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Information derived from soil maps: Areal distribution of bedrock landslide distribution and slope steepness

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Abstract Soil maps can be used to generate maps showing the areal distribution of bedrock. This technique is especially useful in heavily vegetated areas where weathering is intense and outcrops sparse. Broad lithologic categories that are readily distinguished include: diabase/basalt, sandstone, shale, limestone, conglomerate, and hornfels. Using soil maps is not a substitute for field work, but is a valuable tool to aid in making geologic maps. Soil maps can also be used to produce derivative maps showing slope steepness and landslide distribution.

Key words Soil maps — Areal distribution — Slope steepness

Introduction

Soil maps contain a wealth of information that can be used by scientists working in the field of environmental geology. The areal distribution of soil and its importance in site evaluation for construction and slope stability are obvious, but are not the topic of this paper. Instead the focus is on soil maps as a guide to mapping bedrock. Although valuable as a tool to aid in making geologic maps, they are not a substitute for field work. Derivative maps showing slope steepness and landslide distribution can also be made using soil maps.

To illustrate these points I have chosen an 8-km^2 area in Hardy County, West Virginia (Fig. 1). It lies in the Valley and Ridge Province and is underlain by Silurian and Devonian sedimentary rock. The dominant structure is a northeast plunging anticline. The local relief is 300 m. As is typical in the Appalachians, weathering is intense and outcrops are generally restricted to resistant ridges and a few deeply eroded stream valleys. The detailed geologic map, shown in Fig. 5 below, is based on having used this area in a field mapping course for a number of years.

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Soil

Soil is surficial material formed by chemical and physical weathering. Many factors control the type of soil that develops in an area. These factors include climate, topography, time, and parent material. Parent material may be bedrock, saprolite, colluvium, or alluvium. Most soils are layered parallel to the ground surface. The layers in a typical soil profile are (from top to bottom): O horizon—thin dark-colored organic layer, E horizon—light-colored mineral layer of maximum leaching, B horizon—enriched layer, with maximum accumulation of material leached from above, C horizon—slightly weathered parent material, and R horizon—unweathered parent material.

Soil maps

Soil scientists describe soil profiles in great detail and classify them according to nationwide, uniform procedures (Birkland 1984; Van Wambeke and Forbes 1986; Finkl 1988; Soil Survey Staff 1992). Soils with very similar profiles are grouped together in a category known as a soil series. Soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Soil series developed on the Piedmont and Coastal Plain east of the Valley and Ridge are shown in Fig. 2. This illustration demonstrates the importance of topography and parent material on the geographic distribution of soil series. Like geologic rock units, soil series are named for towns or other geographic features near the place where they were first observed and mapped. More than 17,000 soil series have been described and named in the United States (Broderson 1991).

