Block Diagrams and Soil Profile Characteristics in Soil Genesis and Classification Courses

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ABSTRACT

One objective of a soil morphology, genesis, and classification course is to teach students how to generate reasonable hypotheses to explain soil distributions on landscapes. By the end of the course, students can begin to make predictions regarding changes in soil properties as a function of landscape elements and how different groupings of soils are indicated by mapping unit definitions or soil taxa. The *block diagram problem* is an exercise that helps the students to teach themselves about the relationships between taxonomic names, soil properties, and soil distributions on three-dimensional landscapes. The students' task in the block diagram problem is to match a list of soil series to a list of taxonomic names using a block diagram and soil series descriptions. The student is provided with the following information; family names from *Soil Taxonomy*, block diagrams, and soil series descriptions. Block diagrams help students visualize areas of water spreading or concentration, the relative stability of geomorphic surfaces, and distribution of parent materials. Soil series descriptions give morphological clues to the extent to which soil-forming processes have taken place, such as horizon differentiation. Students use principles of soil morphology, genesis, and geomorphology to relate series names to soil taxa. Block diagram problems help evaluate whether the objectives of the course have been met and make excellent homework and final examination questions.

Many soil morphology, genesis, and classification courses emphasize field description of soil properties, factors and processes of soil formation, and principles and types of classification systems, including an overview of nomenclature and diagnostic criteria used in *Soil Taxonomy* (Soil Survey Staff, 1975). It is important to help students visualize landscapes and potential soil mapping units. Much information is presented in short time periods with little opportunity to integrate these concepts. For many students, soil taxonomy may seem to be a bewildering foreign language exercise rather than an informative tool, as originally intended.

A block diagram is an idealized or conventionalized three-dimensional picture of a square or rectangular block cut from the earth's crust (Bilyew, 1964). Its surface shows important features of the landscape while the sides normally form sections of profiles of the underlying geology. Block diagrams are included in soil surveys to show the geomorphic relationships between soils and landscape

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positions. They help students to identify surfaces of water spreading (convex) or concentration (concave), the relative ages of geomorphic surfaces, and the distribution and importance of different parent materials.

Soil series descriptions give morphological clues to drainage characteristics (mottles), organic matter accumulation (color), particle-size classes (texture), and other phenomena associated with horizon differentiation and parent material distribution. The formative elements in soil taxa from *Soil Taxonomy* (Soil Survey Staff, 1975), such as "fluv" and "aqu," provide clues to important soil characteristics and climatic regimes.

The challenge in the block diagram problem is to match soil series to a list of taxonomic names. The students must interpret soil morphological descriptions and geomorphic relationships to make inferences about important diagnostic properties and corresponding soil taxa.

When students complete block diagram problems successfully, they demonstrate that they can speak fluently the "foreign language" of soil taxonomy, in other words, the block diagram tests the students' understanding of formative elements. Successful completion also indicates their ability to relate soil genesis (relative influence of soil-forming factors and processes) to landscape positions and to organize and evaluate a large set of given facts. Block diagrams can lead to discussions of soil genesis in diverse environments and settings including areas that are too far away for field trips and where field mapping exercises are not feasible.

MATERIALS AND METHODS

The block diagram exercise consists of three parts that are assembled by the instructor. The first part is a block diagram from a modern soil survey (Fig. 1 and 2). (Block diagrams are available in USDA-SCS soil survey reports from the following states: Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Texas, Utah, Vermont, Virginia, Washington, and Wisconsin.)

The second part consists of summary descriptions of soil series in tabular or descriptive form (Tables 1 and 2). The third part is an answer sheet with classifications to the family level (Table 3). (The correct answers have been included in Table 3 for the sake of discussion.) The soil profile descriptions may have to be altered slightly for teaching purposes to allow students to make unambiguous matches between soil series and family classifications.

Block diagrams with 3 or 4 taxa are given as practice exercises, working up to more complex diagrams with as many as a dozen taxa used in final or qualifying examination questions. Students are told that block diagrams for practice can be found in various soil survey reports. Exposure to soil survey reports cultivates an understanding of information available in soil surveys, thus adding to the educational diversity of the course.

