PROPOSED CHANGES FOR SPODOSOLS AND SPODIC HORIZONS DESIGNATION

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Proposal 1: Change the criteria for Aquods from requiring aquic conditions *and* redoximorphic features in the albic or spodic within 50 cm of the mineral soil surface, to only requiring aquic conditions within 50 cm of the mineral soil surface.

In Soil Taxonomy (Soil Survey Staff, 2014), Aquods are identified as having redoximorphic features in albic or spodic horizons within 50 cm of the mineral soil surface, or have a histic epipedon. A review of eight official pedon descriptions (OSDs) of mesic Aquods (Alaquods, Duraquods, or Endoaquods) mapped in Land Resource Region (LRR) R and S indicated that all of the soils were sandy and none had histic epipedons. Thus, to meet the requirements of an Aquod all of these soils require redoximorphic features. The two Alaquods (Berryland and Atsion) had no redoximorphic features described. This makes sense because to classify as an Alaquod, more than 75% of the spodic must have <0.1% Fe; so if there is little or no Fe present, redoximorphic features cannot form. Two of the pedons (Pipestone and Mattapoisett) have Fe concentrations in both albic and spodic horizons. Descriptions from the other 4 pedons supported weak evidence of redoximorphic features. If the albic horizons contained redoximorphic features, the features were described as few, fine, and faint depletions. If the spodic horizons contained redoximorphic features, they were described as either 7.5YR 2.5/1 depletions or fine Mn coatings**,** suggesting possible misinterpretations of the color patterns.

In a study of wet Spodosols in the northeastern United States, we examined 11 pedons, five from Maryland, four from Rhode Island, one from Massachusetts, and one from Maine (Table 1). All of the sites except 1,1 and 1,7 from Maryland were saturated with 25 cm of the soil surface for 3 or more weeks during the growing season (Table 2). Sites 1,1 and 1,7 were saturated within 50 cm of the soil surface for 15 and 20% of the year, respectively. None of the soils had redoximorphic features in the albic or spodic horizons, thus, only the two soils with histic epipedons (EP and AQ) met criteria as Aquods. Considering that these soils are typically saturated to, or near, the surface, all of the soils should classify as Aquods. The issue is that little or no extractable Fe is present in the albic and spodic horizons to form redoximorphic features (average ammonium oxalate extractable Fe in the spodic horizons was <0.15%; Table 3). In order to minimize the misclassification of many of these soils, our recommendation is to change the criteria for Aquods from requiring aquic conditions *and* redoximorphic features in the albic or spodic, to only requiring aquic conditions.

Proposal 2: Change the basic criterion for an Alaquod or Alorthod to <0.1% ammonium oxalate extractable (AOE) Fe or at least 3 times as much AOE Al as Fe.

Of the 24 Bh, Bhs, or Bhsm horizons we studied, 80% were dominated by AOE Al instead of Fe (Table 3). In addition, all of the ortsteins were dominated by Al, not Fe. Yet of these 11 pedons, only three (1,3 1,5 and 2,5) had low enough Fe levels to fit within the currently defined "Al" great group (Table 1). Keys to Soil Taxonomy (Soil Survey Staff, 2014) requires less than 0.1% AOE Fe. As noted above, average AOE Fe contents were <0.15% for both the Maryland and New England spodic horizons while average Al contents were 3 to almost 10 times greater (0.26 and 1.28%, respectively). Some of the New England pedons had as much as

2% AOE Al (Table 3). These data call into question why the basic criterion for an Alaquod or Alorthod is a function of the amount of Fe? We propose that the classification criteria be changed to <0.1% AOE Fe or at least 3 times as much AOE Al as Fe. If these two recommendations for Soil Taxonomy are followed, all of the soils would classify as Alaquods except the two Maryland pedons (1,1 and 1,7) that had deeper seasonal saturation and higher concentrations of AOE Fe.

Proposal 3. Amend and clarify criteria for defining Bh and Bhs horizon and their associated ortsteins (Bhm and Bhsm).