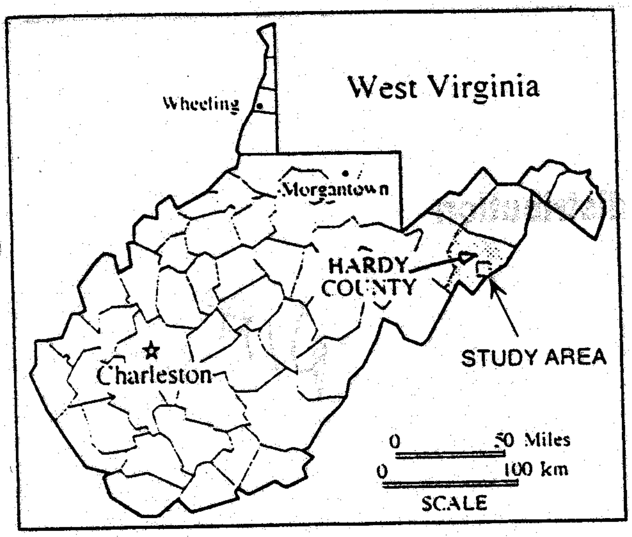


Fig. 1. Index map showing the location of the study area

Soils included in one series differ in the texture of the surface layer, slope, stoniness, or some other feature that affects soil use by man. The various soils that comprise a series are known as soil phases. The name of a phase reflects a feature that affects soil management. The Elliber very cherty loam, 35–65 percent slope is one of six phases that comprise the Elliber series in this part of the Appalachians (Estepp 1980). Generally all phases comprising a series have the same or similar parent material. Parent rock for Elliber soils is cherty limestone. In an area as large as Hardy County, a number of soil series may develop on one type of parent rock. For example, series formed on sandstone include: Dekalb, Drall, Hazleton, Lehew, and Schaffenaker.

While doing field work, soil scientists dig pits and take cores to determine the distribution of soil phases. They also collect data on slope steepness and length, drainage patterns, vegetation, and bedrock. On the basis of these observations, they draw boundaries of individual soils on aerial photographs to produce a soil map. The areas are called soil map units. Generally all of the soil within a map unit is a single phase. Unfortunately it is not always this simple. In some instances small areas (commonly called inclusions) of differing soil types, too small to separate because of map scale, occur within a larger soil map unit. Such units are named for the dominant soil phase.

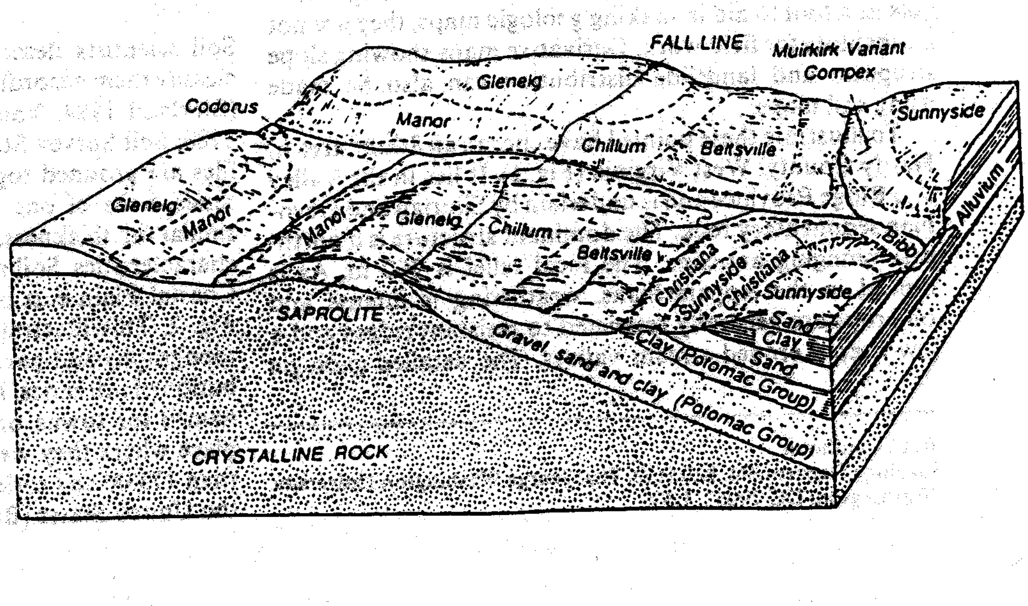
Published soil surveys generally cover one or more counties. In addition to soil maps, these surveys contain a description of each soil type and its parent material, as well as a discussion of the formation and classification of the soils in the area. Most of the soil surveys published since 1957 contain maps printed on a photomosaic base. The usual scale is 1 : 24,000, 1 : 20,000, or 1 : 15,840. In some areas the maps are even more detailed, for example, in Fairfax County, Virginia, where the scale is 1 : 3000. Many of the soil maps show outcrop locations, a very useful piece of information in areas where exposures are sparse. Most soil surveys are published by the USDA Soil Conservation Service. Since 1899, when soil surveys were first made, 4187 have been published, 2405 of which are currently available. Out-of-print surveys may be available in university or other libraries. Each year the USDA produces a "List of Published Soil Surveys." The 1991 edition states that soil surveys published by the USDA, and still in print, can be obtained in one of the following ways:

> Land users in the area surveyed and professional workers who have use for the survey can obtain a free copy from the state or local office of the Soil Conservation Service, from their county agent, or from their congressional representative. Many libraries keep published soil surveys on file for reference. Also, soil conservation district offices and county agricultural extension offices have copies of local soil surveys that can be used for reference.

