The Soil Science - Geology Connection

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Introduction

Geology is an interdisciplinary field. Understanding the basic concepts important to geology often requires that the geologist also understand the basic concepts of a number of other fields, such as chemistry, physics, and mathematics. In addition to these fields, which are beneficial to virtually all specialties within geology, the geologist can be aided by knowledge of a number of disciplines such as biology, geography, meteorology, soil science, computer science, and archeology, depending on the specialty area pursued by the geologist. This article will explain some aspects of the unique relationship between geology and soil science, and give examples of the ways that knowledge of soils can be helpful to the geologist mapping in the field. It seems an ideal time to address this subject given the recent addition of the soil compilers to the North Dakota Geological Survey staff.

Soil Science and Geology

Courses in soil science are often taught in departments with ties to agriculture. Most people view soil science as an agricultural field. While it is true that many soil scientists research agriculturally related issues, the field of soil science can trace several of its roots back to geology. One of the most influential of the early soil scientists, V. V. Dukuchaev, was trained as a geologist (Buol et al., 1997). The concept of the five soil-forming factors, a concept still utilized in soil science today and discussed later in this paper, is credited to Dukuchaev and his work of the late 1800s in Russia.

Geologists were also influential in developing soil science as a discipline in the United States. C. F. Marbut, a geologist by training, was the second director of the U.S. Soil Survey and is considered the founder of American pedology (a specialization within soil science)(Buol et al., 1997). Marbut trained under William Morris Davis, one of the most influential American geomorphologists in the early 1900s. Many of Davis' ideas concerning landscape evolution influenced Marbut's ideas on soil formation. Davis envisioned a set of "normal" processes that lead to a "normal" landscape, an idea seen in Marbut's concept of a "normal" soil formed on a "normal" landscape (Buol et al., 1997). Marbut also considered soils to fall into young, mature, and old categories, just as Davis considered landscapes to fall into these same categories. Although the concepts of "normal" and young, mature, and old soils are no longer accepted in soil science, they were influential concepts in the early 1900s and were borrowed from geology. Marbut made other significant contributions to soil science as well. He was the first to develop a truly multicategorical system for classifying soil (Simonson, 1986a) and developed a list of ten items that should be covered in any soil profile description (Simonson, 1986b). Although this list has been revised, it is still largely valid (Simonson, 1986b).

Other men who were trained as geologists, such as George Nelson Coffey and E. W. Hilgard, also made significant contributions to early soil science in America. In fact, Coffey (1911) noted that most state geological surveys had engaged in soil mapping and other soil studies prior to the 1900s. Hilgard was the first in the United States to write about soils as independent bodies (McCracken and Helms, 1994). Coffey was probably the first in the United States to advocate classifying soils according to the properties of the soil (Coffey, 1912), a method that is still used today. Such an approach may seem like common sense, but in early soil classification systems this was not the case. Many other geologists also made significant contributions to soil science. A more complete discussion of these people can be found in Buol et al. (1997), a series of papers by Simonson published in 1986 in *Soil Survey Horzions*, and McCracken and Helms (1994). As we moved into the 1920s, soil science was trying to establish itself as a distinct, viable field of science separate from geology. C. F. Marbut (Buol et al., 1997) and G. N. Coffey (Coffey, 1916) were two of the key people in that movement.

Given that many aspects of modern soil science evolved from geology, it is not surprising that many soil scientists today are working on issues that are also being studied by geologists. For example, the chemical and structural composition of clay minerals is of great interest to both fields, as are the chemical interactions that take place on the surface of clay minerals. The work of Soil Conservation Service scientists, in particular R.V. Ruhe and his students, provided significant contributions to the understanding of midwestern Pleistocene stratigraphy (i.e. Ruhe, 1969), and geology and soil science share a mutual interest in groundwater protection issues. A prime example of geologists and soil scientists working together to address a groundwater contamination problem can be found in the Walnut Creek watershed in central Iowa (Simpkins and Burkart, 1996).

