Field Identification of Andic Soil Properties for Soils of North-central Idaho

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Introduction

Currently, laboratory measurements are definitive for identifying andic soil properties in both the USDA Soil Taxonomy (Soil Survey Staff 1999) and the World Reference Base for Soil Resources (FAO/ISRIC/ISSS 1998). Andic soil properties, as described in Soil Taxonomy, result mainly from the presence of significant amounts of allophone, imogolite, ferrihydrite or aluminum-humus complexes in soils. The required properties are high acid-oxalate extractable aluminum and iron percentages, low bulk density, and high phosphate retention. In addition, glass is a common component of andic soils of the Inland Northwest region (McDaniel and others 2005).

A large body of work has been devoted to characterizing ash soils for classification and management purposes. Summaries of this work include Shoji and others (1993) and Dahlgren and others (2004). However none of these efforts have addressed the problem of identifying soils with andic soil properties directly in the field. Most soil mapping professionals working with ashy materials are able to identify andic properties under field conditions. However, there is currently no summary of the methods used by individuals to accomplish this identification. A procedure for recognizing andic materials using field characteristics would assist both those lacking experience with these materials and those assessing soils from written descriptions. Also, a logically derived set of selection criteria for detecting andic properties could help even experienced professionals in areas where volcanic ash influence has been diluted by mixing with other materials.

This paper will examine two alternatives for detecting andic soil properties. The first is the development of an empirical model using routinely observed soil features as recorded in soil descriptions from north-central Idaho. The second is the use of sodium-fluoride (NaF) pH to detect the presence of allophane or similar amorphous materials in soils. The objectives of this project were to: 1) identify a set of field-observable characteristics that can reliably identify soils derived from Mount Mazama tephra; 2) develop a simple model using these characteristics to evaluate samples as to whether they meet andic criteria or not; and, 3) evaluate use of NaF-pH in this region as a test for recognizing ash influence.

Methods and Materials

A set of 323 Natural Resources Conservation Service (NRCS) pedon descriptions (or 945 separate soil horizons) from Latah County, Idaho was used to evaluate how well a set of field observations allows an observer to distinguish andic materials from other soil materials. Only horizons having a complete set of observations for all properties and occurring within 50cm of the soil surface were used. Each horizon had been designated as ashy or non-ashy according to the expert opinion of the NRCS soil scientist recording the soil description. The dataset contains 468 horizons designated as ashy and 477 horizons designated non-ashy.

The set of field observable characteristics proposed for recognizing andic materials are soil color (dry and moist), structure, consistence (consistence is the set of stickiness, plasticity, rupture resistance dry and rupture resistance moist), and root abundance. Soil color is described using standard Munsell notation. Structure, consistence and root abundance are described using the methods and nomenclature found in Schoeneberger and others (2002).

Most of the soil properties are described using a number of component elements. For example, soil color is described by the six components of dry hue, dry value, dry chroma, moist hue, moist value and moist chroma (see table 1). This subdivision of properties resulted in a list of 17 properties and/or components that could be used to distinguish between ashy and non-ashy soil horizons. Each component of a property has been assigned one of several possible classes that describe the component for a given soil. For example, dry soil hue could be 5YR, 7.5YR or 10YR. Tables 2 through 6 show the relative frequency distribution for each class used to describe the components of each soil property by tephra or non-tephra parent materials.

The relative frequencies observed for the classes describing the components of each soil property were used to evaluate which components would be useful in discriminating andic from non andic (or "other") materials. A useful discriminator was defined as one that showed: 1) a clustering of 60 percent or more of observations for the tephra material on one component class, and 2) less than 35 percent of observations for the 'other ' materials occurring in that same class.

The pH of a suspension containing 1 g soil in 50 mL 1 M NaF is used as a test for the presence of short-range order minerals. These minerals are commonly early products of the weathering of pyroclastic materials. The action of 1 M NaF on these minerals releases hydroxide ions (OH^-) to the soil solution and increases the pH. A 1 M NaF pH of more than 9.4 at 2 minutes after the NaF solution is added is a strong indicator (in non-calcareous soils) that short-range order minerals dominate the soil exchange complex (Burt 2004).

Table 1—Soil properties proposed as useful for field recognition of tephra derived soil materials with their component elements and descriptive classes.

