Soil Mineralogy: A Missing Factor in Crop Potassium Nutrition

National Association of Independent Crop Consultants

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David Franzen, PhD

Professor Soil Science

NDSU Extension Soil Specialist

Fargo, ND

What the textbooks state:

Available pool
(K on CEC) (Plant available K)

Slowly Available Pool
(K in clay interlayers) (Maybe available over years)

Unavailable Pool
(feldspars) (Your Grandkids might benefit a little)

K soil test method used in North Dakota-

Dry soil K test- (Warncke & Brown, 2015)

http://extension.missouri.edu/explorepdf/specialb/sb1001.pdf

Air-dry soil, 1M Ammonium acetate, fixed shaking time, filter, analyze for K in flame-photometer or AA set up for emission.

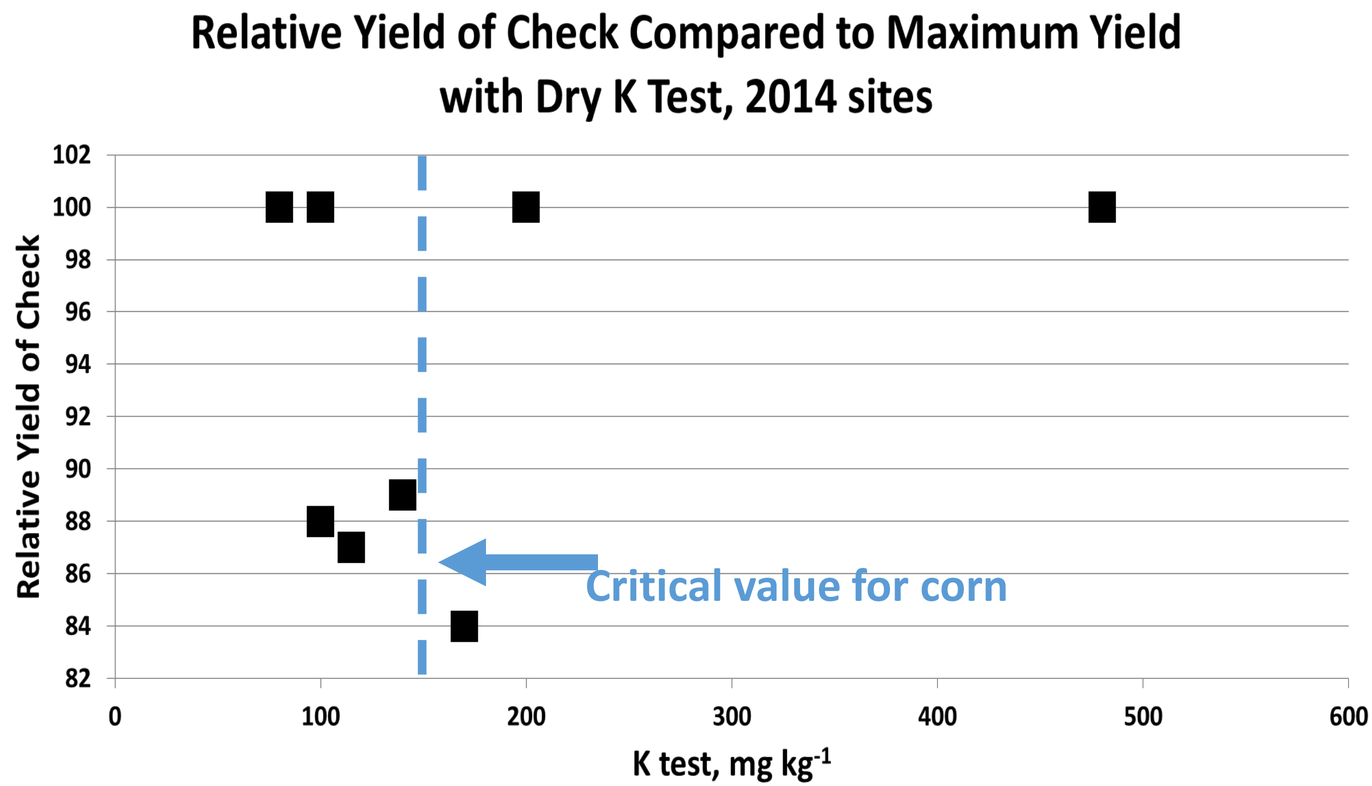
K study started 2014 season

Response to decline in K soil test levels in SE North Dakota as a result of rotation change from wheat/barley/sugar beet, which do not result in high K removal to corn and soybean which removes much K.

Common K soil test values in SE ND are 100-200 ppm.

2014- 10 sites in SE North Dakota.

Only half behaved the way the recommendation indicated. (response if K < 150 ppm, no response if K > 150 ppm.)

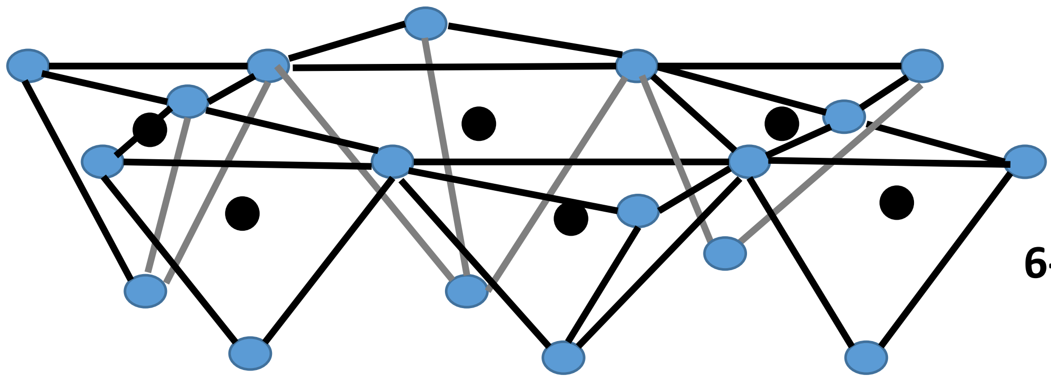


2014 results were very distressing.

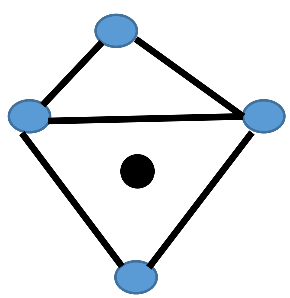
After attending an American Society of Agronomy Symposium (Dr. Don Sparks, U. Del.) we started investigating clay chemistry and soil mineralogy.

