

The Isotic Mineralogy Class of Soil Taxonomy: Issues and Problems

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The isotic mineralogy class was added to U.S. soil taxonomy with the distribution of Issue No. 18 of the *National Soil Taxonomy Handbook* by the Natural Resources Conservation Service (NRCS) on March 9, 1996. It was then published in the seventh edition of the *Keys to Soil Taxonomy* in November of 1996 (Soil Survey Staff, 1996) and the second edition of *Soil Taxonomy* in 1999 (Soil Survey Staff, 1999). The isotic class was adopted in conjunction with the activities of the International Committee on the Classification of Families (ICOMFAM). This committee was established in 1987 with Dr. B.F. Hajek, Auburn University, as Chair. The final recommendations of ICOMFAM were issued in August of 1993, but the isotic mineralogy class was not part of the recommended changes. The isotic mineralogy class first appeared in print in June of 1995 when the National Soil Survey Center circulated a draft revision of the chapter "Family and Series Differentiae and Names" in *Soil Taxonomy*. Isotic mineralogy was approved for use only nine months later. The potential workload impact of the isotic class in 1996 was unknown and difficult to gauge. Since its addition to *Soil Taxonomy*, approximately 800 soil series have been classified with isotic mineralogy.

Many soils influenced with volcanic ash have unique chemical and physical properties but do not meet criteria for the andic soil properties defined in *Soil Taxonomy*. A study in the 1980s (Nettleton and Engel, 1985) highlighted the classification problems of three groups of tephra-influenced soils that have some of the properties now embodied in Andisols, but that failed to meet the criteria for ashy or medial substitute classes as previously defined in the first edition of *Soil Taxonomy* (Soil Survey Staff, 1975). Soils with isotic mineralogy have special properties including higher than normal pH-dependent charge and greater ability to bind or "fix" soluble phosphorus (P) than other soils. The property of high P retention in soils has significance for agro-economic interpretations and environmental concerns. The Andisol order was established, in part, to taxonomically capture soils with this property. In *Soil Taxonomy*, the P retention of soil material is a criterion for andic soil properties and is measured by the New Zealand P retention test (Soil Survey Laboratory Staff, 1995).

The intent of the isotic mineralogy class is to include those soils that have a colloidal fraction that is dominated by short-range order (poorly crys-

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talline) minerals or aluminum–humus complexes, but do not meet all the criteria of the substitutes for particle-size classes (e.g., ashy or medial). However, many soils having isotic mineralogy are not formed from parent materials influenced by tephra or volcanic rocks. The current criteria for the isotic class (from the Key to Mineralogy Classes, p. 825–827 of *Soil Taxonomy*, 2nd ed. Soil Survey Staff, 1999) are as follows:

In more than one-half of the thickness, all of the following:

- a. Have no free carbonates; and
- b. The pH of a suspension of 1 g soil in 50 ml 1 M NaF is more than 8.4 after 2 minutes; and
- c. The ratio of 1500 kPa water to measured clay is 0.6 or more.

The pH by sodium fluoride (NaF) is used as a criterion because this test is simple to perform in the field and is assumed to be a reliable test for the presence of short-range order minerals. Free carbonates in the soil can result in high NaF pH values and high 1500 kPa water/clay ratios, so calcareous soils are excluded from the isotic class. Some pedologists believe the isotic mineralogy class has value because the clay content for particle-size class placement is identified as having been derived from the 1500 kPa water content. This is the case due to use of the calculated clay footnote in *Soil Taxonomy* when apparent dispersion for particle-size analysis in the laboratory is poor (1500 kPa water retention/clay > 0.6). The rule is the formula: Clay % = 2.5(% water retained at 1500 kPa tension % organic carbon). The isotic class keeps such soils with derived clay content in a unique class from other more “normal” soils that disperse well.

We have experienced problems with the consistent application of the isotic mineralogy class when performing their assigned duties of quality assurance for correlation, classification, and database management. This discussion voices these issues and the authors concerns with the isotic mineralogy class since its presence in the taxonomic classification standard for soil survey (*Soil Taxonomy*) cannot be ignored. As Table 1 shows, the MLRA offices represented by the authors (MOs 1, 2, 3, 4, and 6) are responsible for 85% of the soil series currently having isotic mineralogy. We wish to begin this discussion to identify and clarify important issues and communicate them to the soil science community. We hope to involve other individuals with similar (and different) viewpoints and experiences concerning the isotic mineralogy class in this ongoing discussion. The outcome of this discussion should be an improved soil taxonomy. The ultimate goal is a taxonomic classification system that uses appropriate criteria and limits that consistently group soils with valid interpretive differences.