Spodic horizons designated with the "h" suffix (Bh, Bhs, and Bhsm) have colors that are 3/3 or darker. Colors of spodic horizons in the eight OSDs discussed above (had hues from 7.5YR to 2.5YR and colors of black, very dark brown, dark brown, dark reddish brown, and reddish black (X-rite, 2009 Munsell color) and show no apparent relationship between color and horizon designation (as Bh or Bhs). This raises questions regarding how one can or should distinguish between Bh and Bhs horizons in the field. By definition, if the color is 3/3 or darker and "*the sesquioxide component is dominated by aluminum but is present in only very small quantities*" then only "h" is to be used (Bh) (Soil Survey Staff, 2010). If, however, *"the amount of the sesquioxide component is significant"* then the symbol "h" is used in combination with "s" (Bhs).

All of the spodic horizons that we studied had values and chromas <3 (Table 3), meeting the standard criteria for use of the "h" subscript (Bh, Bhs, or Bhsm) in the horizon designation (Soil Survey Staff, 2014). Thus, based on soil color how are Bh horizons differentiated from Bhs? There appear to be at least two approaches to designate spodic horizons as Bh or Bhs. All of the New England spodic horizon designations were Bhs or Bhsm (ortstein). There was at least 0.6% AOE Al in all of the spodic horizons. The general convention here appears to be that except for areas of siliceous sands, there will always be significant Al complexed in the spodic horizon to require the use of the Bhs designation. In Maryland (and likely elsewhere, see Wilson and Righeti, 2010), the convention is that the darkest spodic horizons are designated Bh and the redder (or slightly higher chroma) ones as Bhs. The Bh horizon is typically described above the redder Bhs horizon (De Coninck et al., 1974; Bullock and Clayden, 1980). This approach can be seen in 4 of the 5 Maryland pedons where the chroma of the Bh horizon is at least one unit lower than the underlying Bhs horizon (Table 3). This approach is totally independent of the amount of AOE Fe or Al. For example, the Bh horizon for pedon 2,5 has 0.59% AOE Al while the Bhs horizon of the same profile has 0.30% AOE Al.

By definition (Soil Survey Staff, 2010), "h" is used "if the sesquioxide component is dominated by Al but is present in only very small quantities". Otherwise, "hs" is used "if the amount of sesquioxide component is significant". Thus, the criteria specified for distinguishing between Bh and Bhs does not refer to color. It may also be noted, when examined carefully, that the references in the criteria to sesquioxides are also misguided. In their chapter on sesquioxides, Shaw and West (2006) suggested that the only common Al sesquioxide in soils is gibbsite. We did not determine the Al mineralogy of these soils, but other studies have reported that short-range order aluminosilicates such as imogolite (Wang et al., 1986; Dalgren et al., 1989; Dahlgren and Ugolini, 1989) or proto-imogolite allophane (Farmer et al., 1980; Wilson and Righi, 2010) are the most common Al minerals found in Spodosols. In the strict sense, these minerals are not considered sesquioxides. Thus, additional clarification and guidance is needed for horizon designation of spodic horizons dominated by extractable Al.

Table 1. Pedon locations, current subgroup classification, and appropriate subgroup classification if aquod criteria are changed.

Pedon	Location	Parent material	Current Subgroup Classification	Appropriate Subgroup Classification
EP	Rhode Island	Ice-contact	Histic Duraquod	Duric Alaquod
AJ	Rhode Island	Dense till	Typic Haplohumod	Aeric Alaquod
CP	Massachusetts	Glacial Lacustrine	Typic Haplohumod	Aeric Alaquod
GS	Rhode Island	Outwash	Typic Haplohumod	Aeric Alaquod
SB	Maine	Outwash	Aquic Haplorthod	Aeric Alaquod
AQ	Rhode Island	Ice Contact	Histic Duraquod	Duric Alaquod
1,1	Maryland	Dune Sands	Aquic Haplorthod	Typic Endoaquod
1,3	Maryland	Dune sands	Typic Durorthod	Duric Alaquod
1,5	Maryland	Dune Sands	Typic Durorthod	Duric Alaquod
1,7	Maryland	Dune Sands	Aquic Haplorthod	Typic Endoaquod
2,5	Maryland	Dune Sands	Aquic Haplorthod	Aeric Alaquod

Table 2. Summary of hydrology data collected for the various sites. Growing season was based on soil temperature above 5 degrees Celcius was assumed to be March 1 to December 1 in Maryland and March 15th to November 15th in Rhode Island and Massachusetts.