Some state and county agencies also publish soil surveys that are not in the USDA list.

There are several complications for the geologist who wishes to use soil maps as a guide to compile a geologic map. First, soil map units may contain soils derived from several different parent rocks, as noted above. Second,

Fig. 2. Diagram showing relationship between soil series, parent material, and topography. From Smith (1976), Figure 59. The area shown represents the Piedmont and Coastal Plain in Washington, DC



some soil series have fundamentally different (although related) parent lithologies. For example, Edom soils develop on both limestone and calcareous shale. Third, some soils develop on colluvium, which has moved downslope by creep. Similarly, soils develop on landslides that move surficial material downslope, away from its original bedrock source. These problems may be resolved by geologic field work, provided outcrops are present at strategic locations. If no outcrops exist, the geologist would not know exactly where to locate a particular rock type or contact on a geologic map whether or not soil maps had been used.

Method of compiling a geologic map using soil maps

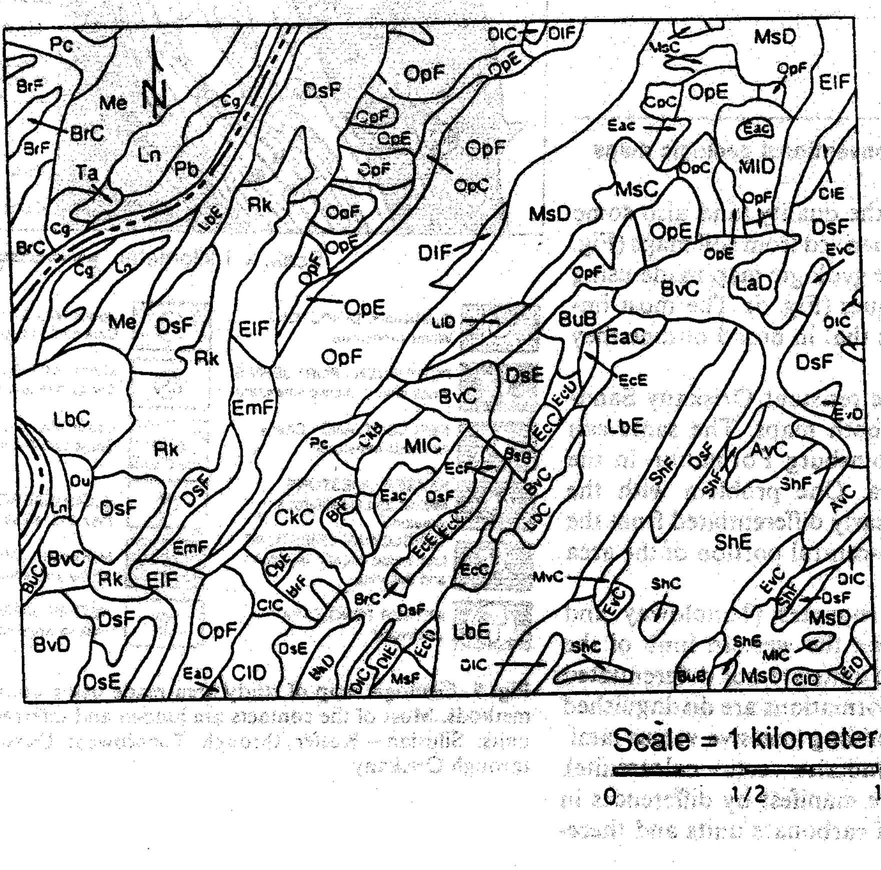
Compiling a geology map from soil maps is very much like painting by number. Soil maps show many map units, each of which is labeled (Fig. 3). Every label is a code representing one soil phase. Labels ElF and EmF are soil phases of the Elliber soil series that develop on cherty limestone. In Fig. 4 all map units with these labels are covered with the same pattern (horizontal lines). When working on a photomosaic they would be colored (e.g., red). This process continues until all of the map units of soil developed on a particular parent rock are color coded. The final product (Fig. 4) is a geologic map with five lithologic map units, derived from 28 soil phases. Two other map units on the derivative geologic map (Fig. 4) show areas of colluvium and alluvium. The next step is to transfer these lithologic map units to a suitable base, generally a 7.5-minute quadrangle. This may require changing the map scale by using an enlarging–reducing opaque projector. The final step involves field checking the map.