Sample Problems

Students are advised to match soil and landscape characteristics with taxonomic names based on connotations of formative elements and diagnostic criteria for various taxa, as found in *Soil Taxonomy* (Soil Survey Staff, 1975). For example, the appearance of aquic or "aqu-" in a taxon should cause them to look carefully at drainage characteristics and low-lying landscape positions. Students can help themselves organize the data by drawing sketches of soil profiles using information found in the tables, such as vertical sections labeled A 0–5 cm (loam) and Bg 5–30 cm (clay loam).

The process of elimination is helpful, because the block diagram problem uses one-to-one matches between series and taxa. However, the series depicted on an individual block diagram do not usually fall within the same soil family, although this is possible in soil taxonomy. The students should be provided with enough information to

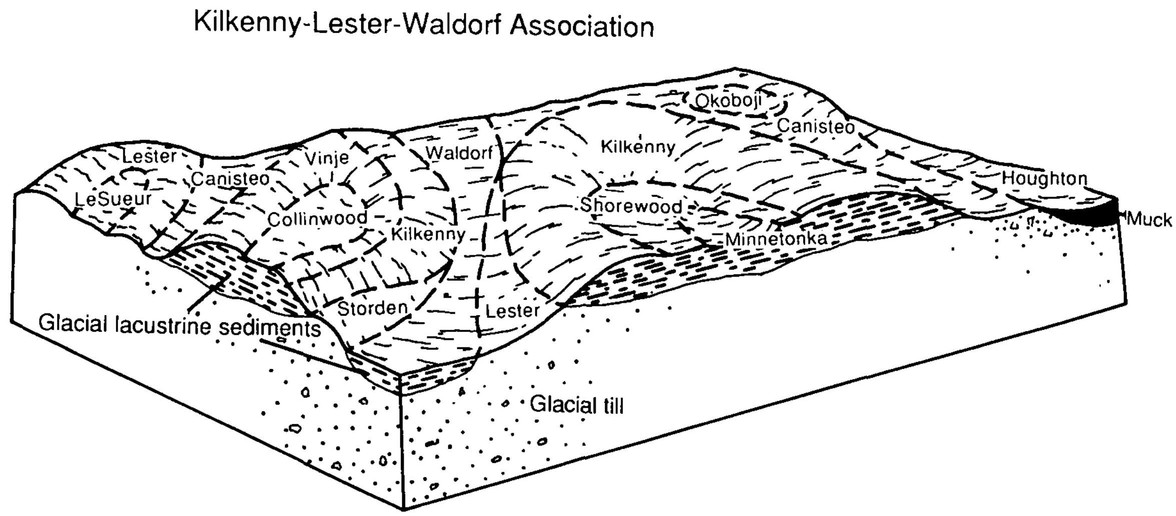

Fig. 1 Block diagram of soils and parent materials in the Kilkenny-Lester-Waldorf Association (Soil Survey of Winnebago County, Iowa).

Table 1. Characteristics of soils in the Kilkenny-Lester-Waldorf Association from Winnebago County, Iowa.