Property	Component elements	Descriptive classes
Soil color	dry hue	5YR, 7.5YR, 10YR
	dry value	2, 2.5, 3, 4, 5, 6, 7
	dry chroma	2, 3, 4, 6
	moist hue	5YR, 7.5YR, 10YR
	moist value	2, 2.5, 3, 4, 5, 6, 7
	moist chroma	2, 3, 4, 6
Structure	grade	weak, moderate, strong
	size[a]	1, 2, 3, 4, 5
	kind[b]	abk, gr, pl, pr, sbk, massive
Consistence	dry rupture resistance	soft, slightly hard, moderately hard, hard, very hard
	moist rupture resistance	very friable, friable, firm
	stickiness	nonsticky, slightly sticky, moderately sticky, very sticky
	plasticity	nonplastic, slightly plastic, moderately plastic, very plastic
Root abundance[c]	very fine and fine roots	few, common, many
	medium and coarse roots	few, common, many
Texture[d]	none	1, 2, 3, 4 ,5 6, 7

[a] Structure size classes are: 1 = very fine, very fine and fine or fine; 2 = very fine to medium or fine and medium; 3 = medium; 4 = fine to coarse or medium and coarse; 5 = coarse.

[b] Structure kinds are: abk = angular blocky; gr = granular; pl = platy; pr = prismatic and sbk = subangular blocky.

[c] Root abundance classes are: few = <2%, common = 2 to 20% and many = >20%.

[d] Texture classes are: 1 = sil; 2 = l; 3 = fsl, vfsl; 4 = sicl; 5 = cl; 6 = sl; 7 = cosl, lcos for definitions of class terms see Schoenberger and others 2002.

Table 2—Observed frequencies for the components of soil color by moisture status and parent material.

Color component	Classes	Moist tephra count	Freq	Other count	Freq	Dry tephra count	Freq	Other count	Freq
		(no.)		*(no.)*		*(no.)*		*(no.)*	
Hue	10yr	145	0.39	120	0.73	240	0.74	138	0.90
	7.5yr	229	0.61	43	0.26	84	0.26	14	0.09[a]
	5yr	0	0	2	0.01	0	0	2	0.01
Value	2	0	0	3	0.02	0	0	0	0
	2.5	5	0.01	2	0.01	0	0	0	0
	3	181	0.48	45	0.27	0	0	0	0
	4	184	0.49	101	0.60	2	0.01	11	0.07
	5	5	0.01	16	0.10	127	0.39	19	0.12
	6	0	0	1	0.01	181	0.56	104	0.68
	7	0	0	0	0	14	0.04	20	0.13
Chroma	2	2	0.01	4	0.03	3	0.01	5	0.03
	3	52	0.14	63	0.41	21	0.07	66	0.43
	4	255	0.68	82	0.53	261	0.81	78	0.51
	6	66	0.18	5	0.03	38	0.12	5	0.03

[a] Component meets criteria for useful ashy soil identifier.

Table 3—Observed frequencies for the components of soil structure by soil parent material.

Structure component	Classes	Tephra count	Freq	Other count	Freq
		(no.)		*(no.)*	
Structure grade	weak	419	0.83	148	0.29[a]
	moderate	83	0.16	349	0.68
	strong	3	0.01	20	0.04
Structure size	1	261	0.52	125	0.24
	2	204	0.40	290	0.56
	3	29	0.06	60	0.12
	4	1	0	29	0.06
	5	9	0.02	11	0.02
Structure kind	abk	0	0	2	0
	gr	196	0.39	91	0.17
	pl	0	0	11	0.02
	pr	0	0	16	0.03
	sbk	311	0.61	395	0.75
	massive	1	0.00	15	0.03

[a] Component meets criteria for useful ashy soil identifier.

Table 4—Observed frequencies for the components of soil consistence by soil parent material.

Consistence component	Classes	Tephra count	Freq	Other count	Freq
		(no.)		*(no.)*	
Dry consistence	soft(so)	474	0.96	19	0.15[a]
	slightly hard (sh)	17	0.03	32	0.24
	moderately hard (mh)	1	0.00	32	0.24
	hard (ha)	0	0.00	42	0.32
	very hard(vh)	1	0.00	6	0.05
Moist consistence	very friable(vfr)	507	0.98	25	0.19[a]
	friable(fr)	11	0.02	97	0.72
	firm(fi)	0	0.00	12	0.09
Stickiness	nonsticky(so)	474	0.93	34	0.25[a]
	slightly sticky(ss)	34	0.07	85	0.62
	moderately sticky(ms)	0	0.00	18	0.13
	very sticky(vs)	0	0.00	1	0.01
Plasticity	nonplastic(po)	465	0.91	16	0.12[a]
	slightly plastic(sp)	43	0.08	51	0.38
	moderately plastic(mp)	1	0.00	54	0.40
	very plastic(vp)	0	0.00	15	0.11

[a] Component meets criteria for useful ashy soil identifier.