Clay chemistry short version:

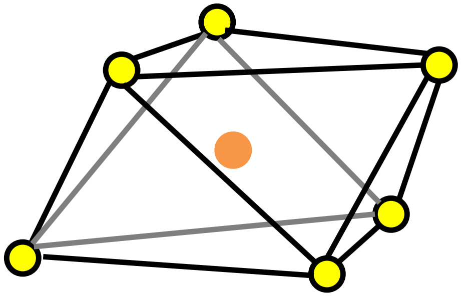
The silicon oxide sheet layer-



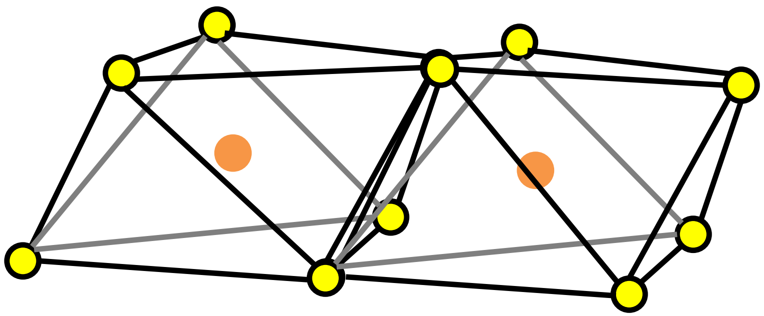
6- SiO_4 in a sheet



The SiO_4 building block

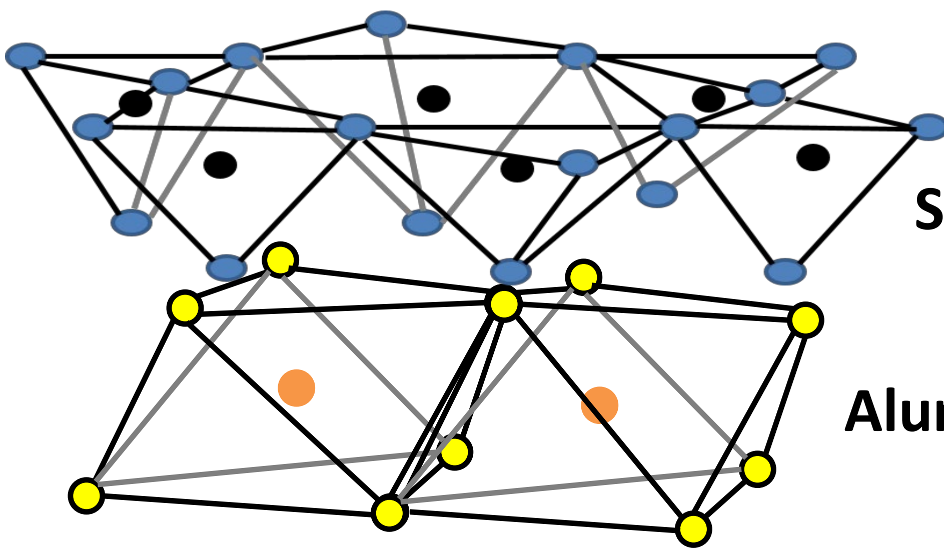


Aluminum hydroxide building block



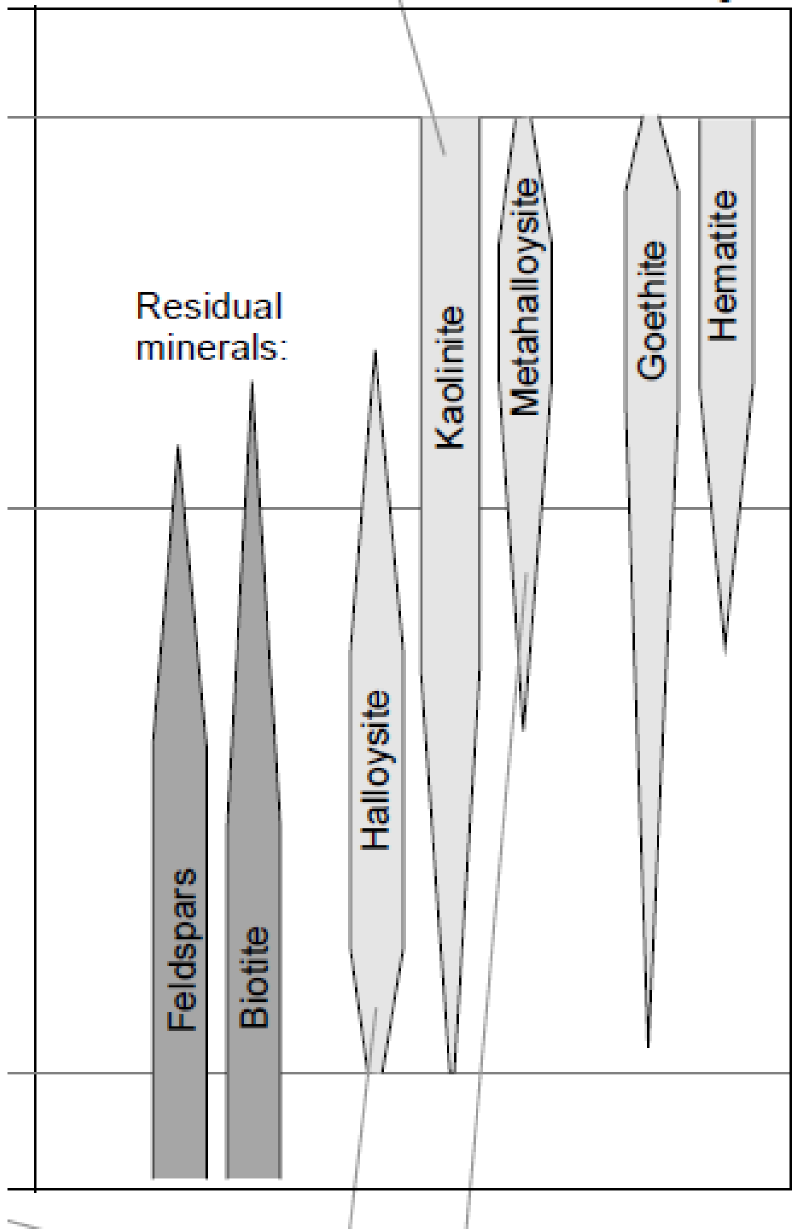
Aluminum hydroxide sheet

A 1:1 silicon oxide sheet bound to an aluminum hydroxide sheet.