Soil series	Drainage class	Parent material	Surface soil	Subsoil	Substratum	Other features
A. Canisteo	poorly drained	glacial till	0–53 cm 10YR 2/1† clay loam	53–117 cm 5YR 5/2 clay loam	117+ cm 5YR 5/2 loam	20+ cm strong efferv.‡ 36+ cm mottles 5YR 4/2
B. Collinwood	somewhat poorly drained	glacio-lacustrine sediments	0–48 cm 10YR 2/1 silty clay	48–102 cm 2.5YR 4/2 silty clay	102+ cm 2.5YR 5/2 silty clay loam	102+ cm slight efferv. 86+ cm mottles 10YR 5/6
C. Houghton	very poorly drained	organic materials	0–20 cm N 2/0 sapric material	20–74 cm N 2/0 sapric material	74+ cm 10YR 2/1 mucky silt loam	
D. Kilkenny	well-drained	glacio-lacustrine sediments	0–20 cm 10YR 3/2 clay loam	20–114 cm 10YR 4/3-4/4 clay	114+ cm 2.5Y 4/4 clay	145+ cm slight efferv. 35+ cm mottles 2.5Y 5/6
E. Le Sueur	somewhat poorly drained	glacial till	0–36 cm 10YR 2/1-2/2 loam	36–89 cm 2.5Y 4/2 clay loam	89+ cm 5Y 5/3 loam	89+ cm strong efferv. 51+ cm mottles 2.5Y 5/6
F. Lester	well-drained	glacial till	0–18 cm 10YR 3/2 loam	18–36 cm 10YR 4/4-5/4 clay loam	86+ cm loam	86+ cm strong efferv. 2.5Y 5/4 10YR 5/8
G. Minnetonka	poorly drained	glacio-lacustrine sediments	0–36 cm 10YR 2/1-3/2 clay loam	36–119 cm 5Y 2/1-5/2 silty clay loam	119+ cm 5Y 6/2 silty clay loam	119+ cm slight efferv. 48+ cm mottles 5YR 5/3
H. Okoboji	very poorly drained	glacial till	0–71 cm N 2/0 silty clay loam	71–122 cm 5Y 3/1 silty clay loam	122+ cm 5Y 5/1 silty clay loam	122+ cm mottles 10YR 5/8
I. Shorewood	somewhat poorly drained	glacio-lacustrine sediments	0–38 cm 10YR 2/1 silty clay loam	38–99 cm 2.5Y 4/2 silty clay	99+ cm 2.5Y 4/2 silty clay loam	107+ cm strong efferv. 21+ cm mottles 2.5Y 5/2
J. Storden	well-drained	glacial till	0–20 cm 10YR 5/3 loam	20–97 cm 2.5Y 5/4 loam	97+ cm 2.5Y 5/4 loam	0+ cm strong efferv. 61+ cm mottles 10YR 5/8
K. Vinje	well-drained	glacio-lacustrine sediments	0–33 cm 10YR 2/2 silty clay loam	33–104 cm 10YR 4/3–4/4 silty clay loam	104+ cm 2.5Y 5/2 silty clay loam	104+ cm strong efferv.
L. Waldorf	poorly drained	glacio-lacustrine sediments	0–48 cm 5YR 2/1 silty clay	48–112 cm 5Y 5/1–5/2 silty clay	112+ cm 5Y 5/2 silty clay loam	112+ cm strong efferv. 69+ cm mottles 2.5Y 5/4

† Colors are for moist soil. ‡ Efferv. = effervescence.

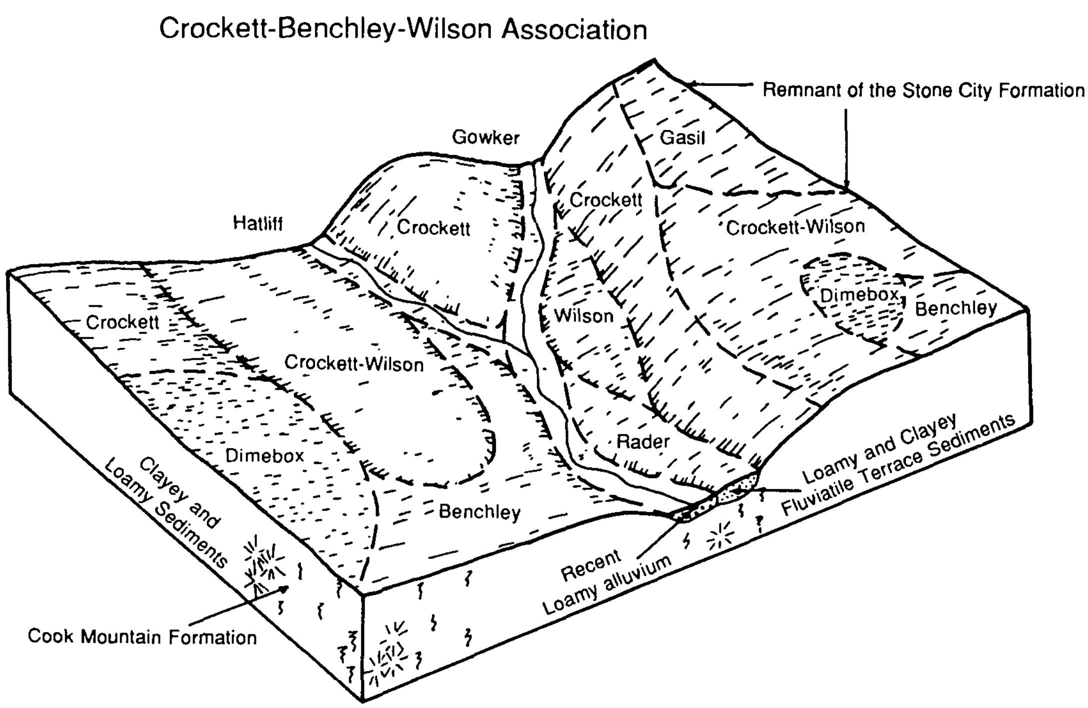

Fig. 2. Block diagram of soils and underlying material in the Crockett-Benchley-Wilson Association (Soil Survey of Leon County, Texas).