Table 5—Observed frequencies for root abundance by root size class and soil parent material.

Root abundance	Classes	Tephra count	Freq	Other count	Freq
		(no.)		*(no.)*	
Very fine and fine roots	none	2	0	4	0.01
	few	12	0.03	33	0.07
	common	93	0.20	223	0.47
	many	366	0.77	216	0.45
Medium and coarse roots	none	95	0.20	171	0.36
	few	158	0.33	199	0.42
	common	207	0.44	88	0.18
	many	13	0.03	18	0.04

Table 6—Observed frequencies of soil textures (for the <2mm fraction) by parent material

Soil texture name	Tephra count	Freq	Other count	Freq
	(no.)		*(no.)*	
sil (1)	465	0.99	320	0.67
l (2)	3	0.01	112	0.23
fsl, vfsl (3)	0	0	10	0.02
sicl (4)	0	0	7	0.01
cl (5)	0	0	4	0.01
sl (6)	0	0	19	0.04
cosl, lcos (7)	0	0	5	0.01

While each of these variables is important in recognizing ash soils, the classification criteria allow for interaction between the two so that no single value serves to discriminate andic from nonandic horizons. In an attempt to define such a threshold value for NaF-pH, a dataset of laboratory measurements from Clearwater County, Idaho was obtained for analysis. The dataset contained 267 horizons with NaF-pH information. These were then grouped into andic (73 horizons) and nonandic (194 horizons) soils. Table 7 reports the mean and standard deviation for these two sample populations. Assuming a normal distribution, it is possible to use these means and standard deviations to calculate a NaF-pH value that corresponds to the critical value for the Z statistic at a chosen level of probability. Table 7 reports these critical values as NaF-pH values at P=.95 and P=.99.

Table 7—Mean, standard deviation and NaF-pH values that are equivalent to the critical values of Z at two levels of probability.

	Mean	Standard deviation	NaF-pH at P=.95	NaF-pH at P=.99
Nonandic	8.58	0.60	9.56	9.97
Andic	10.56	0.36	9.97	9.73

Results and Discussion

Soil color is strongly influenced by parent material (Richardson and Daniels 1993). Table 2 indicates that the only component of soil color useful for recognizing ash influenced soils in north-central Idaho is the moist hue. The ash-influenced materials are noticeably redder in hue (7.5YR vs. 10YR) than other materials for most samples. This is assumed to be a result of the prevalence of ferrihydrite in ashy materials (Dahlgren and others 2004; Ugolini and Dahlgren 2002). Ferrihydrite-containing soils have hues of 5-7.5YR while soils with hues between 7.5YR and 2.5Y tend to contain significant amounts of goethite (Schwertmann 1993).

Soil structure is a complex phenomenon that depends in part on factors such as parent material, climate and the physical and biochemical processes of soil formation (Brady and Weil 2001). Andic soils have a tendency to have weak fine structure that is granular in A horizons and subangular blocky in B horizons (table 3). Soils derived from other materials have similar structure size and kind but exhibit stronger development with a grade of moderate being dominant. Therefore, structure grade is recognized as a suitable identifier for ash-influenced soils.

Consistence is a description of a soil's physical condition at various moisture contents as evidenced by the response of the soil to mechanical stress or manipulation. The consistence of a soil is determined to a large extent by the particle-size distribution of the soil, but is also related to other properties such as organic matter content and mineralogy (http://organiclifestyles.tamu.edu /soilbasics/soilphysical.html). Andic soils have unique consistence properties displaying low rupture resistance (in both dry and moist states), little stickiness and low plasticity (table 4). Each of these components of consistence is useful to separate ash influenced from other materials. They are a reflection of the very low clay contents and unique mineralogy of the ashy material.

