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EPIPEDONS IN PENNSYLVANIA SOILS

by

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INTRODUCTION

Epipedons are zones or layers that have formed at the surface of the soil. They are characterized by the loss of rock structure and by eluviation and/or by darking with organic matter (Soil Survey Staff, 1996). Most epipedons in Pennsylvania are characterized by features indictive of all three of these processes. Epipedons are a part of the USDA Natural Resources Conservation Service (formerly the USDA Soil Conservation Service) soil classification system "Soil Taxonomy" (Soil Survey Staff, 1975, 1996). The epipedon is an attempt to define a soil surface horizon which would account for the disturbance and mixing of the upper horizons, particularly by farming practices (plowing). The Soil Survey Staff (1975) did not want the same soil in plowed fields and adjacent undisturbed areas (in Pennsylvania these would mainly be forests) to be classified differently. Soil Taxonomy (Soil Survey Staff, 1996) identifies seven types of epipedons (Table 1). Of these epipedons the ochric is by far the most abundant in Pennsylvania, and there are only very small acreages of histic, umbric, and mollic epipedons present in the state

Table 1. General features of Soil Taxonomy epipedons (see Soil Survey Staff, 1996 for a more detailed definition).

Epipedon	Thickness	Color	Base Saturation	Parent Material	Native Vegetation
Mollic	thick	dark	high	varies	prairie
Umbric	thick	dark	low	varies	mainly forest
Anthropic†	thick	dark	varies	varies	varies
Melanic	thick	dark	varies	volcanic ash	varies
Histic††	moderate	varies	varies	organic	varies
Plaggen*	moderate	varies	varies	man deposited	mainly forest
Ochric**	thin	light	low	varies	mainly forest

†It has a high phosphorous content due to man's influence.

††It is an organic horizon on a mineral soils, and it usually is found in low, wet areas adjacent to organic soils.

*It is a man-made horizon usually only found in Europe or the British Isles.

**It also can have low organic matter content.

covering a total area of < 0.3% of the state's land surface. Very little information has been gathered or published on the epipedons in Pennsylvania soils. Thus, the intent of this publication is to focus on the distribution, properties, and genesis of the major epipedon that is found in Pennsylvania soils, the ochric epipedon.

This is the fourth publication on the various types of soil horizons that have formed in Pennsylvania. The other publications have focused on the following subsurface zones: fragipans (Ciolkosz et al., 1995a), cambic horizons (Ciolkosz and Waltman, 1995), and argillic horizons (Ciolkosz et al., 1996).

HORIZON NOMENCLATURE

Some confusion exists between soil horizon nomenclature and Soil Taxonomy epipedons such as the ochric epipedon. Soil horizon nomenclature is a qualitative field assessment of the type of pedogenesis that has taken place in a particular layer of the soil. Thus, the horizon symbol A indicates that in the judgment of the field soil scientist this mineral soil horizon shows an observable accumulation of humified organic matter as indicated by its dark color, structure, and occurrence at the soil surface (Soil Survey Div. Staff, 1993). The epipedons of Soil Taxonomy are defined in more quantitative terms on the properties of the upper 18 cm (7 in) or more of the soil after it has been mixed. This was done to keep both cultivated and virgin soil pedons (vertical column of soil; frequently used synonomously with soil profile) classified the same (Soil Survey Staff, 1975; 1996). For thick A horizons this does not significantly affect the properties of the epipedon, but for thin surface horizons such as those developed under forest vegetation the mixing may significantly affect the properties of the horizon of humified organic matter accumulation. The reason is that the A horizon of virgin forest soil pedons in Pennsylvania average about 9 cm (3.5 in) thick and are underlain by an E (zone of eluviation) or Bw (cambic-color and/or structural B) horizon. Thus, when virgin profiles are mixed for classification purposes or by farming activities the original organic matter content is reduced by dilution with lower organic matter content material. In addition, plowing in Pennsylvania as indicated by the thickness of Ap horizons of pedons (Penn State Soil Characterization data base; Ciolkosz and Thurman, 1994) in the past has been 20 to 25 cm (8 to 10 in) deep, with some as deep as 40 cm (16 in). This would give about a 2:1 dilution of the original A horizon material for most of Pennsylvania's Ap horizons. Today most farmers do not plow 25 cm deep. In general, they plow 15 to 18 cm (6 to 7 in) deep, which in many fields produces a two layer A horizon (Ap1, Ap2). This horizon arrangement is also found in areas that are no longer in cultivation and are used as pastures or have reverted to forest.

DISTRIBUTION

Soils with ochric epipedons are found throughout the state. This is to be expected because forest was the native vegetation for almost the entire state during the Holocene (last 10,000 yrs) (Braun, 1950; Delcourt and Delcourt, 1983). The only known exception was small areas (about 40,000 acres total; Ciolkosz and Dobos, 1989) of prairie scattered around the state (Waltman and Ciolkosz, 1995; Waltman, 1988). Soils developed under prairie vegetation tend to have thick, dark colored epipedons which generally classify as mollic epipedons. Although no soils with umbric epipedons have been mapped by the Natural Resource Conservation Service (NRCS) soil survey, there undoubtedly are some in the cool, moist, non-sandy high elevation areas of the state which are frigid or marginally frigid (< 8°C mean annual soil temperature) (Figure 1) and perudic or marginally perudic (precipitation > evapotranspiration all year) (Figure 2) (Waltman et al., 1997) as well as some in poorly or very drained soil areas.