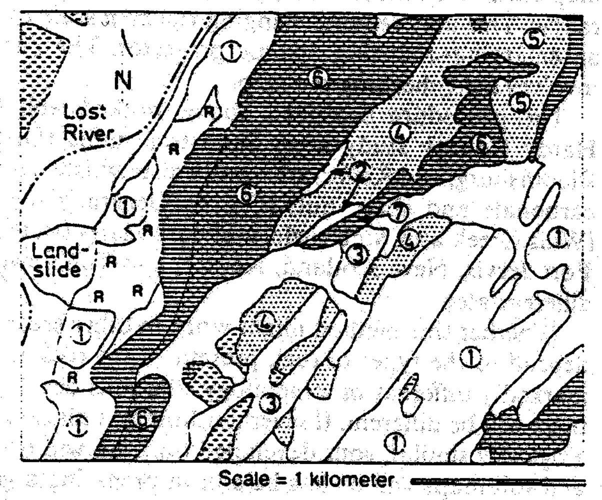
The procedure described above worked well in the Hardy County study area. Sandstone units (Oriskany, Bloomsburg, and Keffer) are readily distinguished from the carbonate and shale units (Fig. 4). Generally the shales (Wills Creek and McKenzie) and carbonates (Port Ewen-Port Jervis, New Scotland, Keyser, and Tonoloway) are differentiated.

Whether this method might work in other areas would depend to the types of rock present. If the rock units are markedly different in mineralogy, the soils developed on them will be different. If several lithologic units are mineralogically similar, soils developed on them will be similar and soil maps will be less helpful in preparing a geologic map. In the Culpeper basin areas underlain by mafic igneous rock, hornfels, conglomerate, and sandstone/shale are readily distinguished on soil maps (Lindholm 1993). Diabase and basalt, which differ texturally, but not mineralogically, are not separated using soil maps. Although the map pattern served to distinguish massive plutons and dikes from concordant tabular bodies, only field work allowed identification of sills and flows.

One advantage of using soil maps to prepare a derivative geologic map is time. The map shown in Fig. 4 was completed in less than a day (excluding drafting). The map of the Culpeper basin, an area of 2,200 km², took less than two months to complete. That works out to more than 36

Fig. 3. Soil map of study area traced from photomosaic base (Estepp, 1980)





Map Symbol	Soil Series	Parent Rock	Rock Unit
	Dekalb, Drall, Hazleton, Lehew, Schaffenaker	Sandstone	(1) Oriskany Sandstone; (2) Sdst. Mem. of Wills Creek Shale; (3) Bloomsburg Fm. & Keefer Sdst.
	Berks, Weikert	Siltstone & Shale (some Sandst.)	All of the McKenzie Shale & part of the Wills Creek Shale.
	Edom, Murrill	Calcareous Shale & Limestone	(4) Mainly Wills Creek Shale; (5) Keyser Ls. & Tonoloway Ls. in NE portion of map area.
	Opequon	Limestone & Calcareous Shale	(6) Mainly Tonoloway Ls., New Scotland Ls., & Keyser Ls.; (7) Lower part of Wills Creek Shale.
	Elliber	Cherty Limestone	Port Ewen-Port Jervis Ls. & part of the New Scotland Limestone.
	Ladig	Colluvium with sandstone frags.	Mainly Oriskany Sandstone that has moved downslope.
R	Rock outcrop and rock rubble	Sandstone	Oriskany Sandstone
	Allegheny, Brinkerton, Buchanan, Chagrin, Clarksburg, Dunning, Ernest, Lindside, Murrill, Potomac,	Colluvium & Alluvium	Mixed source.