Soil and Soil Mapping

Although the examples cited above show that soil science and geology share areas of common interest, they do not necessarily show that knowledge of soil science is in fact beneficial to geologists. To demonstrate that soils knowledge can benefit geologists working on certain problems, I will draw on two examples in which soils information was used in geologic mapping. The first example comes from the

Culpepper Basin, an area in northeastern Virginia. The second example involves some features in North Dakota that have challenged geologic mappers, the strandlines of glacial Lake Agassiz. However, before continuing with these examples, I will review some basic tenants of soil science and soil mapping.

The five soil-forming factors commonly recognized in soil science are climate, time, topography, organisms, and parent material. Climate simply refers to the climate in the area which the soil forms in, time refers to how long the soil has been forming, and organisms refers to the plants and animals (including microorganisms) that interact with the soil. Topography and parent material both have geologic connections. Topography refers to the position in the landscape in which the soil is forming, and is related to geomorphology (the study of landforms). Parent material refers to the original, unaltered geologic deposit in which the soil formed. For example, soil formed in glacial deposits has till as a parent material; soil formed alongside a river has alluvium as its parent material.

When soil maps are made for a county, soil map units are assigned to each unique soil in that county. Each of the numbers on figure 1, such as 26, 73, and 54B, represent a soil map unit established for Grand Forks County. By checking the Grand Forks County Soil Survey (Doolittle et al., 1981), we find that the soils represented by the number 26 formed in fine-silty sediments deposited on a lakebed. Likewise, we can find that number 73 represents soils formed in coarse-silty lake deposits, and number 54B represents soils formed in coarse-loamy beach and delta plain deposits (or in other words, beach or delta deposited parent materials). The map unit designations also give us information about topographic position. The "B" in 54B tells us that this soil map unit has a slight slope (about 1-6 percent) while the lack of a letter behind the 26 and 73 designations tells us these soil map units are very flat, having slopes of less than 3 percent. Checking into the soil survey a little more tells us that the slopes on map unit 54B are convex up.

Taking all this information into account, we can now start to form a picture of what this area looks like. In the northeast and southwest parts of figure 1 there is a flat lake plain. Starting in the northwest and extending to the southeast through the center of the map are two beach-ridges that are slightly raised above the lake plain. I call the areas of 54B beaches instead of delta deposits in this case because of their long, narrow shape and the fact that they are convex up. By using the information on soil maps in this way and then combining it with information from geologic or topographic maps, it is sometimes possible to expand on the current geologic knowledge of an area. Again, this works largely because of the influence of topography and parent material on the soil that eventually forms at a given location. With all this in mind, we are ready to look at examples of using soils information to aid in geologic mapping.