PROPERTIES

Color

The color of epipedons in Pennsylvania soils does not vary much in hue, being dominantly 10YR regardless of whether they are in the forested virgin state (A) or have been cleared, plowed, and put into agriculture (Ap) (Table 2). On the other hand, chroma and value of the surface horizons are affected by plowing. The data in Table 2 indicate an increase of about 1 step in chroma and value between the A and Ap horizons. Thus, upon plowing, surface horizons become

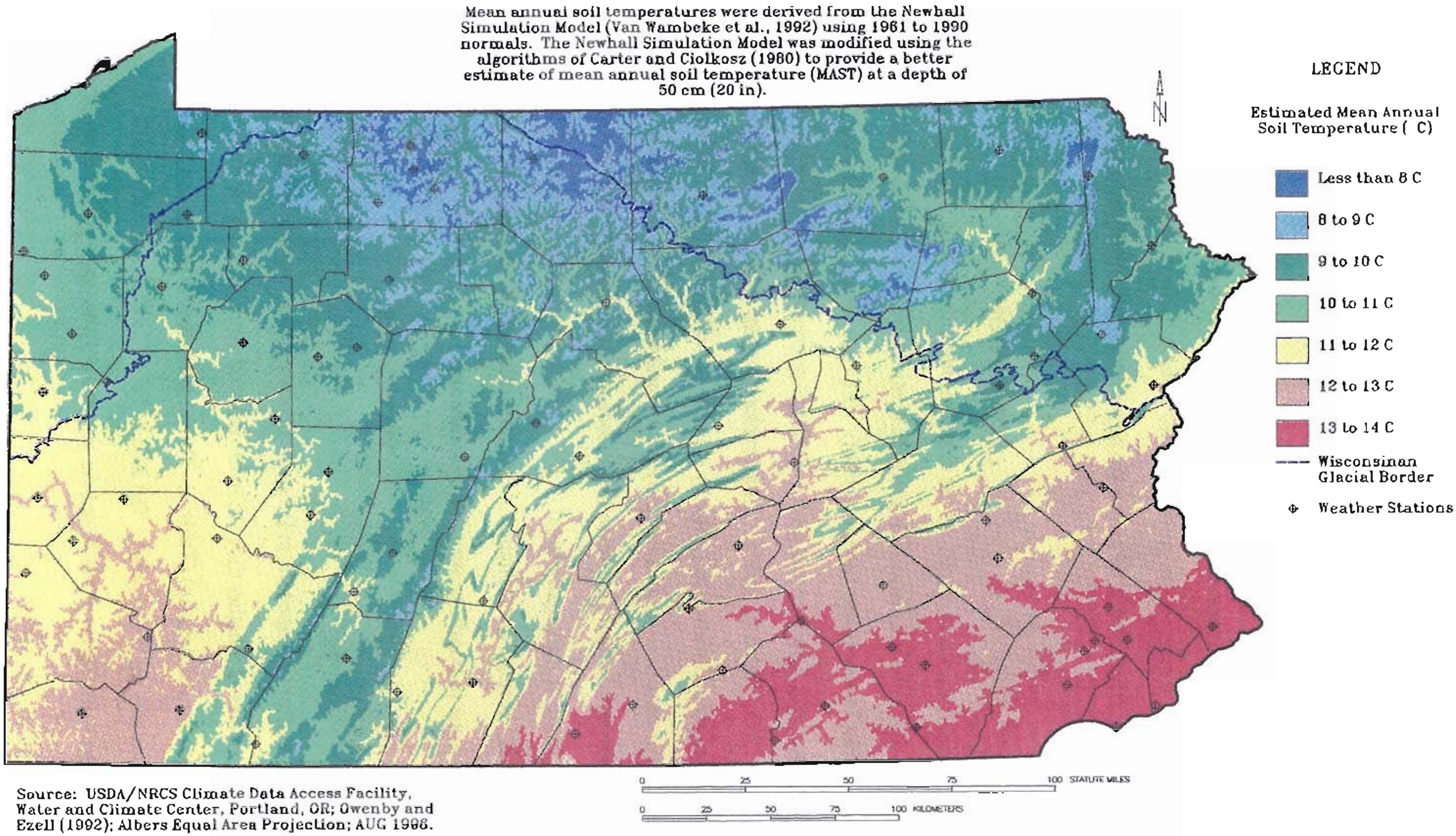

Figure 1. Mean annual soil temperatures of Pennsylvania landscapes.