Table 2. Characteristics of soils in the Crockett-Benchley-Wilson Association from east central Texas.

Soil series	Drainage class	Surface soil	Subsoil	Substratum	Landscape position
A. Benchley	well-drained	0–33 cm 10YR 3/1† clay loam	33–46 cm 10YR 3/1 clay	46+ cm 2.5YR 5/6 clay	broad, sloping ridges weakly defined saddles and footslopes
B. Crockett	well-drained	0–18 cm 10YR 5/4 sandy loam	18–94 cm 10YR 5/4–2.5Y 5/4 clay	94+ cm 2.5Y 4/4 clay	broad, sloping ridges and sidelopes
C. Dimebox	well-drained	0–10 cm 10YR 3/1 silty clay	10–180 cm 10YR 2/1–3/1 clay	180+ cm 10YR 4/1 clay	broad ridges and level saddles
D. Gasil	well-drained	0–41 cm 10YR 3/3–6/3 sandy loam	41–183 cm 10YR 4/4 sandy clay loam	183+ cm 10Y 5/4 sandy loam	ridges and remnants of the Stone City Formation
E. Gowker	well-drained	0–61 cm 10YR 3/1-3/2 clay loam	61–102 cm 10YR 3/2 sandy clay loam	102+ cm 10YR 5/4–5/2 sandy loam	bottomlands
F. Hatliff	well-drained	0–20 cm 10YR 3/3 sandy loam		20+ cm 10YR 5/3–5/1 sandy loam and loamy sand (stratified)	bottomlands subject to flooding
G. Rader	well-drained	0–15 cm 10YR 3/3 sandy loam	15–137 cm 10YR 5/3–6/1 sandy clay loam	137+ cm 10YR 6/2–7/1 clay and sandy clay loam (stratified)	mounded terraces, lower concave areas of headslopes
H. Wilson	somewhat poorly drained	0–18 cm 10YR 3/1 clay loam	18–66 cm 10YR 3/1 clay	66+ cm 10YR 3/1–6/2 clay	broad, gently sloping ridges

† Colors are for moist soil.

match the series to the taxa. To make the exercise less cumbersome and ambiguous, the profile descriptions from the survey can be shortened and edited by the instructor.

Two sample problems are given below, each with different solutions derived independently by two individuals. The first problem was created using the Soil Survey of Winnebago County, Iowa (Jones, 1987) and consists mostly of Mollisols developed on glacial drift parent materials (Fig. 1). The second problem includes soils from four soil orders (Entisols, Vertisols, Alfisols, and Mollisols) on uplands in Leon County, Texas (Neitsch et al., 1989) (Fig. 2).

Kilkenny-Lester-Waldorf Association—Solution no. 1

A quick scan of the answer sheet (Table 3) for the Kilkenny-Lester-Waldorf Association from Winnebago County, Iowa, shows that the following soil characteristics are important: organic soil materials (Histosol); aquic moisture regimes (based on drainage class, landscape position and mottles); argillic horizons (clay translocation with depth); mollic epipedons (colors of surface soils); and a cumulic subgroup (landscape position).

The Histosol is the easiest taxon to match because of the sapric material described in the Houghton series (Houghton, C = 1). The Stordon series is the best candidate for the Entisol because: (i) its steep slopes would limit soil development (Fig. 1), (ii) loam textures throughout indicate little horizon differentiation (Table 1), (iii) loam textures agree with fine-loamy particle size class (vs. fine), (iv) strong effervescence agrees with mineralogy class modifier (calcareous), and (v) the color of the surface soil rules out a mollic epipedon (exclusion from Mollisols) (Storden, J = 2).

Table 3. Answer sheet to sample problems.