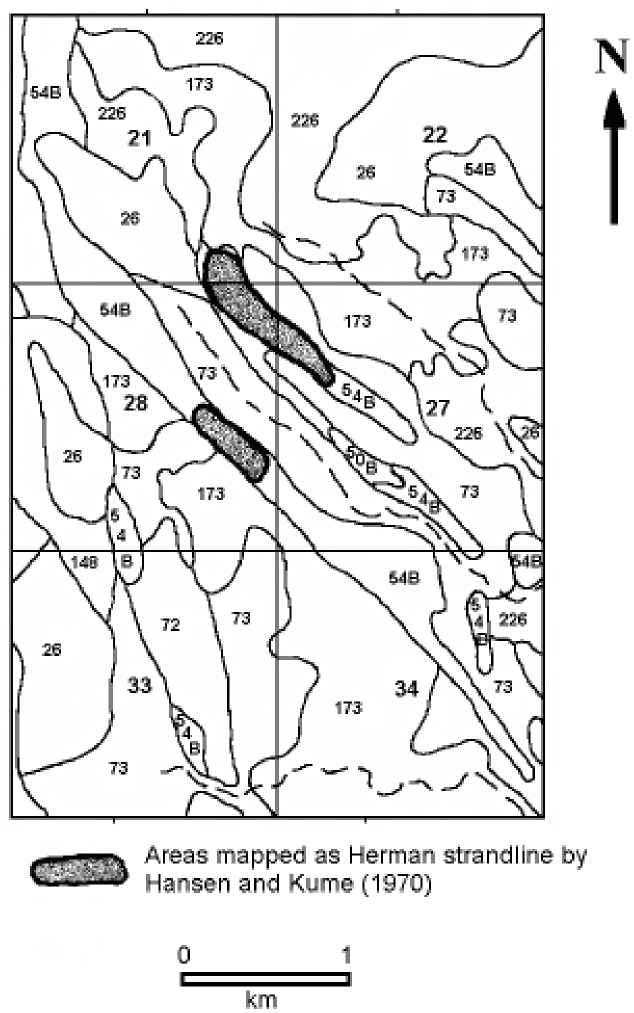

Figure 1 *– A portion of soil map sheet 84 from Doolittle et al. (1981) showing the locations of the southern-most sections of the Herman strandline in Grand Forks County as mapped by Hansen and Kume (1970). Note the linear delineations of soil map unit 54B running through the mapped sections of the Herman strandline and trending to the north-northwest. Soil map units 50B and 54B mark the probable location of the Herman strandline in areas not currently mapped as Herman. The areas shown mapped as Herman by Hansen and Kume (1970) are in Sec. 21, 27, and 28, T. 150 N., R 54 W. Figure from Brevik and Fenton (in press).*

Mapping Applications

The Culpepper Basin of northeastern Virginia is an area characterized by a number of different types of bedrock that are close to the surface, including diabase, basalt, conglomerate, sandstone, and shale. Several of these rock types have different mineralogic compositions, which means they weather differently, have different chemical compositions, and thus they represent distinctly different soil parent materials. When R.C. Lindholm first began his research in the Culpepper Basin, no geologic maps were available. However, realizing that parent materials with distinctly different properties would lead to the formation of different soils, he used soil maps to construct a preliminary geologic map of the Culpepper Basin (Lindholm, 1993; 1994a). As Lindholm conducted his research and was able to field check his soil-based map, and as geologic maps became available for the Culpepper Basin, he found that the soil-based map was often quite accurate. In fact, in some areas, such as along a sandstone-basalt contact, he believes the soil-based map is more accurate than the geologic maps made using traditional geologic mapping techniques. Another study at a site in West Virginia found very similar relationships between the soils and bedrock (Lindholm, 1994b).

The Lake Agassiz basin in eastern North Dakota is a very different setting than the Culpepper Basin. Instead of igneous and sedimentary rocks near the surface, this area is covered with a thick mantle of glacial and pro-glacial lake deposits. Strandlines (beaches and wave-cut scarps) mark former levels at which Lake Agassiz was temporarily stable. These strandlines are difficult to map because the Lake Agassiz basin is very flat and the strandlines do not always stand out. Several parts of the strandlines have also eroded away in the 10,000 or so years since they were formed, and some parts of the strandlines may have never been well formed. The result is the preservation of a series of short, slightly elevated strandline segments for modern day geologists to attempt to map.

In the areas where the strandlines are preserved as beaches the sediments are mainly sand and gravel (Bluemle, 1991; Hansen and Kume, 1970). In contrast, the lake deposits contain a greater percentage of silt and clay than the beach deposits. There is a difference in the parent materials and a change in texture. More sand and gravel are found in the strandlines than in the lake deposits. There is also a topographic difference between the relatively high strandline and the low lake plain. Admittedly, I did state earlier that the Lake Agassiz basin is very flat, and that makes mapping the strandlines in some areas quite difficult. However, differences in topographic position of only a few centimeters are not easily noticeable to human observation, but can still make a difference in soil formation. Finally, the combination of "high" topographic position and coarse-textured parent material means the soils forming on the strandline will be better drained than the surrounding soils, again affecting the way the soils will form. Taken together, these factors indicate that the strandlines may be traceable on soil maps in areas where they have not been mapped previously using traditional geologic techniques.

To date, I have worked on only two strandlines, the Herman and Norcross strandlines in Grand Forks County. However, the results have been encouraging. Figure 1 shows part of Soil Map Sheet 84 from the Grand Forks County Soil Survey (Doolittle et al., 1981). Hansen and Kume (1970) mapped the shaded areas as the Herman strandline. Look above and below the shaded areas and trace down the long, linear areas marked either 50B or 54B. The numbers 50B and 54B represent what I refer to as strandline-indicative soils. The soil scientists who mapped Grand Forks County described these soils as having moderately coarse to coarse textured (sand to sand and gravel) parent materials and forming on beach ridges (topographic position). When looking at the soil map, it appears the Herman strandline can be extended both to the north and the southeast of what is currently mapped as Herman strandline (Hanson and Kume, 1970). Figure 2 shows the results of continuing this sequence to the southern border of Grand Forks County. Complete discussions of the methods used in this work and the conclusions reached so far can be found in Brevik et al. (1998) and Brevik and Fenton (in press).

