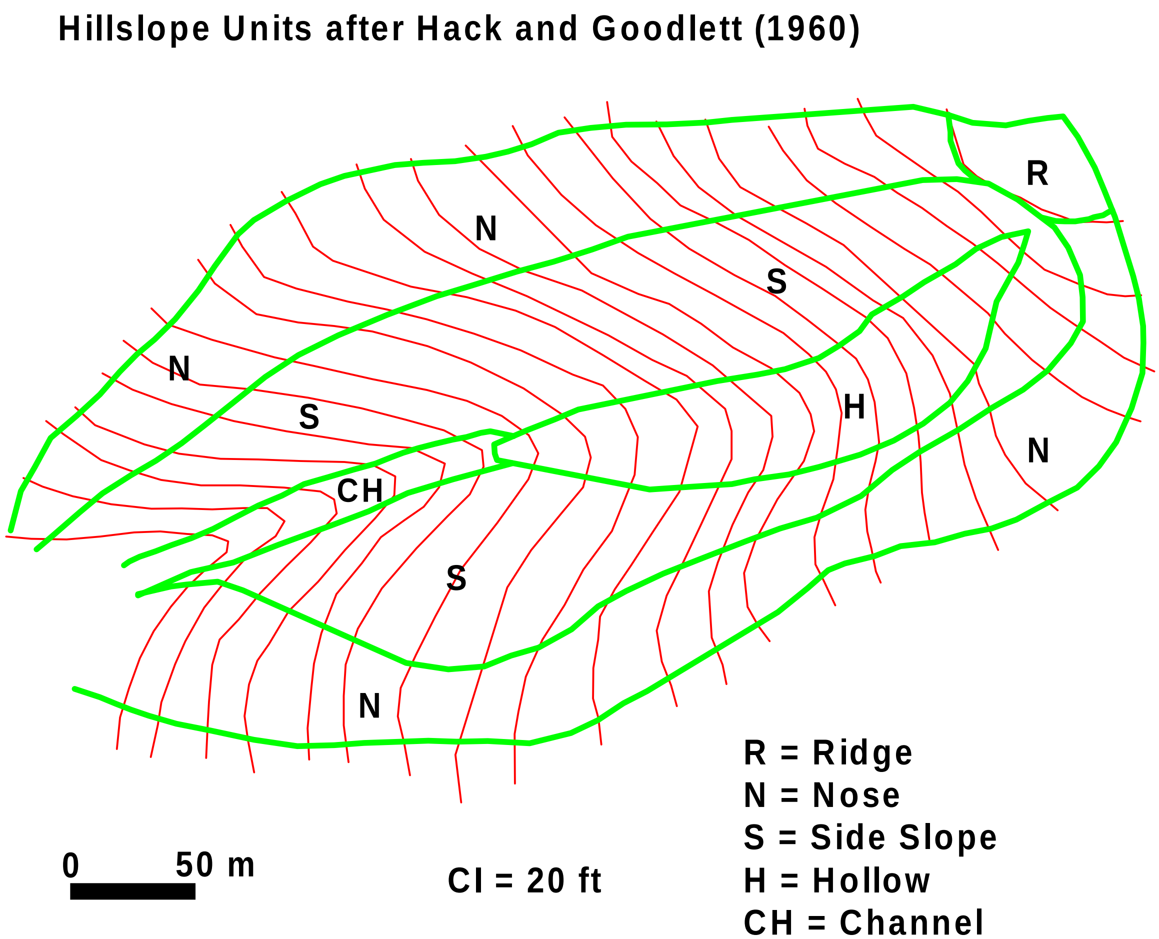

Figure 5-1. Hillslope landform elements after Hack and Goodlett (1960). Net transport flow paths are divergent on nose, covergent in hollows, and parallel on side slopes (Reneau and others, 1989). Noses represent drainage divides between zero- to first-order tributaries. Ridge crests serve as drainage divides between higher-order watersheds.