Kilkenny-Lester-Waldorf Association:		
1.	Houghton (C)	loamy, mixed, euic, mesic Terric Medisaprists
2.	Storden (J)	fine-loamy, mixed (calcareous), mesic Typic Udorthents
3.	Canisteo (A)	fine-loamy, mixed (calcareous), mesic Typic Haplaquolls
4.	Lester (F)	fine-loamy, mixed, mesic Mollic Hapludalfs
5.	Le Sueur (E)	fine-loamy, mixed, mesic Aquic Argiudolls
6.	Kilkenny (D)	fine, montmorillonitic, mesic Mollic Hapludalfs
7.	Minnetonka (G)	fine, montmorillonitic, mesic Typic Argiaquolls
8.	Shorewood (I)	fine, montmorillonitic, mesic Aquic Argiudolls
9.	Collinwood (B)	fine, montmorillonitic, mesic Aquic Hapludolls
10.	Okoboji (H)	fine, montmorillonitic, mesic Cumulic Haplaquolls
11.	Waldorf (L)	fine, montmorillonitic, mesic Typic Haplaquolls
12.	Vinje (K)	fine, montmorillonitic, mesic Typic Hapludolls
Crockett-Benchley-Wilson Association:		
1.	Hatliff (F)	coarse-loamy, siliceous, nonacid, thermic Aquic Udifluvents
2.	Rader (G)	fine-loamy, mixed, thermic Aquic Paleustalfs
3.	Gowker (E)	fine-loamy, mixed, thermic Cumulic Hapludolls
4.	Gasil (D)	fine-loamy, siliceous, thermic Ultic Paleustalfs
5.	Crockett (B)	fine, montmorillonitic, thermic Udertic Paleustalfs
6.	Dimebox (C)	fine, montmorillonitic, thermic Udic Pellusterts
7.	Benchley (A)	fine, montmorillonitic, thermic Vertic Argiustolls
8.	Wilson (H)	fine, montmorillonitic, thermic Vertic Ochraqualfs

The drainage classes and the importance of aquic moisture regimes help to discriminate between the remaining 10 series. There are three groupings among the series: very poorly and poorly drained (Canisteo, Minnetonka, Okoboji, and Waldorf), somewhat poorly drained (Collinwood, Le Sueur, and Shorewood), and well drained (Kilkenny, Lester, and Vinje). Among the taxa, aquic moisture regimes are expressed at two levels: suborder (Aquolls) and subgroup (Aquic Arguidolls and Aquic Hapludolls).

The four very poorly and poorly drained series correspond to the four Aquolls. The Canisteo series has strong effervescence beginning at 20 cm depth and is the best match for the fine-loamy, mixed (calcareous), mesic Typic Haplaquolls (Canisteo, A = 3). Okoboji, with its relatively thick surface material, corresponds best to the fine, montmorillonitic, mesic Cumulic Haplaquolls (Okoboji, H = 10). The Minnetonka and Waldorf series remain. One has an argillic horizon (Argiaquolls, 7) and the other does not (Haplaquolls, 11). The textures given in Table 1 indicate that the Minnetonka has a clay translocation in the subsoil. Thus, the Minnetonka series belongs to the Argiaquolls and the Waldorf series belongs to the Haplaquolls (Minnetonka, G = 7; Waldorf, L = 11). In the above examples, the student needs to know what the formative elements "aqu" and "argi" mean in terms of morphology.

Somewhat poorly drained soils (Shorewood, Le Sueur, and Collinwood) correspond to taxa with aquic intergrades expressed at the subgroup level, such as Aquic Arguidolls. The Le Sueur series formed on glacial till and has clay translocation suggesting an argillic horizon (Table 1) (Le Sueur, E = 5). Shorewood also has a clay translocation with depth and was formed on finer-textured glacio-lacustrine sediments (Shorewood, I = 8). The Collinwood series, with no textural evidence for an argillic horizon, fits in the fine, montmorillonitic, mesic Aquic Hapludolls (B = 9). In these cases, the student had to look at textures in Table 1 and relate them to the particle-size classes and the formative element "argi" in the taxa listed in Table 3.

All but the Vinje, Lester, and Kilkenny series have been eliminated. These are the well-drained soils, they have no "aqu" in their name. The student can write the remaining taxa on a piece of scratch paper; one fine-loamy and one fine, montmorillonitic, mesic Mollic Hapludalf and a Typic Hapludoll. The Vinje, with no indication of a clay translocation with depth and relatively fine textures, belongs to the Typic Hapludolls (Vinje, K = 12). The Lester soil is found on glacial till and has loam to clay loam textures, so it should have the fine-loamy particle size class (Lester, F = 4). The Kilkenny series, with clay loam and clay textures, is more likely to have the fine particle-size class and montmorillonitic mineralogy class (Kilkenny, D = 6).