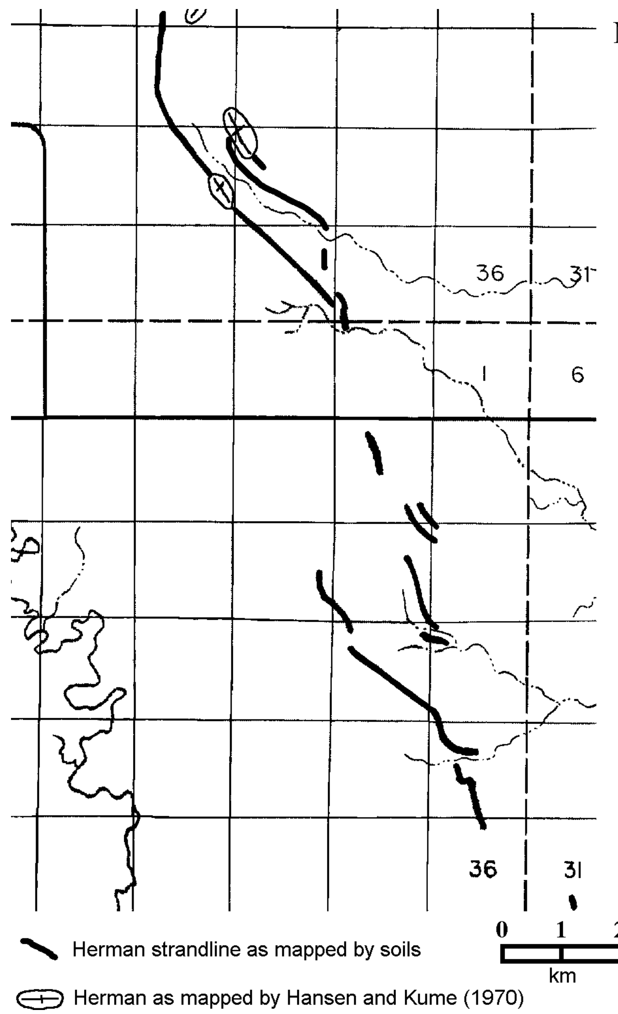

Figure 2 *– Map of part of southern Grand Forks County, showing areas that have been mapped as Herman strandline based on soil maps compared to areas mapped as Herman strandline by Hansen and Kume (1970). The mapped areas of strandline occur in portions of T. 149 N., R. 54 W., T. 150 N., R. 54 W., and Sec. 31, T. 149 N., R. 53 W. Base map from Hansen and Kume (1970). Figure from Brevik and Fenton (in press).*

The summary of the studies discussed above should not be interpreted in any way to imply that geologists no longer need to do field mapping, and can instead rely on soil maps. Geological maps and soil maps are made for very different reasons and because of that are not interchangeable. Soil maps also do not work well when trying to differentiate parent materials with similar properties, such as the diabase and basalt in the Culpepper Basin (Lindholm, 1993; 1994a). In some regions complex interactions between different geomorphic features (such as between adjacent strandlines in the Lake Agassiz basin) make differentiating those features based on soils alone impractical (Brevik and Fenton, in press). What these examples are intended to stress is that soil maps can be a powerful tool when used in conjunction with geologic maps and/or traditional geologic mapping techniques.

Conclusions

Geology and soil science have shared a common history in many ways, and researchers in each field still address many similar questions today. Knowledge of soils can benefit a geologist beyond just mapping. Geologists working in environmental consulting, geomorphology, paleoenvironmental reconstruction, wetlands research, and other areas can also benefit. Given that topography and parent material are two of the soil-forming factors and that soil mapping is frequently done by soil-landform relationships, soil scientists also have much to gain through the study of geology and geomorphology. The addition of the soil compilers to the staff at the North Dakota Geological Survey is a good, natural fit. Hopefully it will help lead to increased cooperation between geologists and soil scientists in researching areas of mutual interest in North Dakota.

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