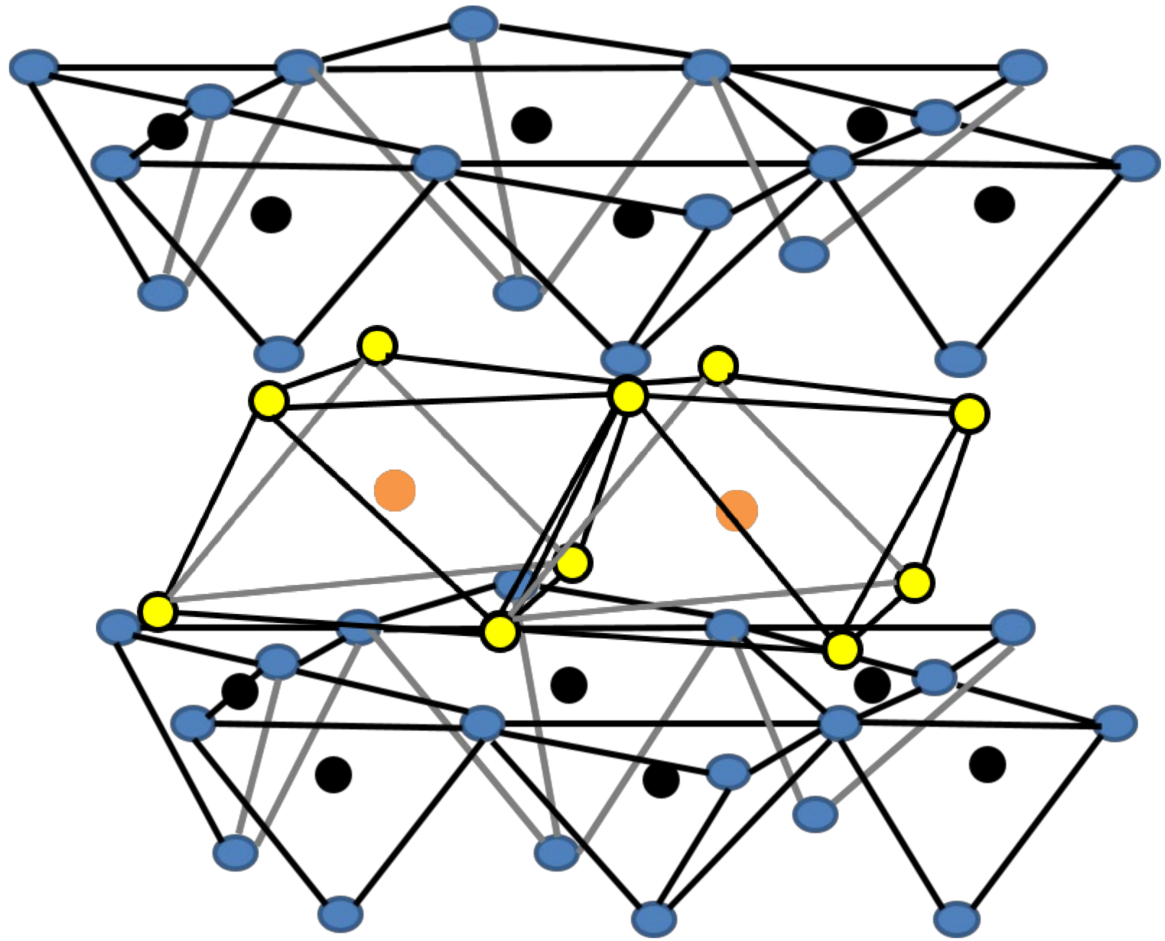
Bound by partial charge from $O^{-\rho}$ and $OH^{+\rho}$

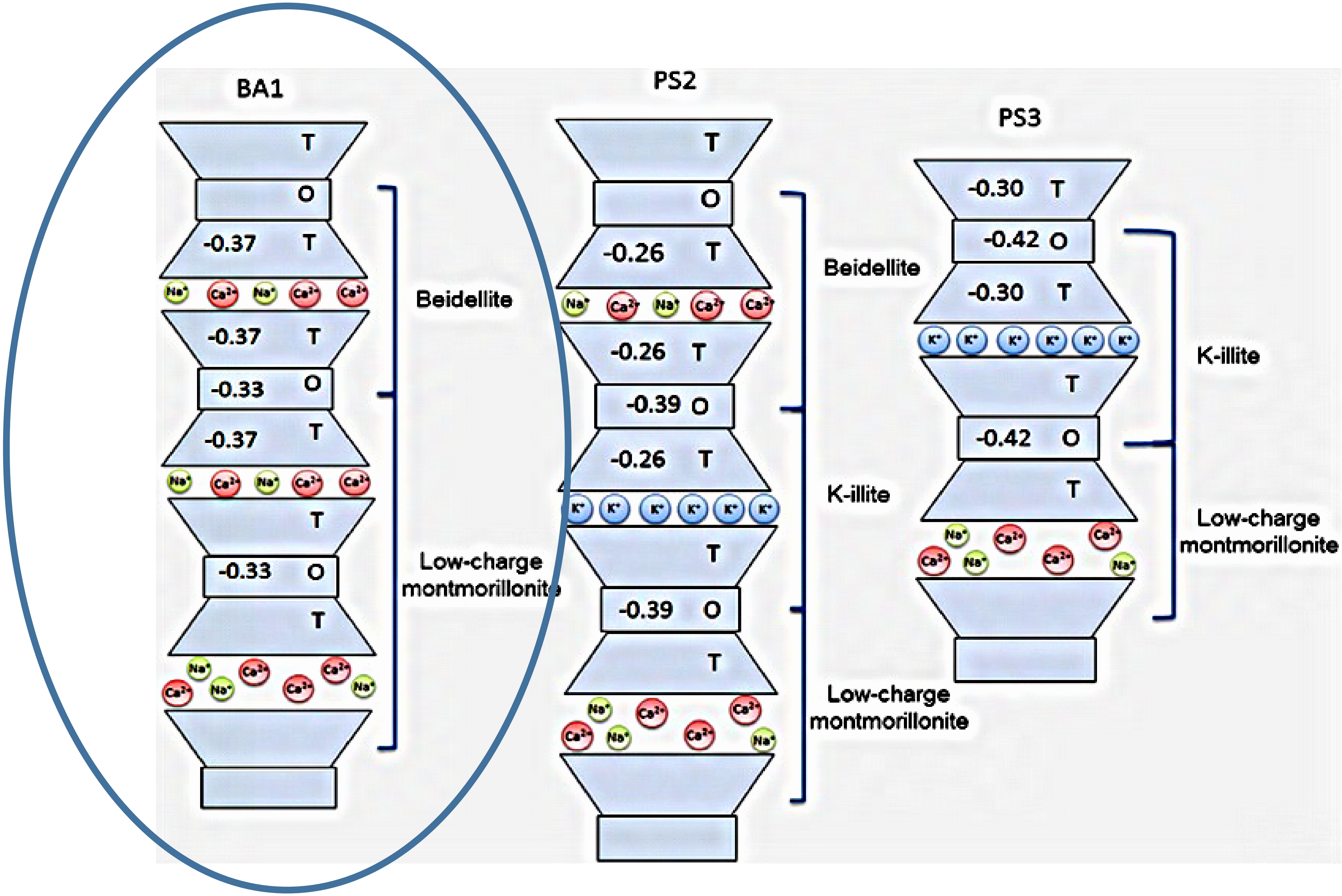
Soils developed on the Danburg Granite & Athens Gneiss in the Piedmont of Georgia:



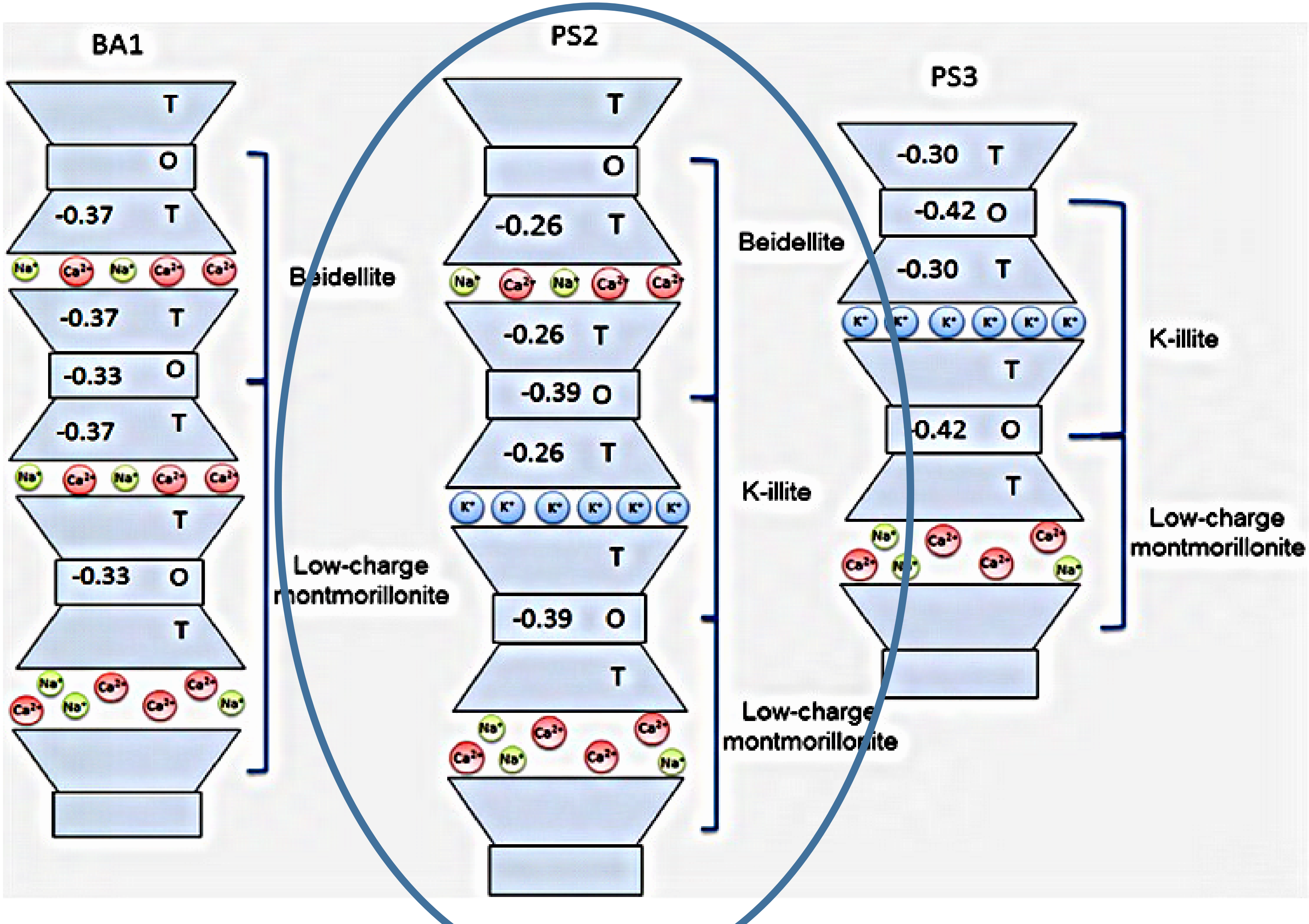
A 2:1 clay-

Sheet of Aluminum hydroxide with 2 sheets of Silicon oxide- one above, one beneath.