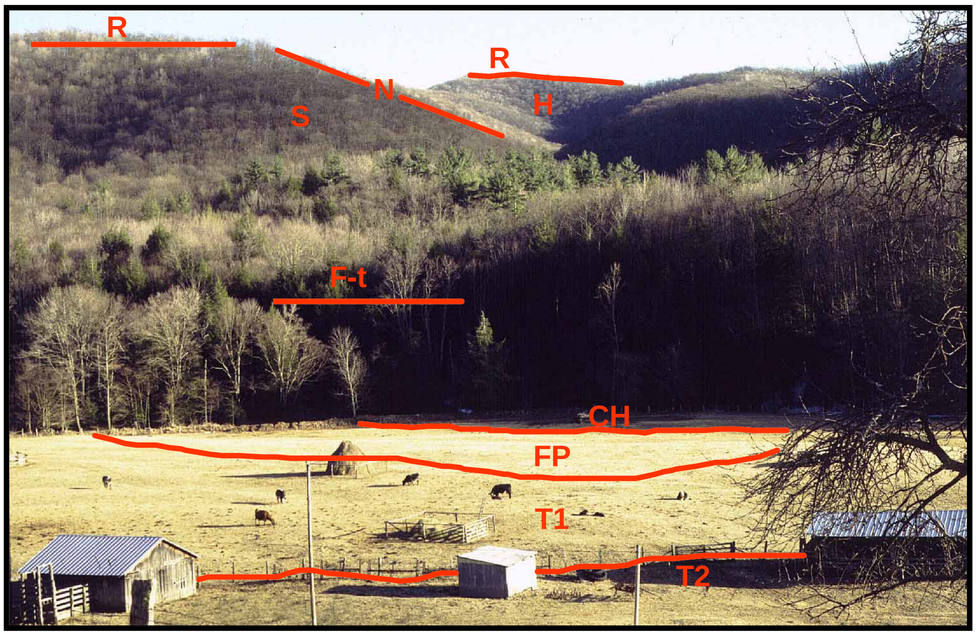

Figure 5-2. Principal landform elements recognized in the unglaciated, humid-mountainous landscape of the central Appalachians. Label identification is as follows: R = ridge, N = nose, S = side slope, H = hollow, CH = channel, FP = floodplain, T1 = low terrace, T2 = intermediate terrace, F-t = Fan terrace. Photograph is from the North Fork basin, Pocahontas County, West Virginia. See text for discussion.