Fig. 4. Derivative geologic map of study area. Compiled from soil map shown in Fig. 3.

km^2/day, which is considerably faster than normal geologic mapping. Another advantage is that the derivative geologic map may show a pattern of rock units that is closer to the truth than a geologic map made using conventional field mapping techniques (Lindholm 1993). This is especially true in areas where weathering is intense and soils are thick.

Comparison of derivative and conventional geologic maps

To give the reader an idea of the quality (and also some problems) of the geologic map derived from soil maps (Fig. 4), it will be compared with the geologic map made using conventional mapping techniques (Fig. 5). The most important point of comparison is that in broad outline they are very similar.

The outcrop pattern for the resistant Oriskany Sandstone is nearly the same on both maps. The same can generally be said for the Bloomsburg Formation in the central part of the map area. One problem with the Bloomsburg is that it is not clearly differentiated from the Keefer Sandstone in the south-central portion of the area on the derivative map.

The thick sequence of carbonates (Tonoloway and Keyser) is clearly delineated on the western limb of the anticline, but the stratigraphic units are not differentiated on the derivative map. These formations are distinguished in the field by differences in bedding (massive versus laminated) and limestone types (micrite versus calcarenite). Such differences would not be manifest by differences in soils developed on the several carbonate units and there-

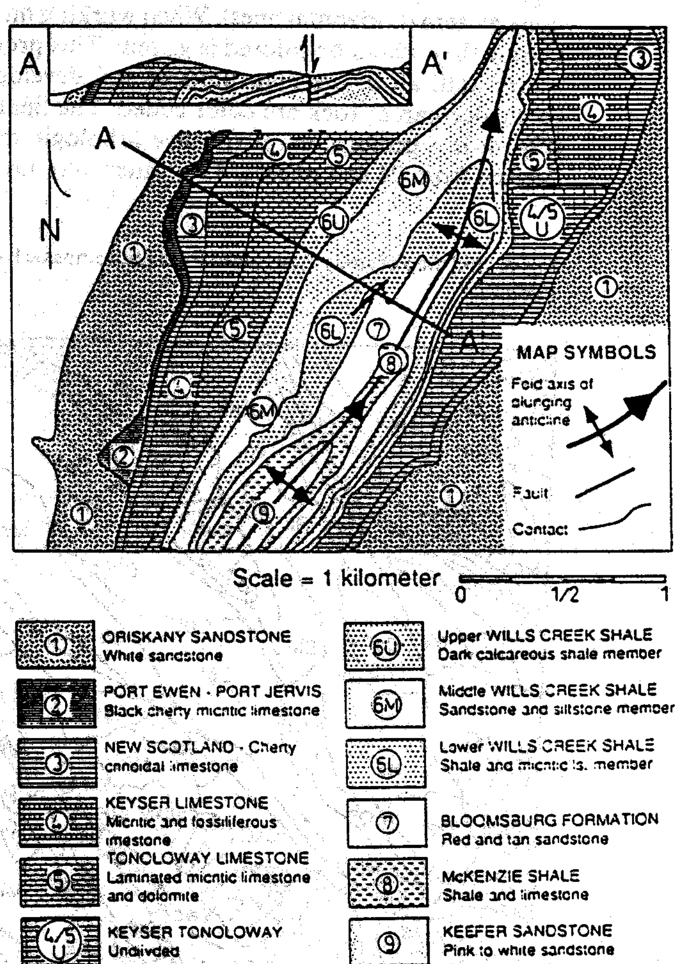


Fig. 5. Geologic map of study area made using conventional field methods. Most of the contacts are hidden and inferred. Age of rock units: Silurian—Keefer through Tonoloway; Devonian—Keyser through Oriskany

fore would not be reflected on the derivative map. Similarly the cherty limestones of the Port Ewen-Port Jervis and the New Scotland form a single map unit on the derivative map.