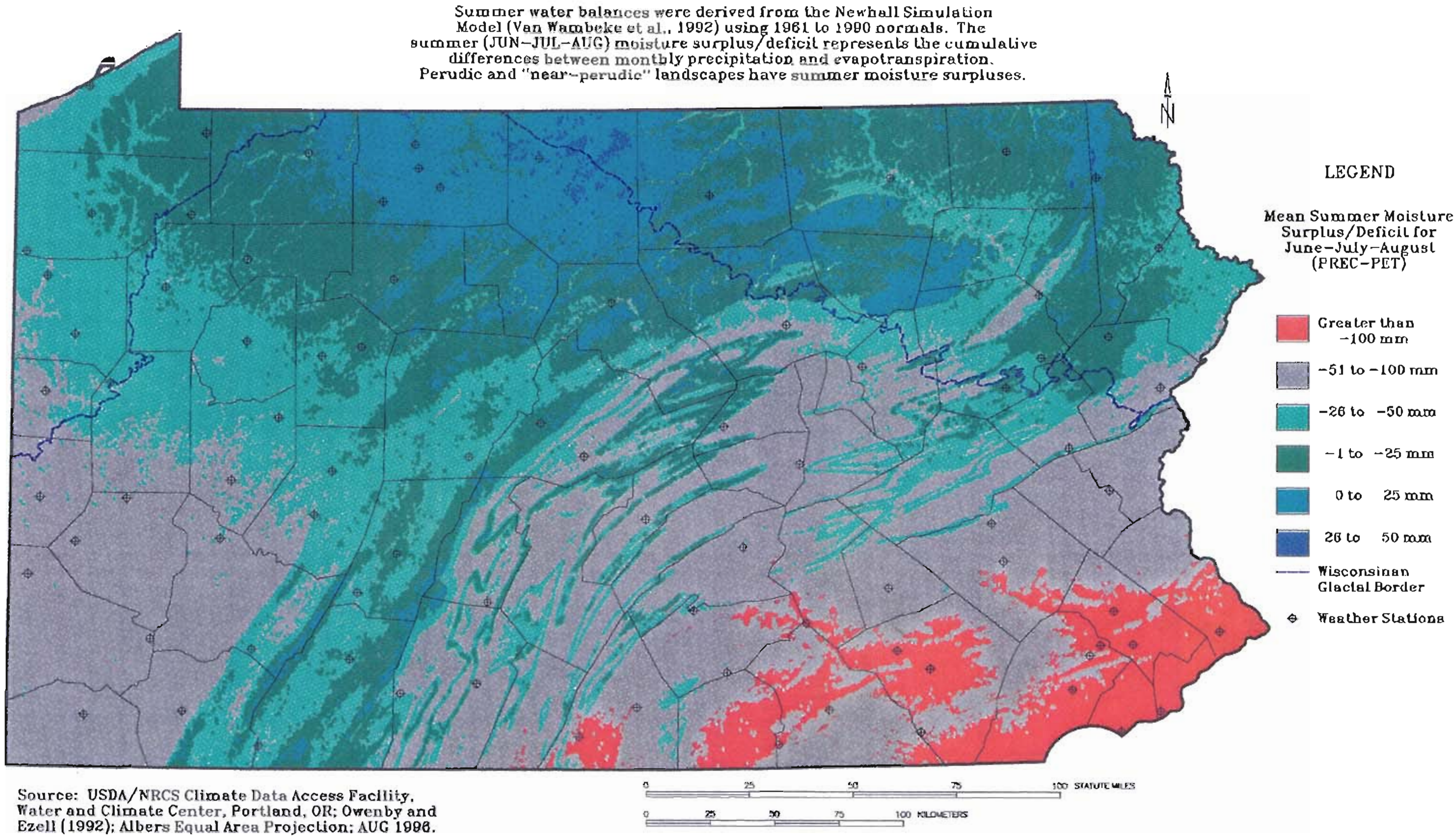

Figure 2. Mean summer (June–July–August) water balance of Pennsylvania landscapes. Perudic and "near-perudic" landscapes have summer moisture surpluses.

Table 2. Number of pedons with various hue, value, and chroma (Munsell) in the Penn State Soil Characterization Lab database (Ciolkosz and Thurman, 1994). Minesoils were not included in these data.

Munsell	Number of Pedons					Number of Pedons	
	Value+		Chroma+			Hue+	
Steps	A	Ap	A	Ap	Hue	A	Ap
0	0	0	9	2	2.5 Y	4	30
1	0	0	64	12	10 YR	131	353
2	60	9	86	232	7.5 YR	22	65
3	86	215	28	201	5 Y	28	42
4	37	267	8	67	2.5 YR	3	22
5	13	24	0	0	10 R	0	1
6	1	0	2	0	N	9	2

+Moist state.

slightly brighter (increase in chroma) and lighter (increase in value) in color. The reason for this change is twofold. Firstly, the A horizons are thin (about 9 cm, 3.5 in.) as compared to Ap's (about 22 cm) and are underlain by lighter and brighter colored E or B horizons. Thus, when the A horizons are mixed with the underlying material, the dark humic material is diluted with the lighter and brighter colored material. Secondly, when plowed, some of the organic material may be oxidized at a more rapid rate than in the natural, forested, unplowed state, because of an increase in the rate of microbiological activity due to a greater degree of aeration, an increase in temperature (more direct sunlight) and to the addition of fertilizer and lime to the soil.