Pedon	Consecutive weeks ponded during growing season	Consecutive weeks <15 cm during growing season	Consecutive weeks <25 cm during growing season
EP	6 weeks	>6 weeks	>6 weeks
AJ	0 weeks	11 weeks	13 weeks
CP	1 week	9 weeks	11 weeks
GS	2 weeks	3 weeks	5 weeks
SB	0 weeks	1 week	5 weeks
AQ	6 weeks	>6 weeks	>6 weeks
1,1	0 weeks	0 weeks	0 weeks
1,3	0 weeks	7 weeks	10 weeks
1,5	0 weeks	3 weeks	7 weeks
1,7	0 weeks	0 weeks	<1 week
2,5	0 weeks	2 weeks	3 weeks

Hydrology and Reducing Conditions Notes:

CP. Water levels were monitored from March 15th until June 15th on a weekly basis in 2010 and by a logger (every 4 hours) in 2011. Three IRIS tubes were installed in 2010 during the growing season and showed 100% removal.
GS. Data loggers collected water table depths every 6 hours in 2011 from Jan through October and in 2013 from April to September. Three IRIS tubes were installed in 2011 and showed on average 50% removal.
AJ. Water table were collected on a weekly basis from March 15th to June 15th in 2010 and 2011. Three IRIS tubes were installed in 2011 and showed on average 50% removal.
AQ and EP. Ponding was monitored from March 15th to June 15th from 2003 to 2009
SB. Water table was monitored weekly from June 23rd to August 7th in 2006.
1,1, 1,3, 1,5, 1,7, and 2,5. Water table depths were measured every two weeks from 1989 to 1994.

Table 3. Munsell color components; soil organic carbon (SOC), optical density of oxalate extract (ODOE); ammonium oxalate extractable Fe and Al (AOE Al and AOE Fe) contents.

Pedon	Horizon	Hue (YR)	Value	Chroma	SOC (%)	ODOE	AOE Al (%)	AOE Fe (%)
EP	Bhsm1	6.4	1.7	1.0	2.94	1.73	0.67	0.08
EP	Bhsm2	5.5	1.6	1.7	3.01	1.97	0.85	0.10
SB	Bhs1	5.1	1.5	1.3	3.09	2.00	0.66	0.10
SB	Bhs2	4.4	1.5	1.9	4.43	1.46	0.63	0.14
AQ	Bhs	5.8	1.5	1.5	3.02	1.07	0.71	0.16
AQ	Bhsm	5.3	1.3	1.0	2.74	1.63	0.73	0.35
AJ	Bhs1	4.7	1.5	0.8	7.50	2.50	1.54	0.11
AJ	Bhs1	4.9	1.4	0.9	6.30	2.50	1.54	0.12
CP	Bhs1	5.4	1.1	0.7	10.1	2.50	2.16	0.13
CP	Bhs2	5.7	1.4	1.3	17.0	2.50	2.06	0.13
GS	Bhs1	5.0	1.3	1.0	8.90	1.97	1.98	0.16
GS	Bhs2	5.3	1.5	1.2	6.06	2.07	1.80	0.15
1,1	Bh	7.3	2.3	1.1	1.18	0.46	0.10	0.24
1,1	Bhs	7.6	2.2	2.1	1.94	0.44	0.28	0.16
1,3	Bhsm1	5.3	1.7	1.8	0.96	0.46	0.24	0.00
1,3	Bhsm2	5.9	1.7	1.0	0.87	0.81	0.21	0.00
1,3	Bhs	5.4	1.9	1.7	0.64	0.35	0.08	0.00
1,5	Bhsm	5.5	2.0	1.8	2.80	0.75	0.55	0.02
1,5	Bh2	5.8	1.9	1.0	0.95	0.22	0.08	0.00
1,5	Bhs	5.8	2.1	2.1	0.42	0.10	0.05	0.00
1,7	Bh	7.0	2.1	1.3	1.83	0.46	0.26	0.37
1,7	Bhs	8.5	2.7	2.4	0.82	0.13	0.43	0.14
2,5	Bh	6.2	1.8	1.3	3.42	1.13	0.59	0.02
2,5	Bhs	7.5	2.9	2.7	0.90	0.19	0.30	0.02