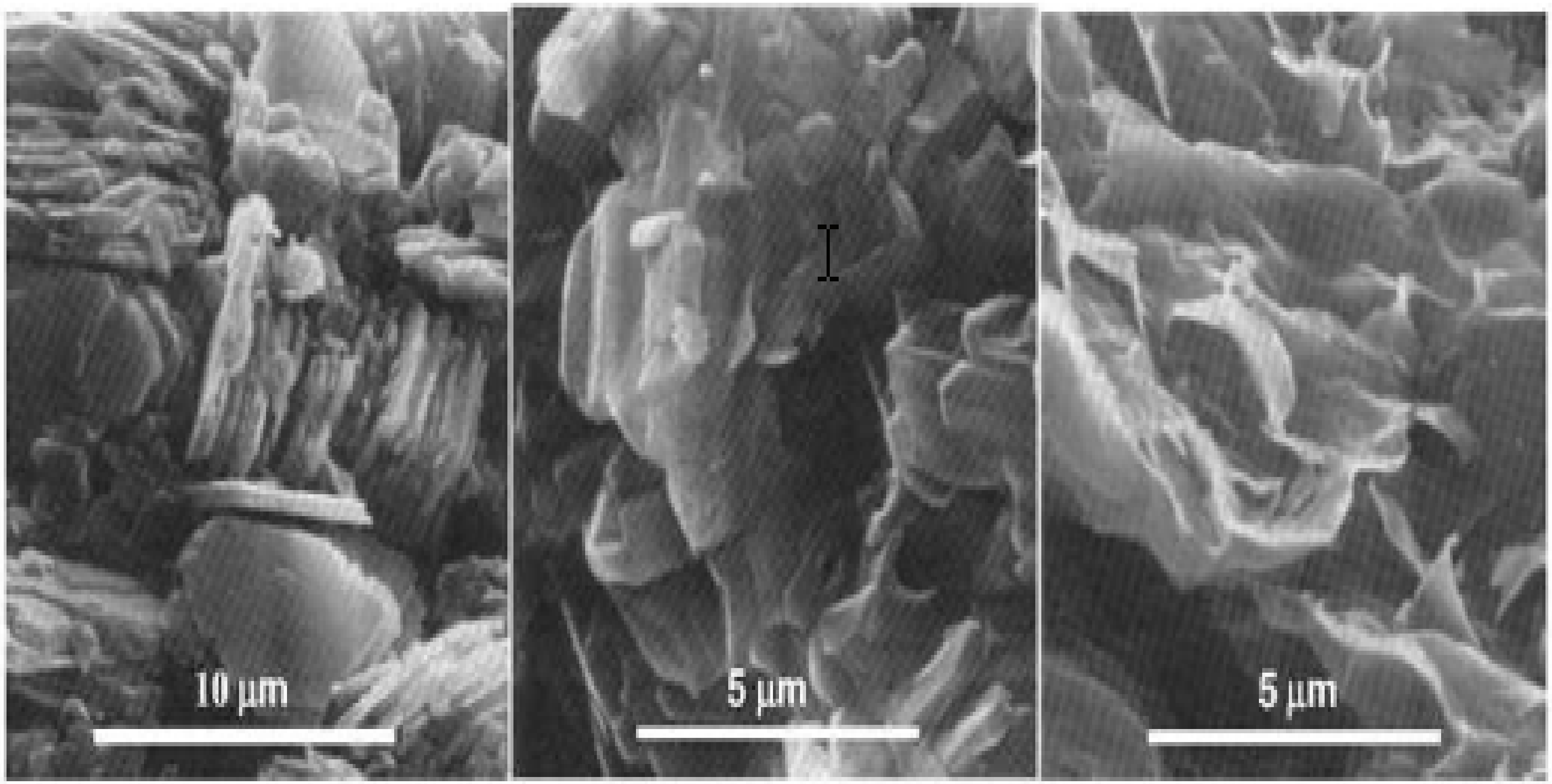




Smectite (beidellite and montmorillonite) and illites diagrams



Smectite (beidellite and montmorillonite) and illites diagrams



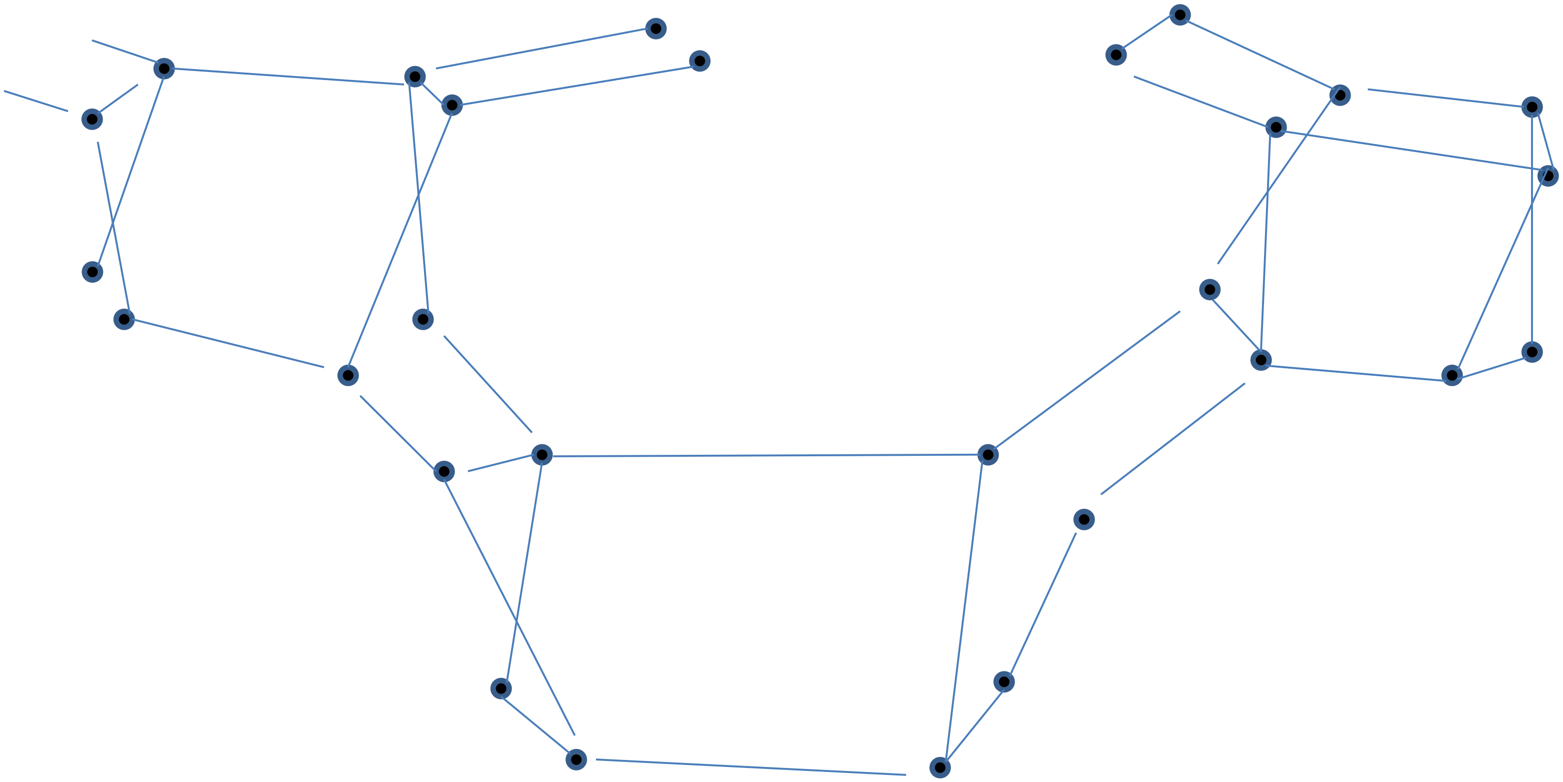
Micrographs of kaolinite (1:1 clay) left
Illite (limited shrinking 2:1 clay) center
and Smectite (high shrink/swell 2:1 clay) right

Smectites ‘fix’, or temporarily retain K when soil is dry

Illites do not ‘fix’ K when dry

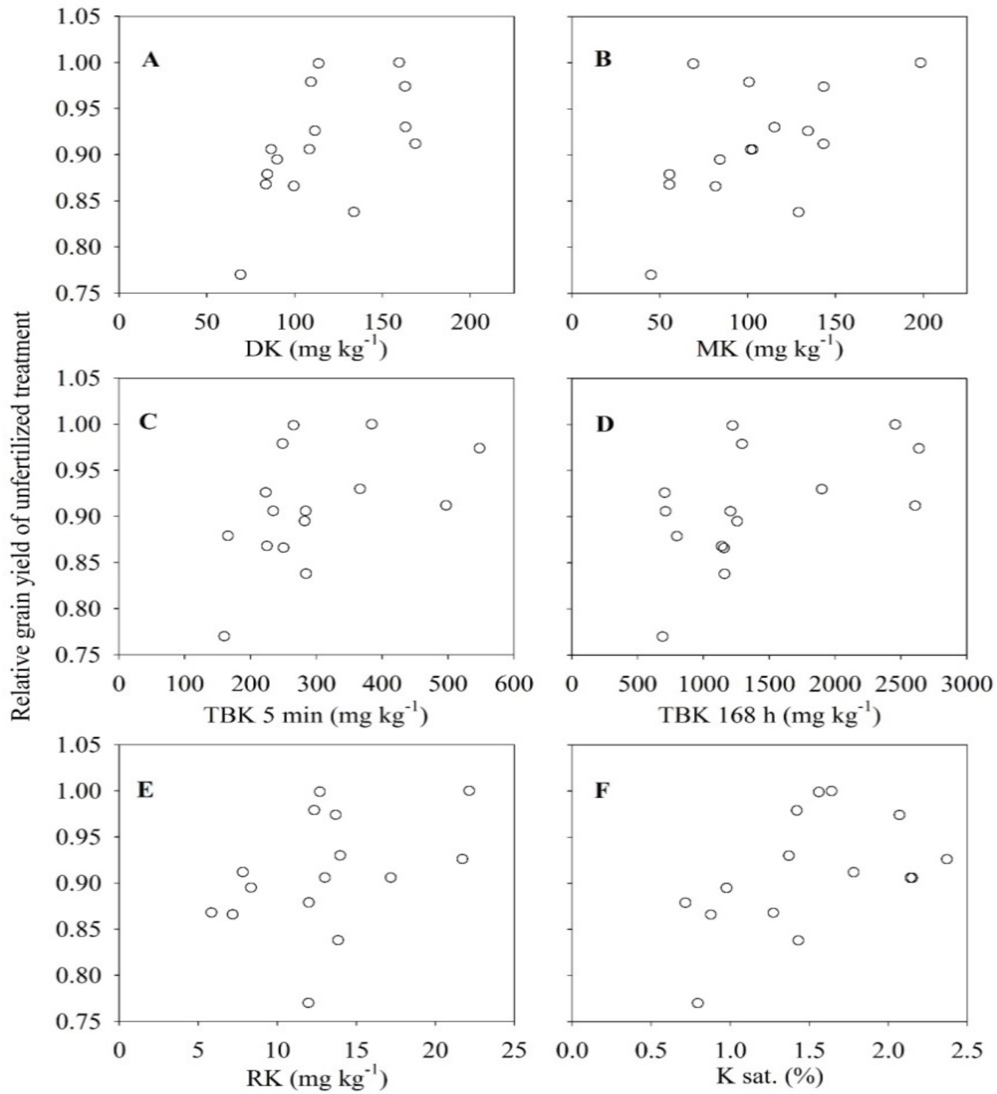
Smectite clays, particularly those with high interlayer charge (beidellite) 'fix' K during dry soil periods and prevent K release upon shrinking/collapse. This is a reversible process when the soil re-wets.