The soil characterization data also indicates that there are slight differences in value and chroma of about 40% of the Ap2 horizons when compared to the Ap1 horizons. These Ap2 horizons are mainly one step higher in value (lighter) and chroma (brighter). This difference is apparently related to a difference in organic carbon (organic matter) content between the Ap1 and Ap2 horizons (Table 3). The difference between A and Ap value and chroma is also explained by an organic carbon content difference of A = 5.27% and Ap's = 1.78%. The organic carbon color relationships noted have also been reported for a number of soils in other areas (Schulze et al., 1993; Qian et al., 1993). There also appears to be a weak trend of decreasing chroma with poorer drainage (Table 9).

Table 3. Characteristics of Ap1 and Ap2 horizons.

Horizon	Average Percent				Number of Pedons
	Organic Carbon	Sand	Silt	Clay	
Ap1	1.95	30.8	48.1	21.1	38
Ap2	1.18	29.6	48.8	21.6	38

Texture

The texture of the epipedons in Pennsylvania does not vary as greatly as the texture of the subsurface horizons. Figure 3 is a general presentation of the surface texture of Pennsylvania soils and shows that silt loam is the dominant surface texture (63%) with loam second (23%) and sandy loam third (8%) in abundance (Table 4). Thus, three textural class groupings make up about 94% of the textural of Pennsylvania epipedons. When virgin pedons are mixed by plowing, the texture of the plow layer (Ap) is usually not different than the original A horizon because the underlying E or Bw horizon is usually the same or a very similar texture. An exception occurs if the plowed horizon is eroded, and subsequent plowing mixes an underlying argillic horizon (Bt) into the Ap, which in turn increases the clay content of the Ap. In extreme cases, all of the A may be eroded and the farmer may be plowing in the Bt horizon. This condition is very obvious in limestone and other soil areas in the spring when farmers work their fields. The red or brown (Bt horizons) areas in the fields contrast greatly with the dark brown (moist) to light brown (dry) uneroded Ap areas. In these cases the eroded areas are usually on small ridges or rises in the field. The preponderance of silt loam as a surface texture is related primarily to three factors. The first factor is the large quantity of shale and siltstone that is the bedrock of the state. When these materials weather, they tend to form a silt loam material. The second factor is that as soils form and become older, clay is dispersed in the upper horizons, and eluviated downward forming Bt argillic horizons (Ciolkosz et al., 1996). This results in the increase in concentration of silt in the A and E horizons and the formation of a silt loam texture. The third factor is the addition of eolian silt to the soil surface.