Issues and Problems with Isotc Mineralogy

The following items are issues that we have found with the isotic mineralogy class:

- **Apparent lack of interpretive value of the isotic class vs. the mixed mineralogy class**
- **Difficulty in applying the class based on easily observed field correlation guides such as soil parent material, geology, vegetation, landscape position, and soil climate regimes**

The apparent lack of interpretive value of the isotic mineralogy class was recently highlighted in a paper on the application of the isotic class in eastern Oregon (Wilson et al., 2002). This review reinforces the difficulty many soil scientists have determining significant differences in use, management, or productivity between similar soils that have mineralogy that is marginal between isotic and mixed. The isotic class can seem more reasonable if an assumption is made that interpretive differences do exist between the isotic and mixed classes yet the differences have not yet been documented with detailed studies. However, placement into the isotic class for pedons can only be definitely made with field and laboratory data that document NaF pH, 1500 kPa water contents, and clay contents. Soils with isotic mineralogy are, at best, very difficult to correlate using field guides such as soil parent material, surficial geology, or plant community. In the Southern Rocky Mountain soil survey region of the MLRA regional office in Lakewood, CO, the isotic class is easier to correlate with plant community and soil climate. This regional office has identified soils with isotic mineralogy in plant communities of subalpine coniferous forest or alpine tundra. These soils are not influenced by volcanic ash, but their mineralogy class is often hard to predict. Even within the above "potential isotic zone," soils with mixed or isotic mineralogy are intermingled over short distances. Although soils in the isotic mineralogy class may be correlated to soils and landscapes on a broad regional basis, on a smaller scale their occurrence is less predicable.

- **Classification and correlation problems of similar soil series separated only by mineralogy class**

Since interpretive differences may not be apparent in soils with isotic vs. mixed mineralogy, practical decisions must be made when correlating soil series in active soil survey projects and in reclassifying established series. The MLRA regional office in Portland, OR has decided to avoid proliferating new soil series based solely on the isotic mineralogy class in survey areas where similar soils with mixed mineralogy exist in close proximity. In such survey areas soils with isotic mineralogy are correlated as taxadjuncts to established series having mixed mineralogy. In addition, they are using a pragmatic approach to consistently differentiate between isotic and mixed mineralogy. Generally, forested soils having enough volcanic ash influence to meet Andic or Vitrandic subgroup criteria and lacking andic soil properties are classified with isotic mineralogy. Nonforested rangeland soils with the same degree of volcanic ash influence are classified with mixed mineralogy unless glass contents are high enough for substitute classes (e.g., ashy) and glassy mineralogy. This model attempts to use historic, field-observable guides such as soil

climate and vegetative communities for consistent application of the unobservable mineralogy classes. Establishing new soil series differing only in mineralogy class becomes a considerable workload for both the field soil scientists and the soil data quality specialists responsible for final correlation and quality assurance. The time involved in establishing new soil series with subtle taxonomic differences often cannot be justified when little added value results from the effort.

- **Appropriate criteria or critical values for the class (NaF pH and 1500 kPa water/clay ratio)**

Two of the criteria for the isotic class have very questionable value. NaF pH is not as effective as other chemical-optical methods, such as ammonium oxalate extractions, in determining the presence of poorly crystalline minerals (Soil Survey Laboratory Staff, 1995). For this reason it is not a criterion for andic soil properties. It does have the advantage of being easy to use in a field setting. However, if the results of the test are questionable, then the test raises more questions than it answers. The NaF pH test has been used for several years now in the mapping of suites of soils formed from parent materials of either volcanic (andesite) or plutonic (granodiorite) rocks in the Sierra Nevada Range of eastern California and western Nevada. Results show that many soils in either suite have NaF pH values above 8.4. The soils formed in materials derived from granodiorite are dominated by the primary minerals quartz, potassium feldspar, and mica. The soils formed in materials derived from andesite are dominated by sodium feldspars and siliceous aggregates. Both suites of soils have little influence from volcanic ash nor do they have the organo-metallic compounds indicative of spodic properties. The NaF pH test has limited value when it cannot support a basic mineralogical difference that is readily observed due to differences in surficial geology or content of gravel-size rock fragments, silt, clay, or coarse sand.

- **Inappropriate inclusion of some soils that have an unreliable 1500 kPa water/clay ratio because it is based on very low clay and 1500 kPa water contents**

The 1500 kPa water to measured clay ratio of 0.6 or more is another criterion of the isotic mineralogy class that has questionable value in some soils. This ratio has traditionally been used as a proxy for poor dispersion after laboratory particle-size distribution analysis (PSDA). Use of 1500 kPa water/clay ratio as a criterion for isotic mineralogy is meant to be an indicator of the presence of short-range order minerals or aluminum-humus complexes. Soils with these substances often disperse poorly, if at all, prior to particle-size analysis. However, many soils that have relatively low clay content and lack poorly crystalline minerals often have 1500 kPa water/clay ratios of 0.6 or more. Ratios of 1500 kPa water/clay are meaningless in such soils. A discussion of this ratio on p. 42 in the *Soil Survey Laboratory Information Manual* (Soil Survey Laboratory Staff, 1995) states, "ratios above 0.5 for some samples with less than 5 to 10 percent clay may erroneously indicate poor

PSDA dispersion (National Soil Survey Laboratory Staff, 1990).” Since the 1500 kPa water/clay ratio is not an exacting measure of either poor dispersion or short-range order minerals for all soils, nor all ranges in clay content, its use as a criterion for isotopic mineralogy without qualification for clay content raises questions on the appropriateness of the criterion.