Potassium feldspar-



3-D framework of SiO_4 and Al_2O_3 tetrahedrals isomorphous substitution of Al for Si ~ ¼ of the time results in significant negative (-) charge. Potassium within the open spaces helps balance charge.

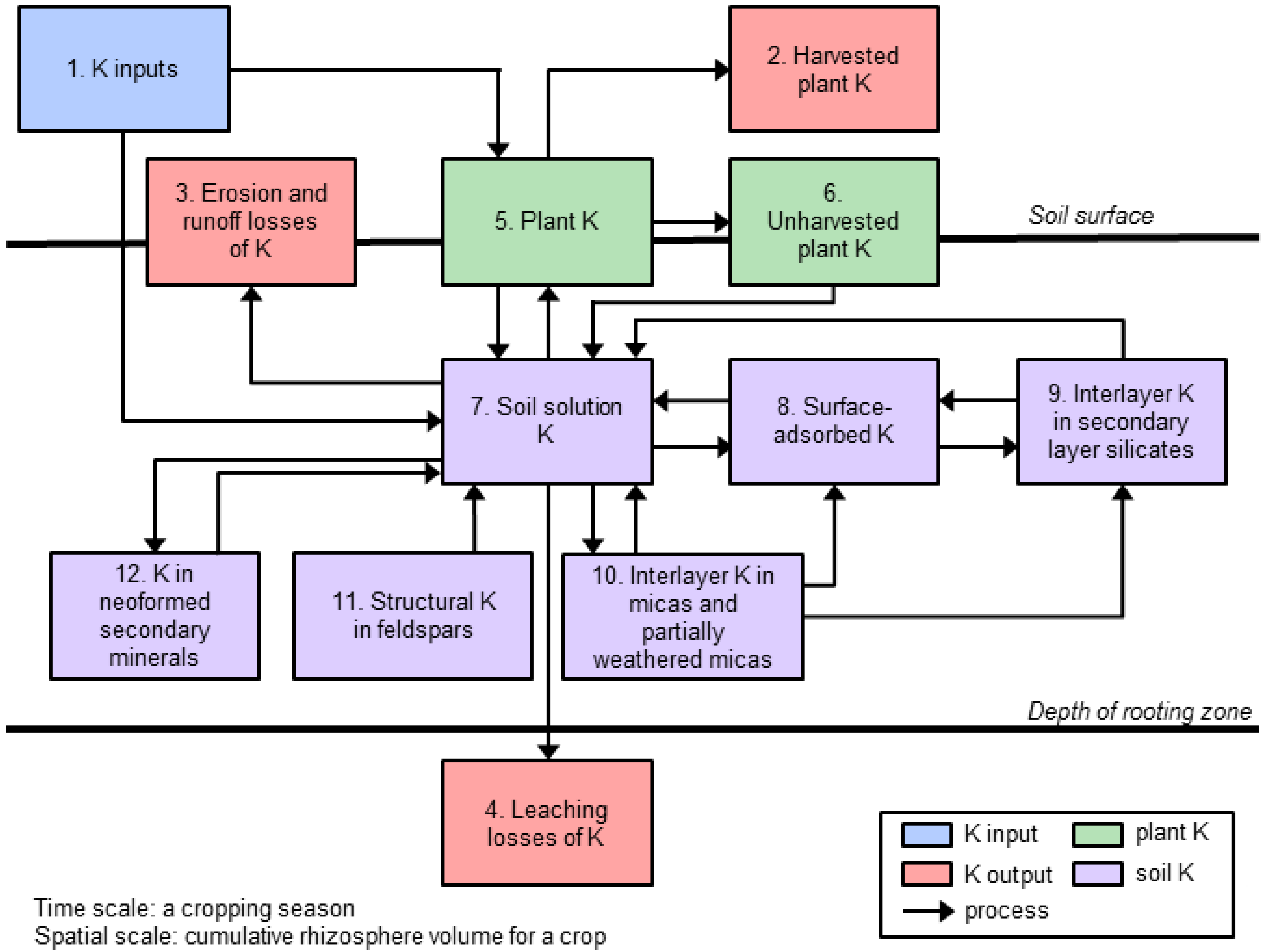
Examination of different K soil testing methods:



Test	R^2
Dry K	0.49
Moist K	0.47
TBK 5min	0.33
TBK 1 wk	0.30
Resin	0.16
CEC	0.42

In 2015 and 2016 we added a total of 19 additional sites.

Of 29 K rate studies, only a little of half responded as expected using the dry soil K test only.


1. K inputs
2. Harvested plant K
3. Erosion and runoff losses of K
5. Plant K
6. Unharvested plant K
Soil surface
7. Soil solution K
8. Surface-adsorbed K
9. Interlayer K in secondary layer silicates
12. K in neoformed secondary minerals
11. Structural K in feldspars
10. Interlayer K in micas and partially weathered micas
Depth of rooting zone
4. Leaching losses of K
K input
plant K
K output
soil K
process
Time scale: a cropping season
Spatial scale: cumulative rhizosphere volume for a crop