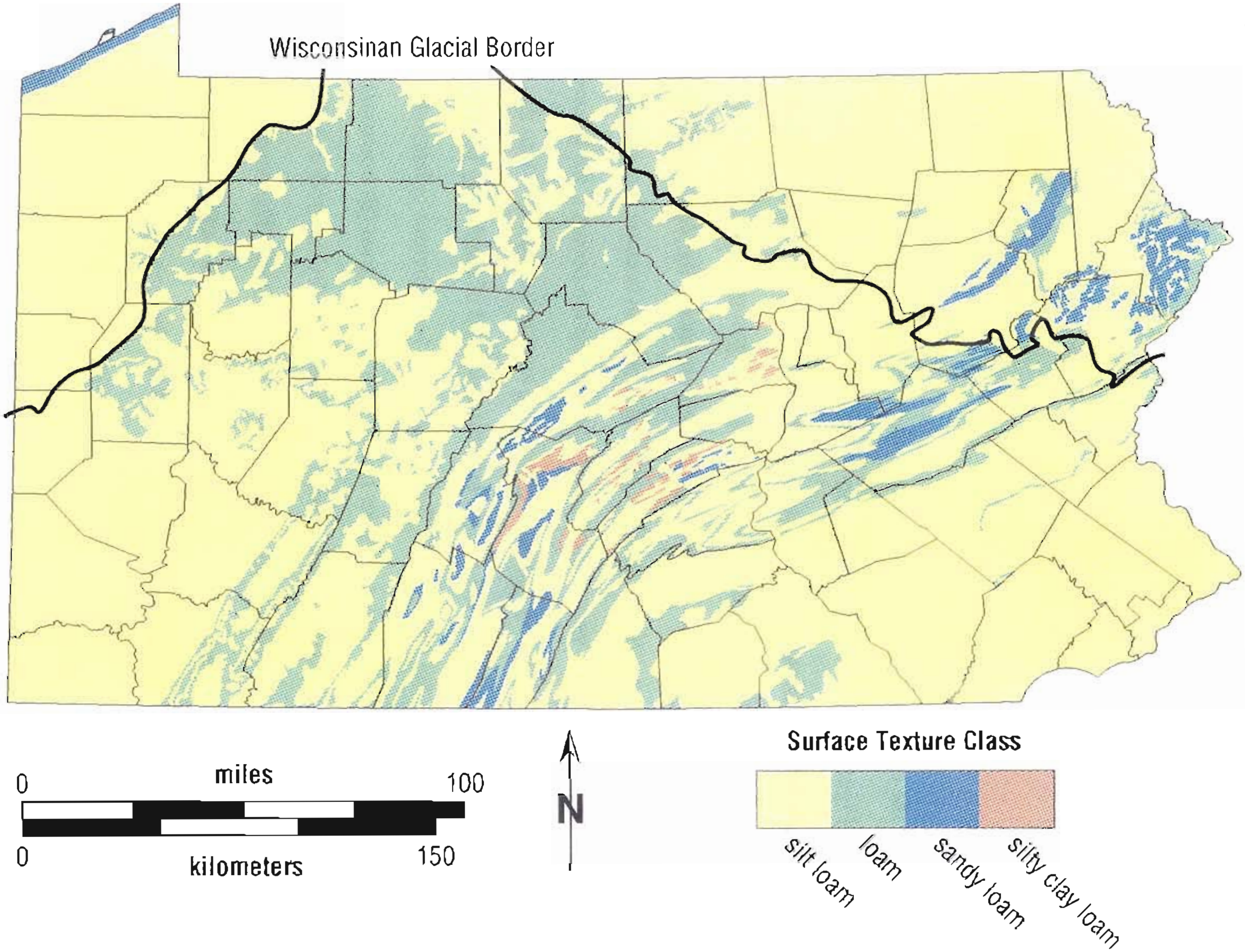

Figure 3. Generalized surface soil texture distribution for Pennsylvania. These data were modified from the USDA NRCS STATSGO database (Soil Survey Staff, 1994). The loam area in the unglaciated northcentral and Ridge and Valley areas has a significant component of sandy loam included. Pennsylvania covers an area that is about 300 miles east-west and 170 miles north-south.

Table 4. Distribution of textural classes of Pennsylvania soils. These data are from the USDA Natural Resource Conservation Service (NRCS) Map Unit Use File (MUUF). The MUUF was obtained from the NRCS office in Harrisburg, PA, in 1991, and is complete for all counties of Pennsylvania.

Textural Class	Acres in Pennsylvania	Percentage of Pennsylvania's Area	Number of Counties of Occurrence***
Silt Loam	18,119,422	63.10	67
Loam	6,525,691	22.73	67
Sandy Loam	2,236,137	7.79	50
Silty Clay Loam	459,706	1.60	44
Loamy Sand	121,109	0.42	19
Fine Loamy Sand	93,960	0.33	32
Clay Loam	12,099	0.04	1
Very Fine Sand Loam	11,115	0.04	5
Loamy Fine Sand	9,557	0.03	2
Silty Clay	9,495	0.03	2
Fine Sand	5,254	0.02	1
Sand	5,231	0.02	6
Organic Soils	43,747	0.15	20
Other*	1,061,842	3.70	64
Total	28,714,365**	100.00	

*Includes urban land, rock outcrops, stoney land, made land, gravel pits, quarries, cuts and fills, stripmines, ore pits, dumps, and water.
**Does not include water in some counties.
***Pennsylvania has 67 counties.

Recent work by Carter (1988) and Cronce (1988) indicates significant addition of eolian materials to Pennsylvania soils. These findings are supported by studies in other areas (Simonson, 1995; Smith et al., 1970; Reheis, 1995). Of particular note is the conclusion of Cronce (1988) that 25 to 50% of the silt in the upper horizons of limestone soils in central Pennsylvania is of eolian origin (see Ciolkosz et al., 1995b for a discussion of limestone soil genesis).

Structure

The type of structure in A and Ap horizons according to the data in Table 5 is similar. This is somewhat surprising. From the author's experience, it was expected that in A horizons granular structure would be dominant while in Ap's subangular blocky would be dominant. Thus, the data in Table 4 may not accurately indicate active plowing areas, but rather Ap horizons in hay fields or

Table 5. Structural type for the pedons of the Penn State Soil Characterization Laboratory Database (Ciolkosz and Thurman, 1994).

	Percent					
Horizon	Granular	Subangular blocky	Angular blocky	Platy	Massive	Single grain
A	81	14	1	0	2	2
Ap	80	16	1	3	0	0

pastures. This is a reasonable conclusion because grass vegetation has a major influence in the formation of granular soil structure. Although there is some uncertainty with regards to the granular structure data, there are some differences noted with platy structure. There is a strong tendency for Ap2 horizons to have platy structure while the Ap1 can be granular or subangular blocky. The reason for this may be compaction of the Ap2 by equipment riding over the surface or more likely the formation of ice lens in the soil during the winter which creates pressure on the soil material forming platy structure (Czurda et al., 1995). Platy structure is common in virgin profile E horizons right under the A horizon at about the same depth as Ap2 horizons. Thus, the formation of ice lens both in E and Ap2 horizons is a feasible mechanism for platy structure formation. The preponderance of silt loam material in surface horizons of Pennsylvania soils may also aide in the formation of ice lens because silt loam material absorbs large quantities of water from below during the freezing process. Because of this tendency, silt loam material is notorious for its frost heaving potential (USDA-SCS, 1971).