Kilkenny-Lester-Waldorf Association—Solution 2

Another possible thought process to determine the correct matches for the Kilkenny-Lester-Waldorf association is as follows. Examination of the family names identifies one Histosol (1), two Alfisols (4, 6), one Entisol (2), and eight Mollisols (3, 5, 7, 8, 9, 10, 11, 12). The one Histosol is obvious because only one series, Houghton (C), has organic soil material (sapric) (Houghton, C = 1). The colors and thicknesses of surface horizons indicate the possibility of mollic epipedons in eight series (A, B, E, G, H, I, K, L).

This leaves D, F, and J for the Alfisols and the Entisol. Only D and F have a clay translocation in the subsoil. The student should remember that argillic horizons are diagnostic for Alfisols. The Storden series, J, does not have the clay increase with depth to suggest an argillic horizon. It has a loam texture and effervescence from the surface, which are consistent with the fine-loamy particle-size class and the calcareous class of the Udorthent (J = 2). The two Alfisols have different particle-size classes, fine-loamy (4), and fine (6). These match with subsoil textures of clay loam and clay for F and D, respectively (F = 4, D = 6). At this point, the student has eliminated the four "non-Mollisols" from further consideration.

To distinguish the eight Mollisols, soil moisture regimes are now considered. Four taxa have aquic soil moisture regimes expressed at the suborder level (3, 7, 10, 11). Four of the remaining series are described as being very poorly or poorly drained (A, G, H, L). Of these four Aquolls, one has an argillic horizon (7) and one has a thick epipedon (10). Only one of the poorly drained series has an obvious clay translocation into the subsoil (G) and is thus selected as the Argiaquoll (G = 7). Only H meets the color requirement for mollic to a depth of greater than 50 cm, a criterion for cumulic subgroups. The subsoil texture of silty clay loam is consistent with a fine family and thus H is the Cumulic Haplaquoll (H = 10). The two remaining Aquolls have particle-size classes of fine-loamy and fine, which match with subsoil textures of clay loam and silty clay for A and L, respectively (A = 3, L = 11).

Four Mollisols remain; three are aquic intergrades (5, 8, 9) and three remaining series are somewhat poorly drained (B, E, I). The two with clay increases in the subsoils (E, I) match with 5 (fine-loamy) and 8 (fine) on the basis of particle-size classes (E = 5, I = 8). Matching the remaining somewhat poorly drained series, B, with 9 is supported by a fine particle-size class and a silty clay subsoil texture. One soil series, K, and one taxon, 12, remain. Again the soil characteristics are consistent with the taxonomic name: clay loam subsoil—fine particle-size class; dark surface—mollic epipedon; well drained—no aquic characteristics.

Crockett-Benchley-Wilson Association—Solution no. 1

The soils used in this example are from the east central part of Texas. The most important features used to match series to family names are landscape position (Fig. 2), drainage class, soil colors, and textures. All soils in the Crockett-Benchley-Wilson Association have stratified clay, shale, and sandstone parent materials of the Cook Mountain Formation, with the exception of the Gasil series. The Gasil series formed on clay, silts, and sands interbedded with glauconitic sands of the Stone City Formation.

The easiest series to eliminate in this block diagram are those in low lying areas. Table 2 and Fig. 2 show that the Hatliff series is subject to flooding and has stratified substratum and is probably a Fluvent (F = 1) (Table 3). In addition, the Hatliff series' sandy loam and loamy sand textures agree with the Fluvent's coarse-loamy particle-size class. The Gowker series could be mistaken as a Fluvent if the student relied on the block diagram alone, because of the Gowker's floodplain position. Its very dark gray and grayish brown surface colors suggest that it is a Mollisol and its clay loam and sandy clay loam textures agree with a fine-loamy particle-size class (E = 3).

The Vertic Ochraqualf is the only taxon with an aquic moisture regime expressed at the suborder level (Table 3). Looking at Table 2, the Wilson series is the soil with the poorest drainage (somewhat poorly drained). Its clay loam and clayey textures are consistent with vertic soil properties (H = 8).