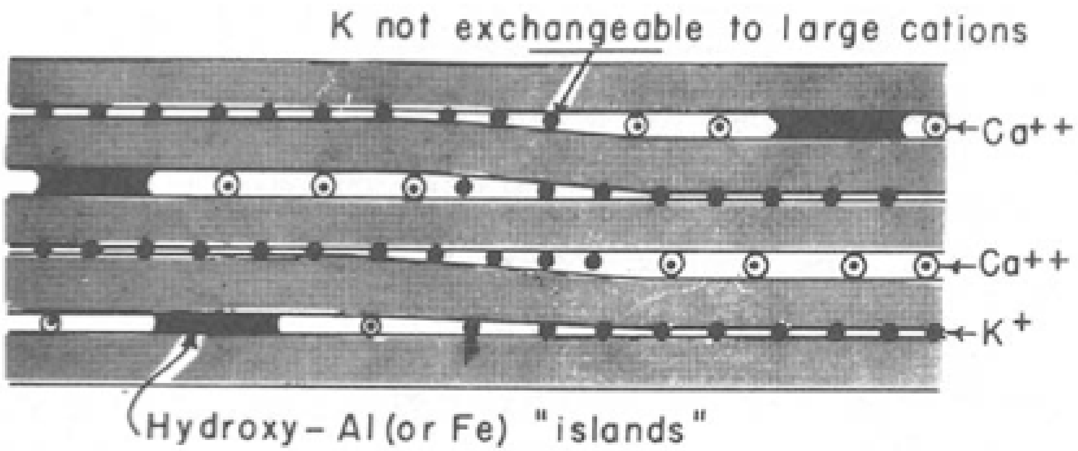


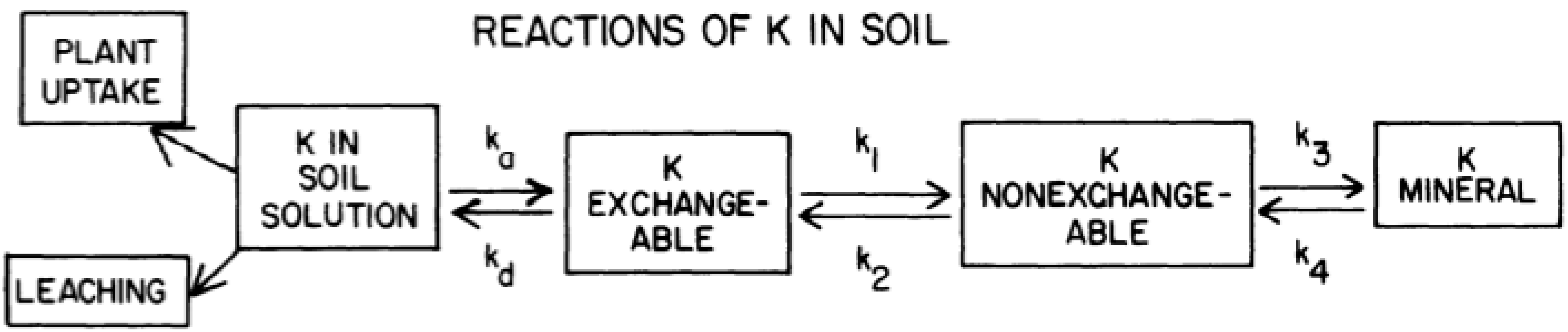
Fig. 9–23. Proposed model of an expansible layer silicate with interlayers indicating effect on K fixation (Rich, 1968a).

From Sparks and Huang 1985

Forms of K in soils explored by Sparks et al., AJ. 1980 (meq/100 g)

Site	Exchangeable	Non-Exch	Feldspar	Mica	Total K
Greensville	0.11	0.17	5.4	0.8	6.5
Nottoway	0.10	0.22	11.3	0.4	12.0

No yield responses to K recorded at these and other sites of similar mineralogy over a series of years, despite low K soil test values.