Field observations have noted a high degree of root proliferation in ashy surface horizons in north-central Idaho. While the data show a slight trend toward greater root abundance in the ashy materials, the difference compared to the other parent materials was not sufficient to allow use of this characteristic as a discriminator (table 5). The recording of root abundance as broad classes rather than actual counts per area may have reduced the usefulness of this comparison.

A series of simple models for recognizing ash-influenced soil materials were created using the components identified as useful discriminators of ashy material. They were tested through a process of trial and error. During this testing it was discovered that soil texture could be used to help improve model performance. This is true even though that property did not meet the criteria set for recognition as a useful discriminator. Soil texture proved to be a special case where the high degree of clustering on the silt loam class (99.6 percent of observations) for the ash-influenced material helped the model to recognize these materials. This improved performance results from better separation of the ash-influenced materials from low plasticity materials of other origins. During this phase, it was also determined that moist rupture resistance would not be used in the final model. Even though this component met the criteria for a useful discriminator, it is strongly related to dry rupture resistance. The addition of moist rupture resistance did not improve the model. Dry rupture resistance was preferred because it had more-easily recognized classes and greater consistency in application by different observers.

A final model was created for evaluating whether a soil sample classifies as andic material. The model scores a soil based on the six identified properties and /or components as follows:

moist hue – 7.5YR=1, other=0;
structure grade – weak=1, other=0;
dry rupture resistance – soft=2, other=0;
stickiness – nonsticky=2, other=0;
plasticity – nonplastic=2, other=0;
texture – silt loam=2, other=0.
A score >= 8 is andic material while <8 is nonandic.

This model was used to evaluate the original dataset and returned an error rate of 7.6 percent. There were approximately equal percentages of false positives and false negatives. Of the 468 horizons designated ashy by the expert observers, the model failed to recognize 37. These 37 false negatives were due primarily to their lack of the expected moist hue and plasticity characteristics. Of the 477 horizons designated-non-ashy by expert observers, 35 were misidentified by the model as andic materials. These 35 horizons are silt loams that are low in clay and that have rupture resistance, stickiness and plasticity characteristics similar to andic materials. The model correctly discriminated between andic and nonandic materials in 92.4 percent of cases.

NaF-pH has been identified as a simple and convenient index for the presence of andic materials (Fieldes and Perrott 1966). Work by Kimsey and others (2005) found a strong (R^2 =.82) correlation between NaF-pH and acid oxalate extractable Al and Fe. Another study by Brownfield and others (2005) reported a good correlation (R^2 =.66) between tephra percent (based on grain counts) and NaF-pH. A critical pH value of 9.4 has been suggested as the threshold for recognition of tephra dominated materials (Soil Survey Staff 1995). The calculations shown in table 7 indicate that, for the Clearwater County data, this threshold value is too low. The table shows that 95 percent of the distribution of NaF-pH values for andic horizons is greater than or equal to 9.97. Interestingly, the same NaF-pH value of 9.97 is the upper bound below which 99 percent of the distribution of nonandic values is found. Rounding to one decimal place gives a NaF-pH of 10.0 as a suggested threshold for recognizing andic materials. When applied to the Clearwater County data, this threshold causes an error rate of about 10 percent (7 out of 73 horizons misidentified) for andic horizons and about 3 percent (6 out of 194 horizons misidentified) for nonandic horizons. Using a threshold pH value of 10.0 allowed for correct classification of horizons in about 95 percent of cases.

Summary

Two methods for field identification of volcanic ash influenced soil horizons were explored. A simple empirical model was developed for ash recognition using the easily observable qualitative properties of moist hue, structure grade, dry rupture resistance, stickiness, plasticity and texture. This model successfully discriminated between tephra and other materials in about 92 percent of cases. A model like this can be used to help those not expert in soil classification to recognize andic soil materials, to evaluate written descriptions when soil samples are not available and to help more experienced soil classifiers in conditions where the tephra is highly mixed with other materials. One principal weakness of this model is that it is developed for Mount Mazama ash in north-central Idaho. Soils formed in volcanic ejecta in other areas may have a different set of identifying characteristics.

The second method for identification of andic materials was the use of NaF-pH. While the analysis used here depended on laboratory measurements, the NaF-pH can be readily measured in the field. Data from Clearwater County, Idaho showed that using a threshold value of 10.0 pH units correctly classified soil horizons in about 95 percent of cases. The use of NaF-pH to detect allophanic material has broad application to many different volcanic materials. However, identification of the most useful threshold value may be subject to regional variation.

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