Using the isotopic mineralogy class as currently defined may include in the class soils that have no or low amounts of poorly crystalline minerals. Some of the aforementioned soils in the Sierra Nevada Range are examples. Soils such as the Temo series (mixed, shallow Typic Cryopsamments) and Toiyabe series (mixed, frigid, shallow Typic Xeropsamments) illustrate the problem. These soils are formed in parent materials derived from granodiorite and have negligible influence from volcanic ash. They are not highly weathered soils and do not have the organo-metallic compounds found in soils with spodic properties. Laboratory data exist for several pedons of these soil series. Some qualify for the isotopic mineralogy class, but it is unlikely that these soils have significant amounts of poorly crystalline minerals. This assumption for the lack of poorly crystalline minerals is based on parent materials, very coarse textures, the presence of crystalline clay minerals in the total clay fraction, and marginal NaF pH values. Other supporting data exists for these pedons that shows relatively low oxalate aluminum plus one-half iron percentages (by ammonium oxalate) and low New Zealand P retention values.

• **Broad application of the class from soils influenced with volcanic ash to soils with high amounts of organo-mineral substances (andic soil materials vs. spodic materials)**

As of July 30, 2003 there were 125 soil series with isotopic mineralogy classified in the order of Spodosols. Most of these series are not influenced by volcanic ash in the parent materials, but instead are highly weathered and dominated by organo-mineral compounds and poorly crystalline oxides of iron and aluminum. Applying the same isotopic class criteria to soils with spodic materials and to volcanic ash-influenced soils will group soils that have significantly different parent materials, properties, and interpretations.

Recommendations

There are several options available to improve the criteria for the isotopic mineralogy class. These are presented below as points for general consideration and discussion. However, if the current criteria or their limits cannot be better defined, dropping the class from U.S. soil taxonomy is also a viable option.

Future options for isotopic mineralogy criteria

1. NaF criterion and use

- Discontinue use of NaF pH as a criterion, or
- Substitute use of New Zealand P retention for NaF pH as a criterion, or

- Substitute use of aluminum plus one-half iron percentages (by ammonium oxalate) for NaF pH as a criterion, or
 - Continue use of NaF pH as a criterion, but raise the critical pH from 8.4 to a more appropriate value
2. 1500 kPa/clay ratio criterion and use
- Discontinue use of 1500 kPa water/clay ratio as a criterion, or
 - Exclude soils with sandy or sandy-skeletal particle-size class, or
 - Waive the 1500 kPa water/clay ratio as a criterion for soils with low clay content, or
 - Substitute use of aluminum plus one-half iron percentages (by ammonium oxalate) for 1500 kPa water/clay ratio as a criterion, or
 - Continue use of 1500 kPa water/clay ratio as a criterion, but raise the critical value from 0.6 to a more appropriate value

Both New Zealand P retention and aluminum plus one-half iron percentages (by ammonium oxalate) correlate very well with each other and with NaF pH (Wilson et al., 2002). For the above options, the critical value for New Zealand P retention could possibly be set at 25% or more, and the critical value for aluminum plus one-half iron percentages could be 0.4% or more. These limits are also used in Requirement 2 for andic soil properties in *Soil Taxonomy* (Soil Survey Staff, 1999). The critical value for NaF pH could possibly be raised to more than 9.4. Similarly, the critical value for 1500 kPa water/clay ratio could possibly be raised to more than 1.0. Both of these values were previously used in the definition for the diagnostic soil characteristic “amorphous material dominant in the exchange complex” from the first edition of *Soil Taxonomy* (Soil Survey Staff, 1975).

Summary

On the basis of the issues raised in this discussion, we recommend that the concept and criteria of the isotic mineralogy class be reevaluated. The goal is the consistent use and application of this class for series differentiae. To carry the discussion forward toward this goal, more background information on the isotic mineralogy class is needed. Specifically, there should be a published explanation of the intent of the class, the interpretive and management differences that justify the class, and the rationale for the current criteria and their critical limits. It would also be beneficial to learn of problems or successes that soil scientists in other regions are having applying the current criteria. With this additional information, we can consider whether to prepare a formal proposal to revise the current criteria for isotic mineralogy or to propose removing the class from *Soil Taxonomy*.

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Table 1. The number of soil series (as of 30 July 2003) with isotopic mineralogy for each of the NRCS MLRA regional offices that have the assigned series responsibility.

MLRA regional office	Number of soil series with isotopic mineralogy
Portland, OR (MO1)	457
Davis, CA (MO2)	40
Reno, NV (MO3)	34
Bozeman, MT (MO4)	109
Lakewood, CO (MO6)	17
St. Paul, MN (MO10)	10
Indianapolis, IN (MO11)	1
Amherst, MA (MO12)	68
Morgantown, WV (MO13)	4
Auburn, AL (MO15)	2
Anchorage, AK (MO17)	1
Lexington, KY (MO18)	34
All MOs	777