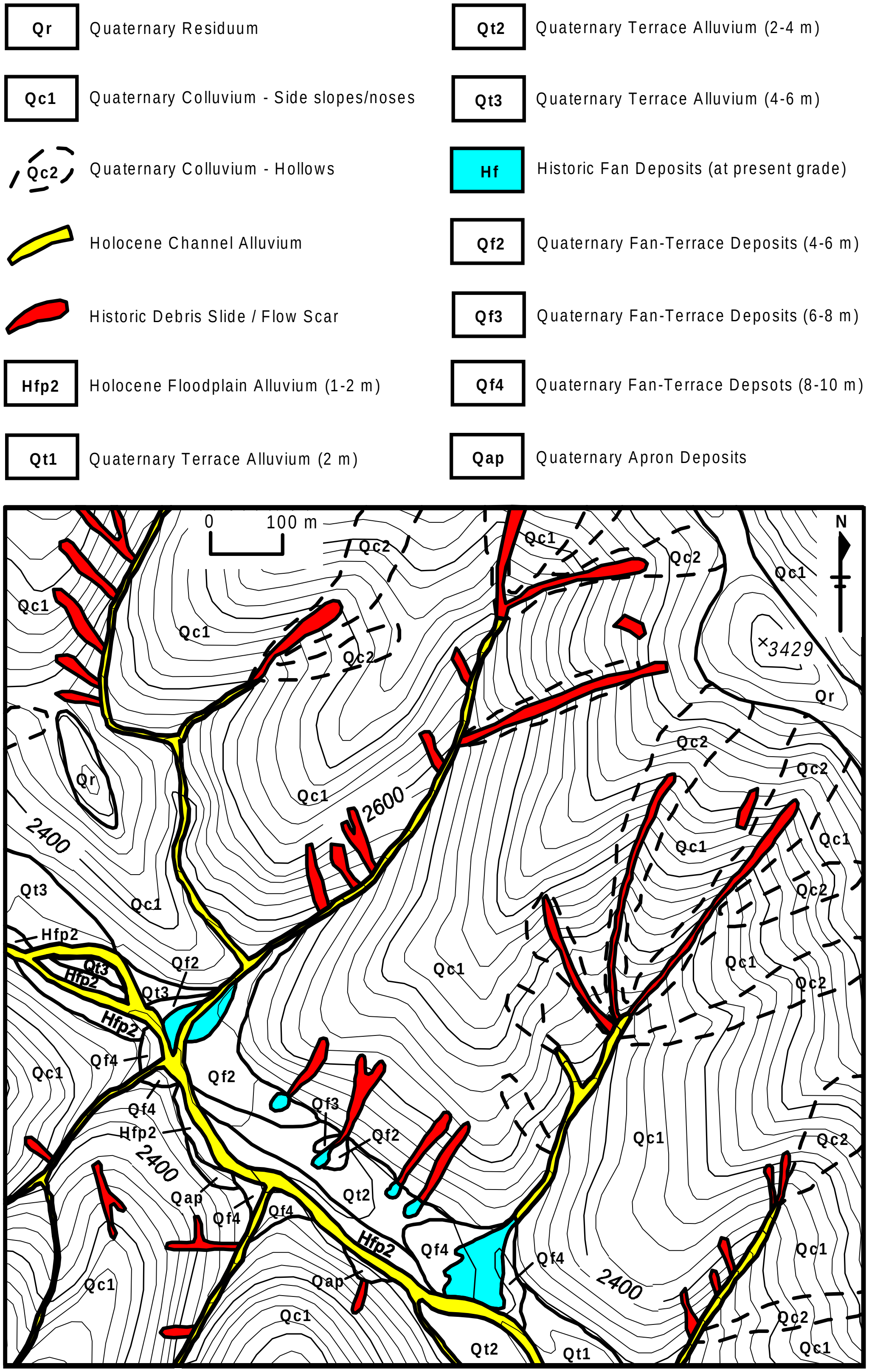

Figure 5-7. Portion of the surficial geology map for the Little River area, Augusta County, Virginia. Features were originally mapped at a scale of 1:9,600 (Taylor and Kite, 1998). Refer to Table 5-3 for an expanded explanation of map units. Contour interval = 40 ft.

Table 5-3. Example Application of Surficial Map Criteria at the Little River Basin, Augusta County, VA.

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
Qr	Quaternary Residuum	Quaternary (Undiff.)	Residuum	Ridge-Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,r,r-v,c-bdt-l)	Predominantly associated with ridge crests supported by the Pocono Formation.
Qc1	Quaternary Colluvium (Side Slopes)	Quaternary (Undiff.)	Colluvium	Nose-Side Slope Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,c1,n/s-v,c-bdtl)	Predominantly associated with side slopes underlain by the Hampshire Formation. Includes the Hazleton and Hazleton-Lehew soils series (Hockman and others, 1979).
Qc2	Quaternary Colluvium (Hollows)	Quaternary (Undiff.)	Colluvium	Hollow Veneer	Cobble- to Boulder-Diamicton with Silty Loam Matrix	(Q,c2,h-v,c-bdt-l)	Predominantly associated with zero- to first-order hollows underlain by the Hampshire Formation.
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 sixth-order streams. Unit includes channel alluvium and portions of adjacent floodplain too small to map at the given scale.
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 second- to sixth-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 second- to sixth-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.
Hfp2A	Holocene Floodplain Alluvium (1.0 to 2.0 m surface)	Holocene	Alluvium	Floodplain	Sandy Loam	(H,a,fp2A,s-l)	Sandy slack-water deposits upstream from Hearthstone Lake. Unit includes low-lying surfaces 1.0-2.0 m above present channel grade with a flood recurrence interval of approximately 3 to 5 years. Buried root flares common.

Table 5-3 (Cont.).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
Hfp2B	Holocene Floodplain Alluvium (1.0 to 2.0 m surface)	Holocene	Alluvium	Floodplain	Clayey Loam	(H,a,fp2B,cy-l)	Clayey slack-water deposits immediately upstream from Hearthstone Lake. Unit includes low-lying surfaces 1.0-2.0 m above present channel grade with a flood recurrence interval of approximately 3 to 5 years. Mud cracks and buried root flares common.
Hd	Holocene (Historic) Delta Deposits	Holocene (Historic)	Lacustrine Delta	Delta	Sandy Loam	(H,ld,d,s-l)	Historic lacustrine delta deposits associated with the flood-control reservoir at Hearthstone Lake.
Qt1	Quaternary Low-Terrace Alluvium (2.0 m surface)	Quaternary (Undiff.)	Alluvium	Terrace (Floodplain?)	Cobbles-Boulders and Pebbly Loam (rounded to subrounded)	(Q,a,t1,c-b-pl)	Low-terrace deposits associated with second- to sixth-order streams. Unit includes low terrace surfaces 1.0 to 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 sixth-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 sixth-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 sixth-order streams. Unit includes terrace surfaces 4.0 to 6.0 m above present channel grade.
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. Primarily the result of June 1949 flood event.
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.

Table 5-3 (Cont.).

Map Unit Label	Map Unit Description	Age	Origin (Process)	Landform	Material (Texture)	Four-Fold Identifier	Comments
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 / Flow Scar	Holocene (Historic)	Debris Slide / Debris Flow	Scar	Commonly Scoured to Bedrock	(H,ds/df,sc,rk)	Slide scars associated with the June 1949 flood event. Debris slides transformed into debris flows with attendant erosion of surficial materials to bedrock. Identified by youthful and disturbed vegetation. Bedrock surfaces may be scratched and striated.