There are two aquic intergrades, but the Udifluvent has been eliminated, leaving the Aquic Paleustalf. The Rader series tends toward an aquic moisture regime because of its landscape position, lower concave areas of headslopes, which are areas of water accumulation (Fig. 2, Table 2). Classification in the Alfisols requires an argillic horizon, which is supported by clay translocation from the surface soil (sandy loam) to the subsoil (sandy clay loam).

There is one Vertisol on the list (Table 3). Broad ridges and level saddles are prime locations for the formation of shrink swell clays (Fig. 2). Using landscape position and silty clay and clayey textures, the Dimebox series is the best candidate for the Udic Pellustert (C = 6).

The Benchley series is found on weakly defined saddles and footslopes (Fig. 2). The clay content increases with depth, from a clay loam to a clay (Table 2), suggesting an argillic horizon. The dark surface colors, required for mollic epipedons, place the Benchley series in the family of fine, montmorillonitic, thermic Vertic Argiustolls (A = 7).

The remaining two series, Crockett and Gasil, both have evidence for an argillic horizon based on textures (Table 2). The two remaining taxa are the Udertic Paleusterts and Ultic Paleustalfs. The Crockett series has relatively finer textures (clays vs. sandy clay loams), suggesting that it would be a better candidate for the intergrade to the Uderts and the fine family (B = 5). The Gasil series' sandy loam and sandy clay loam textures fit better with the fine-loamy, siliceous, thermic Ultic Paleustalfs (D = 4). In addition, the Gasil series is located on ridges and remnants of an older formation, which corroborates the more highly leached Ultic subgroup.

Crockett-Benchley-Wilson Association—Solution no. 2

The identification of family classifications for series of the Crockett-Benchley-Wilson association can also be accomplished as follows. In checking the family classifications (Table 3), one Entisol (1), one Vertisol (6), two Mollisols (3, 7), and four Alfisols (2, 4, 5, 8) are found. The Entisol has a coarse-loamy particle-size class and only one soil (F) has an appropriate subsoil texture (sandy loam, Table 2) (F = 1). Only one soil (H) has a drainage class other than well-drained. The best match for this soil is with the aquic soil moisture regime (H = 8).

Three remaining series have colors that could be mollic (A, C, E), but only two Mollisols are named. Vertisols often have colors that meet the requirement for mollic epipedons. In examining the textures of A, C, and E, only C must have a clay content above 30% in the surface layer. This, together with a high clay content throughout, makes C the best choice for the Vertisol (C = 6). In considering A and E, A does not have dark colors thick enough for cumulic (>50 cm) and E does not apparently have a clay translocation in the subsoil (clay loam over sandy clay loam). Thus, A is the best choice for the Argiustoll (A = 7) as it does have a clay increase (clay loam over clay) and E is the best choice for the Cumulic Hapludoll (E = 3) because it has 100 cm of soil dark enough for mollic.

Three soils (B, D, G) and three Alfisols (two fine-loamy and fine) remain. Only one, B, cannot be fine-loamy because it has a clay subsoil texture. Thus, it is the fine Paleustalf (B = 5). Mismatching the final two is not a major problem. Both D and G have subsoil clay increases and thick subsoil, both consistent with Paleustalfs. The landscape position of "ridges" for D and "concave areas" for G can be used to assign D to the better drained taxon, 4, and D to the aquic intergrade, 2 (D = 2, G = 4).

DISCUSSION

Block diagram problems have been used for more than 10 yr as homework and final examination questions in Soil Science 118 (Soil Morphology, Genesis, and Classification) and in written qualifying exams at the University of California at Riverside. During the fall semester of 1989, the senior author used them in examinations and homework sets in Natural Resources 360 (Origin and Classification of Soils) at Humboldt State University. The block diagram problem was introduced at the beginning of both courses to show the students what they would be able to accomplish by the end of the course.

A common problem for students in any discipline is how to select and use information from lists of terms and tables of data. (Originally, we gave the students profile descriptions directly from the surveys, but found that instructor-generated tables cut down on the initial frustration levels.) A student might see a taxon with "aqu" somewhere in the name, but assign it incorrectly to the first poorly drained series they see on the list, without considering other possibilities. After the most obvious cases have been eliminated, the instructor encourages students to rank the series according to one property at a time or state whether it has a certain diagnostic property at all. The properties of interest should come from formative elements in the list of taxa. Which have aquic moisture regimes? Which is most "aquic"? Are there any mollic epipedons? Which is most "mollic"?