The complex mosaic of lithologies in the Wills Creek Shale is not easily interpreted on the derivative map, although the upper contact (with the Tonoloway) and lower contact (with the Bloomsburg) are easily recognized on the western limb of the anticline. This outcrop belt of the McKenzie Shale is also shown on the derivative map.

In summary, in many ways the two maps are similar. The discrepancies emphasize the importance of basic geologic mapping. Extensive field work must be done if the research goal is a published geologic map. Soil maps can be a valuable aid to the geologist, but they are not a substitute for old-fashioned field work.

Slope steepness and landslide location

Soil surveys contain a wealth of information about slope steepness. Many soil phases are partly defined on the basis of slope steepness. A derivative map showing slope steepness is made using the same technique described in the section "Method of compiling a geologic map using soil maps." The difference is that soil map units with the same slope steepness are combined. The derivative slope-steepness map for the Hardy County study area is shown in Fig. 6.

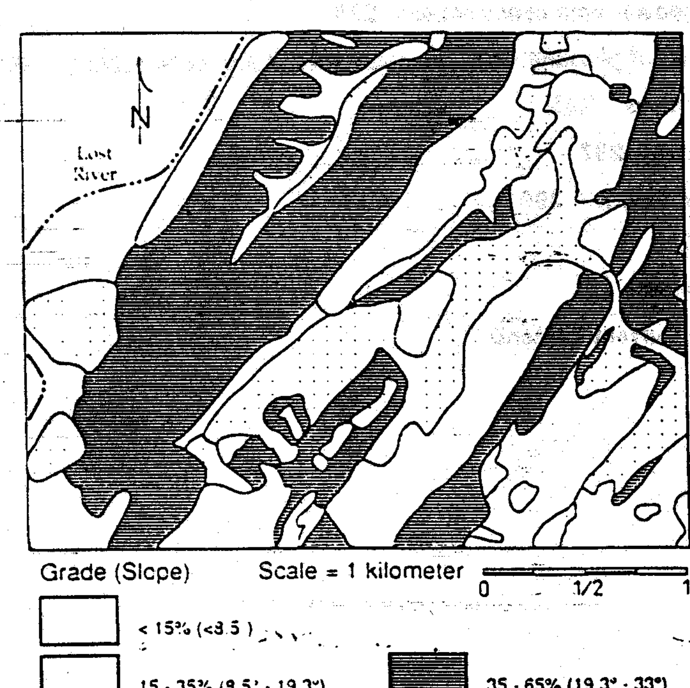


Fig. 6. Slope steepness map of study area. Compiled from soil map shown in Fig. 3

In some cases the location of ancient landslides can be delineated from soil maps. One such slide has diverted Lost River in the western part of the study area (labeled "landslide" in Fig. 4). Its topographic expression and the scar at the head of the slide is obvious to a novice geologist. Soils of the Ladig series are developed on the slide. These soils, whose parent material is described as "colluvium with sandstone fragments," also occur in a northeast trending belt, east of the fold axis. Although hidden beneath a thick forest, it is likely that this belt is the manifestation of landslides that moved down from the Oriskany ridge to the east.

Conclusions

Many environmental studies that require detailed geologic maps are done under severe fiscal constraints. Preliminary use of soil maps to delineate bedrock distribution allows the geologist to concentrate limited field work on critical areas. This not only saves time and money, but may result in a superior product.

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