Although the type of structure of the A and Ap horizon may not be different, their size does show a slight difference, with the A horizons having slightly smaller size structure (Table 6). This difference is most likely due to the packing of some smaller structural units into larger units during cultivation and formation of the Ap horizon.

Although the characterization laboratory data does not show a major difference in the grade (degree of development) of soil structure between the A and Ap horizons, it does show an increase in grade with both A and Ap horizons with an increase in silt plus clay content (Table 7). This is to

Table 6. Structural size for the pedons of the Penn State Soil Characterization Laboratory Database (Ciolkosz and Thurman, 1994).

	Percent						
Horizon	Very fine	Fine	Very fine and fine	Fine and Medium	Medium	Medium and Coarse	Coarse
A	10	59	4	7	16	2	2
Ap	4	57	1	14	18	4	2

Table 7. Structural grade relationships of pedons from the Penn State Soil Characterization Laboratory database (Ciolkosz and Thurman, 1994).

		Average Percent					Number	Percent
Horizon	Structural Grade	Organic Carbon	Sand	Silt	Clay	Clay plus Silt	of Pedons	of Pedons
A	Weak	5.25	42	44	14	58	124	70
	Moderate	5.15	26	53	21	74	45	25
	Strong	3.96	10	72	18	90	8	5
Ap	Weak	1.70	28	54	18	72	385	71
	Moderate	1.88	21	57	22	79	150	27
	Strong	2.04	11	50	39	89	9	2

expected because the finer size soil particles, particularly clay, tend to promote structure formation (Baver, 1963). Organic matter also promotes structure formation (Baver, 1963; Tisdall, 1996; Stevenson, 1994), particularly granular structure, but the data in Table 7 does not show a trend of increasing structural grade with increasing organic carbon content, with the possible exception of the data for Ap horizons.

In Ap horizons that have not been plowed for a number of years and grass is the major vegetation, the upper part of the Ap develops a darker color and distinct granular structure. This is usually described as an Ap1, Ap2 sequence, although an argument can be made for an A, Ap sequence.

Organic Matter Content

In the laboratory, organic matter content is usually determined by analyzing for the organic carbon content, and then a conversion factor is used to calculate the organic matter content (Ranney, 1969; Magdoff et al., 1996). For Pennsylvania surface horizons, Ranney (1969) determined that the most suitable conversion factor was 2. Thus, a surface horizon with 1.50% organic carbon would have 3.00% organic matter. Data from the Penn State Soil Characterization Laboratory is given in Figures 4 and 5 and Table 8. These data indicate that for Ap horizons the average organic carbon content is about 1.8% with the majority being between 1 and 2 percent. The data also indicate that for A horizons the organic carbon content is higher (about 5.3%), and it has a wider range. The data also shows that the Ap horizons average about 2.4 times the thickness of the A horizons. In particular the data in Table 8 presents an interesting comparison. If we use the bulk density for A and E horizons given in Table 8, and calculate the organic carbon content of a mixture of 13 cm of E material with 9 cm of A material, the organic carbon content would be about 2.70% for the mixture. This compares to 1.78% for the Ap horizons, and indicates that on

Table 8. Averages for various characteristics for A and Ap horizons from the Penn State Soil Characterization Laboratory Database (Ciolkosz and Thurman, 1994).

	Average							
		Percent						
Horizon	Thickness (cm)	Sand	Silt	Clay	Organic carbon	Bulk density (g/cc)	pH	CEC (meq/100 g)
A	9	37	47	16	5.27	1.02	4.6	28.7
E	13*	37	48	15	0.93	1.40	4.7	11.3
Ap	22	26	55	19	1.78	1.27	5.9	18.4

*Depth 15-28 cm

the average for Pennsylvania soils when a soil is converted from forest to agriculture it loses about 1% of organic carbon in the plow layer. Similar results have been reported for soils of the Midwestern U.S. (Mann, 1985, 1986; Burke et al., 1989) and Canada (Goldin and Lavkulich,