Once students make a tentative match, they should test their hypothesis using other properties. For example, I may think that Series A matches Taxon X because the series has mollic properties and the taxon is a Mollisol, but I should ask myself if Series A has textures consistent with Taxon X's particle-size class. As with many kinds of puzzles or problems, students get better with practice, so it's a good idea to start off with simple block diagrams with four or five taxa or lengthier lists with a few free answers. It is always beneficial to discuss the solutions in an informal group setting where students can see different approaches to the problem and learn how others avoided pitfalls. In homework assignments, students were encouraged to compete individually or work together in teams to solve these "puzzles".

The block diagram problem integrates many of the concepts taught in soil morphology, genesis, and classification courses. Once the problem has been attempted as a homework assignment or test problem, it can be used for further discussion. The following are suggested discussion questions. What kinds of information are found in taxonomic names? What are some of the most important differentiating characteristics used at different levels of soil taxonomy? Why is it important to recognize landscape elements (e.g., summits, shoulders, sideslopes, footslopes, toeslopes, floodplains)? What effect does slope have on soil development? Which landscape positions are more "stable"? How does water move on concave vs. convex surfaces under given climatic regimes and parent material configurations? Why is it important to know something about different parent materials in an area?

Different individuals have different ways of solving problems. There is no unique solution to match the series to the taxa. The individual who gave the first solution (for both examples given in this paper) relied more heavily on hypotheses generated from the block diagram, using geomorphology to make inferences about drainage classes, aquic moisture regimes, and likely locations for cumulic subgroups. This individual also looked at areas where soils might be highly differentiated, on the oldest geomorphic surfaces (the Gasil series, an Ultic Paleustalf on summit positions of Fig. 2), and the places where the soils might be the youngest, due to continuous erosion (the Storden series, a typic Udorthent on well-drained sideslopes of Fig. 1). The second individual used the information from Tables 1 and 2 in a very efficient manner, and could have solved the problem without the block diagram. Although we have written the solutions in prose form here, the instructor may wish to devise a flow chart or dichotomous key to organize the information.

An important point is that when an individual goes to the field to characterize soils, whether for general soil survey or for more detailed field experiments, there probably won't be any tables of information from which they can generate hypotheses regarding soils distributions or formation. The students will have to make their own guesses about the magnitude of field scale variability and how it could affect the intended land use or experimental design. An important skill that can be obtained from soil genesis and classification courses is the ability to make hypotheses about soil-forming processes (additions, removals, translocations, and transformations) in the context of the landscape or geomorphic setting.

CONCLUSIONS

Although we have not gathered performance data for block diagram problems specifically, most students in our courses were able to solve the problems by the end of the term, at least partially. The block diagram problem is an accessible tool that can lead the students beyond the mere memorization of facts, descriptive morphological terms, and formative elements associated with soil taxonomy. The students who thoroughly understand the course material, based on high examination and homework scores, were able to make perfect matches between series and taxa. With practice, they met the objective of generating reasonable hypotheses about soil distributions on landscapes by matching soil series to taxonomic names.

The block diagram problem serves as a conceptual bridge between soils and nonsoils students and disciplines. For example, the block diagram can be used to introduce geomorphology to soil science students. It is important for all students to gain an appreciation for soil variability over space and time. Hydrologists, geologists, and engineers often work at landscape scales where soil properties vary significantly over short distances. In terms of time, geologists may be interested primarily in phenomena occurring over the past hundreds of thousands to millions of years. Degrees of soil development, related to different geomorphic surfaces, can be used to generate interesting hypotheses about past climates and faulting history and the block diagram provides a good starting point for discussion.

REFERENCES

Bilyew, G.L. 1964. Block diagrams. USDA-SCS, Cartographic unit, Ft. Worth, TX.

Jones, R.G. 1987. Soil survey of Winnebago County,Iowa. USDA-SCS, U.S. Gov. Print. Office, Washington, DC.

Neitsch, C.L., J.J. Castile, and M.R. Jurena. 1989. Soil survey of Leon County, Texas. USDA-SCS, U.S. Gov. Print. Office, Washington, DC.

Soil Survey Staff. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA-SCS Agric. Handb. 436. U.S. Gov. Print. Office, Washington, DC.