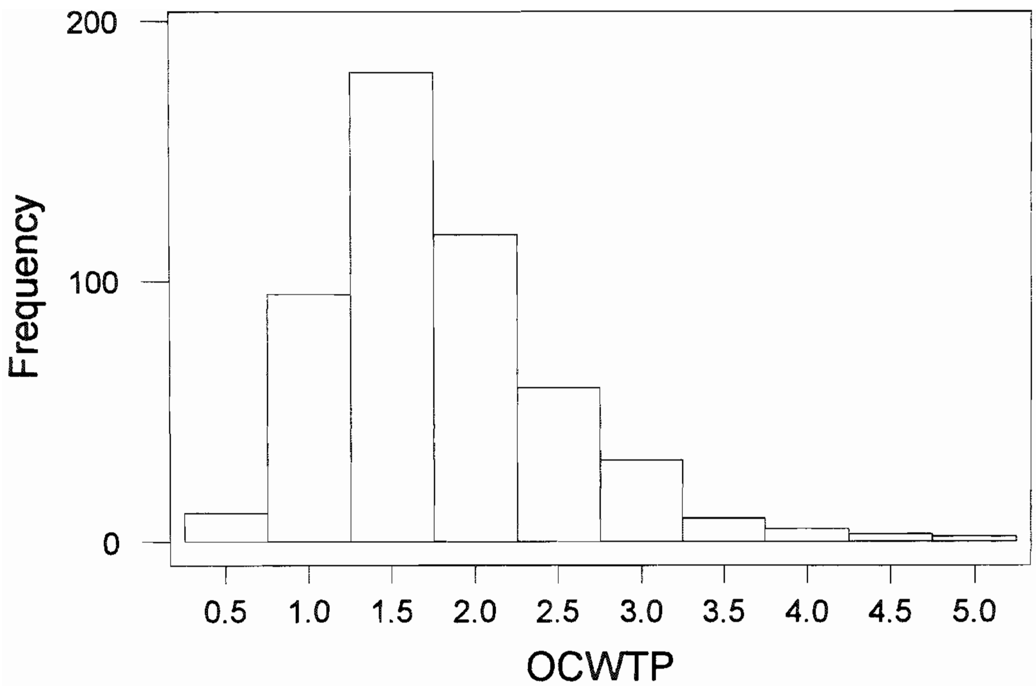

Figure 4. Organic carbon weight percent (OCWTP) frequency distribution for Pennsylvania Ap horizons. Data from Ciolkosz and Thurman (1994).

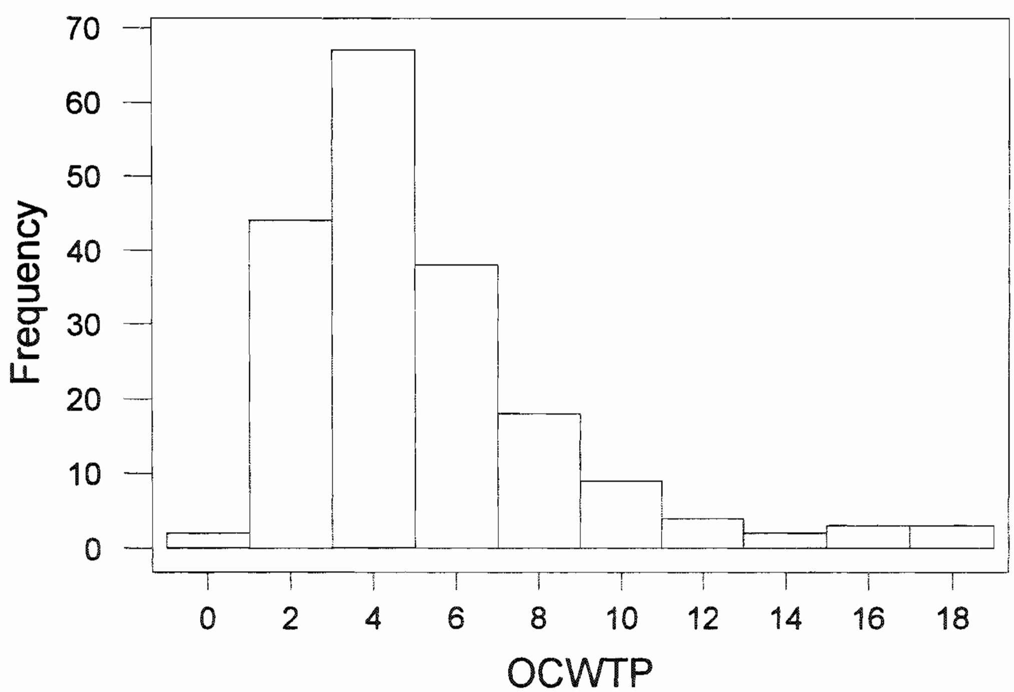

Figure 5. Organic carbon weight percent (OCWTP) frequency distribution for Pennsylvania A horizons. Data from Ciolkosz and Thurman (1994).

1990; Ellert and Gregorich, 1996; Gregorich et al., 1995). This conclusion may not hold for all Ap horizons. Some studies have indicated that large additions of organic material, particularly manure can maintain virgin levels of organic matter in soils or raise levels that have been lowered due to cultivation (Peters et al., 1997; Rasmussen and Collins, 1991). Of the large number of studies done on organic carbon dynamics (most are associated with soil carbon-CO_2 associations and global warming) only two have been done in Pennsylvania. Some recent short-term studies have been done at the Rodale Institute Research Center near Kutztown (Wander and Traina, 1996; Peters et al., 1997), and some older studies were done on the Penn State University campus at State College (White et al., 1945). The State College study was done on the Jordan soil fertility plots (Holbert, 1956) and compared cultivated and grass management over extended periods. These studies indicate in 72 years on Hagerstown soil, grass vegetation increased the organic carbon content about 1% (2.33 vs. 1.45) above that in untreated cultivated areas.

The data in Table 8 also indicate that Ap horizons have a higher pH than A horizons. This is logical because liming soils is a common agricultural practice in Pennsylvania as well as elsewhere.

FACTORS AFFECTING ORGANIC MATTER CONTENT

Climate

Climate (temperature and precipitation) are two factors that influence soil organic matter content. They influence both the type of vegetation (e.g., forest vs. prairie) and the amount of material that is added to the soil as well as where the bulk of it is added (trees-to the surface; prairie-below the surface) (Anderson, 1987). In Pennsylvania there is a limited area of soils that have developed under prairie vegetation (Waltman, 1988; Waltman and Ciolkosz, 1995). The study of Waltman and Ciolkosz (1995) indicates that the prairie soils had three times more organic matter than forest soils of similar texture. These differences were mainly due to the greater thickness of the prairie soil epipedon because the percent organic matter was similar between the prairie and forest soils studied. In addition, both lower temperature and higher precipitation also impart a higher organic matter content to soils (Burke et al., 1989; Anderson, 1992). Lower temperature reduces the rate of biological decomposition of the added organic matter while increased precipitation increases biomass production which increases the amount of organic matter added to the soil (Stevenson, 1994). No studies have been done to evaluate the effect of temperature and precipitation on the organic matter content of Pennsylvania soils. In addition, the Penn State Soil characterization database (Ciolkosz and Thurman, 1994) does not have an adequate number of pedons samples in the cooler and higher precipitation areas of the state to make an evaluation of these parameters.

Texture

Soil texture is frequently cited as a factor affecting soil organic matter content (Burke et al., 1989; Scott et al., 1996; Anderson, 1995). According to Sikora et al. (1996), finer-textured soils protect soil organic matter from decomposition by adsorption on to clay surfaces, encapsulation by clay, and by entrapment in pores too small for microorganism entry. An examination of the Penn State characterization data does not show any distinctive trend of organic carbon with sand or clay content.

Drainage

As with texture, drainage is frequently cited as a factor affecting organic matter content with poorly drained soils having a greater amount of organic matter than better drained soils (see data in Mann, 1985 and Gregorich et al., 1995). The data in Table 9 does not give a clear picture of this relationship. For A horizons, with the exception of moderately well and poorly drained soil, this trend seems to hold. Complicating this evaluation is a trend of increasing clay content with poorer drainage. Thus, some of this trend may be associated with texture. Although the percent organic matter trend, with increasing poor drainage, is erratic, the total amount accumulated increases because there is a distinctive increase in thickness of the A horizons with poorer drainage. The data for Ap horizons shows a similar thickness and a slight trend of increasing organic carbon with increasing wetness; but as with the A horizons, this trend coincided with an increase in clay content. Thus, again it is uncertain what effect this association has on the organic carbon content.

Table 9. Organic carbon soil drainage class relationships for Pennsylvania A and Ap horizons.

Drainage Class	Average Thickness (cm)	Average Percent Organic Carbon	Sand	Silt	Clay	Munsell Value†	Munsell Chroma†	Number of Pedons
				A Horizons				
Well	8	4.71	43.7	44.2	12.1	3	2	112
Moderately well	8	6.10	32.2	49.6	18.2	3	2	32
Somewhat poorly	13	4.97	32.5	49.6	17.9	3	2	14
Poorly	14	4.17	26.6	52.1	21.3	3	2	15
Very poorly	20	5.99	20.9	49.5	29.6	3	1	11
				Ap Horizons				
Well	22	1.73	30.1	51.8	18.1	4	3	278
Moderately well	24	1.70	20.4	60.7	18.9	4	3	116
Somewhat poorly	22	1.95	21.1	58.4	20.5	4	2	73
Poorly	23	2.04	16.1	59.9	24.0	4	2	43
Very poorly	20	3.49	13.0	56.7	30.3	4	2	3

†Moist state

CONCLUSIONS

The ochric epipedon is the dominant surface horizon in Pennsylvania soils. It encompasses Pennsylvania's Ap horizons and a mixture of the A and E or Bw horizons for the state's better drained virgin soils. The amount of underlying material necessary to be mixed with the A horizon to form an ochric epipedon decreases with poorer drain until no material is needed for very poorly drained soil. The reason being, that A horizon tend to become thicker with increasing poorer drainage. The color hue of the A and Ap horizons is dominantly 10YR 3/2. The Ap horizons have a slightly lighter (value) and brighter (chroma) color than A horizons. The texture of the ochric epipedons are dominantly silt loam (63%) and loam (23%). The structure of A and Ap horizons is mainly weak granular with a weak trend of increasing grade (degree of development) with increasing silt + clay content. The organic matter (organic carbon) content (percent) of Ap horizons is less (about one-third) than that of A horizons; but Ap horizons are thicker. But, even accounting for the difference in thickness, the Ap have less total organic matter content than A horizons. An examination of the Penn State soil characterization data did not show a distinctive trend of organic matter content with clay content except when a comparison was made of organic carbon with drainage. This evaluation showed an increase in organic matter with poorer drainage, and a parallel trend of increasing clay content. Thus, it is uncertain of the magnitude of the impact of poorer drainage and clay content on increasing organic matter content.

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