where

k_a = adsorption rate coefficient in h^{-1},

k_d = desorption rate coefficient in h^{-1},

From Sparks and Huang 1985

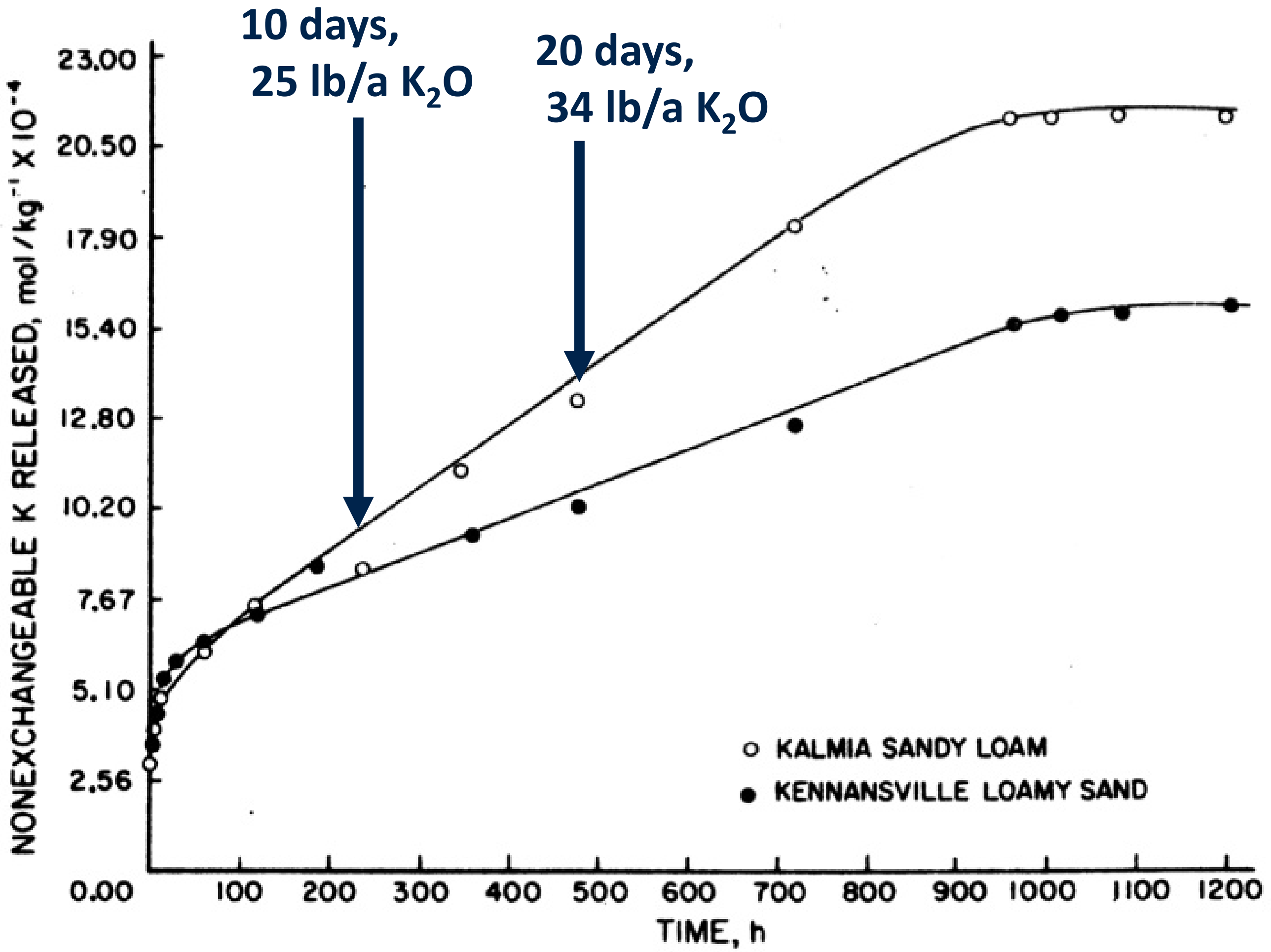


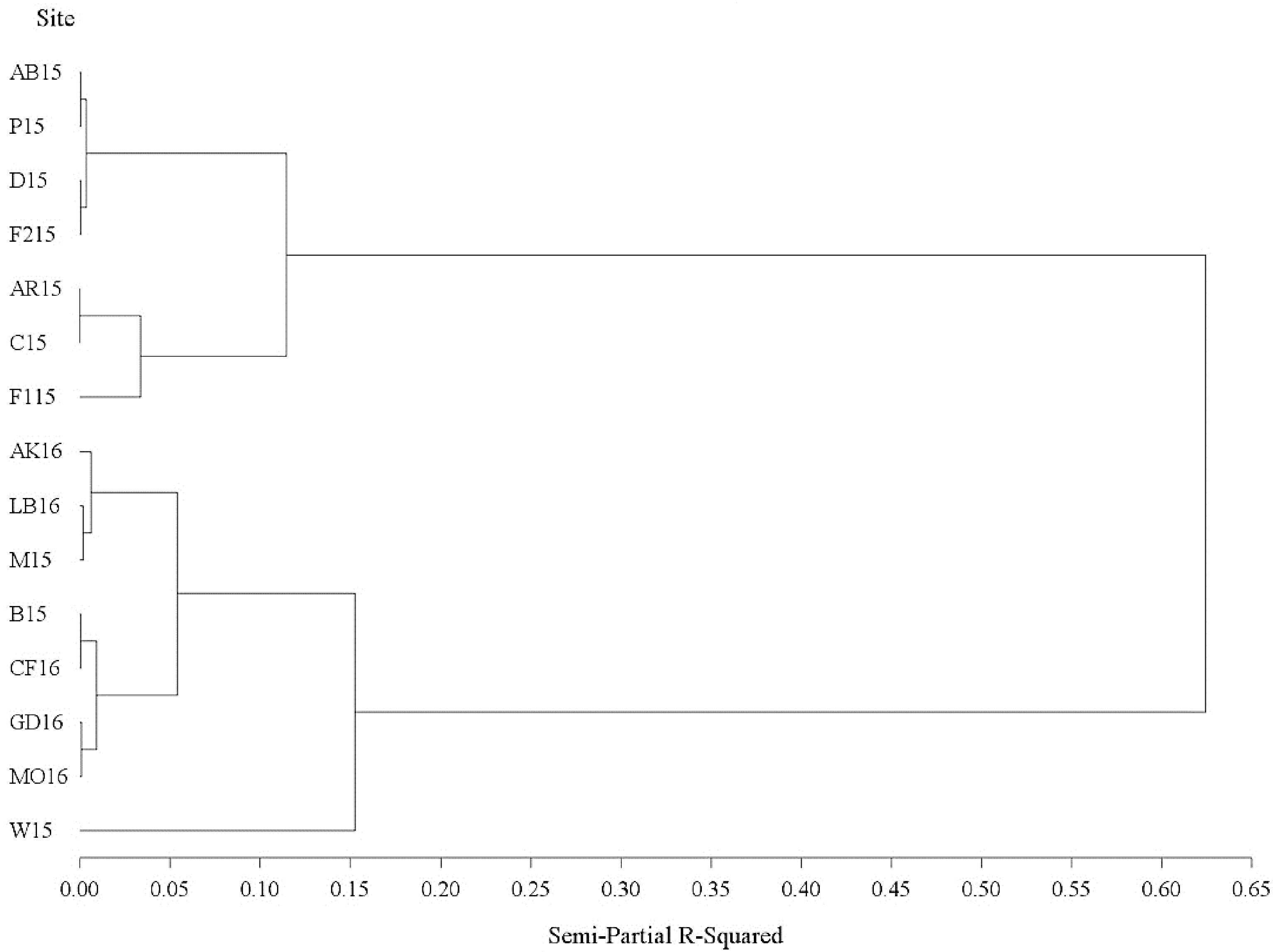
Fig. 1—Amount of nonexchangeable K released vs. time in the 0.45- to 0.60-m depth of Kalmia and Kennansville soils.

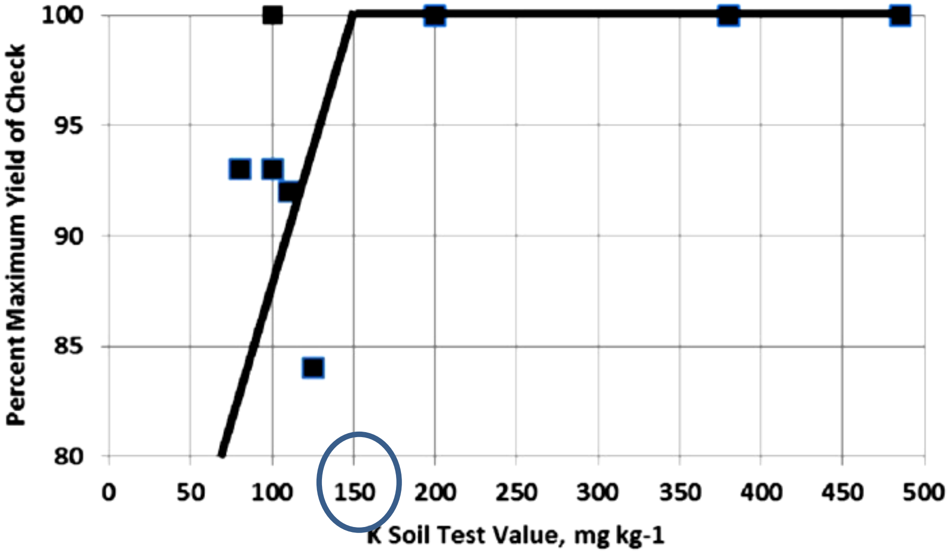
From Martin and Sparks, SSSAJ 1983

The sand fractions of soil from M.C. Sandusky et al., 1987 released 300 lb K_2O into a H^+ saturated resin over a 30-day period. (a Sparks study)

Most of this release was from potassium feldspar-K

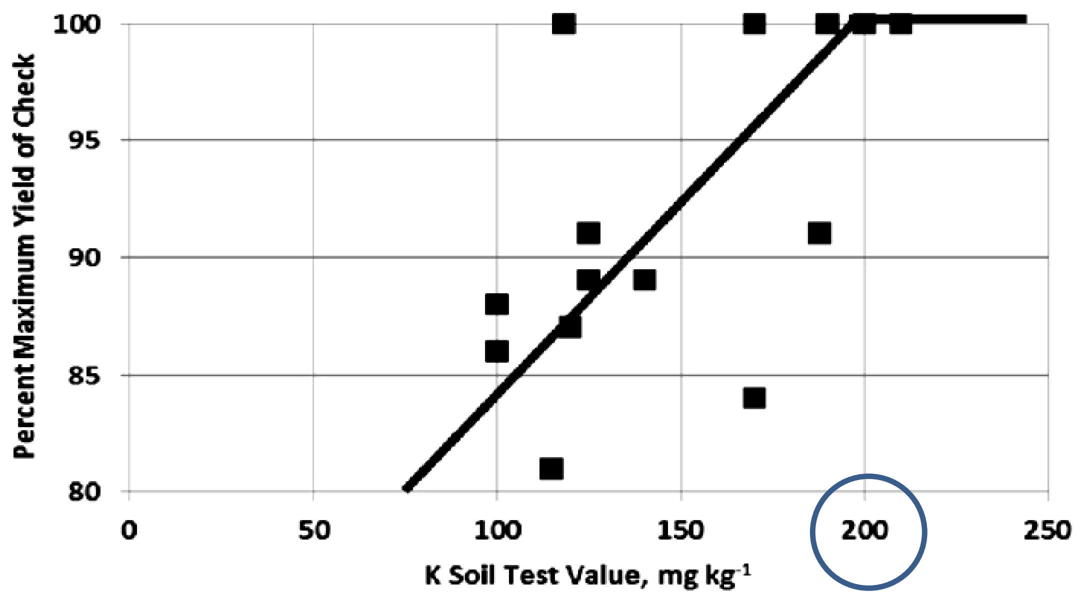
Used statistics to cluster the sites into two groups. The ratio of smectite to illite that was best for dividing our data-set was 3.5





Smectite/illite ratio < 3.5

Smectite/illite ratio > 3.5



Minerals & Clays measured in survey-

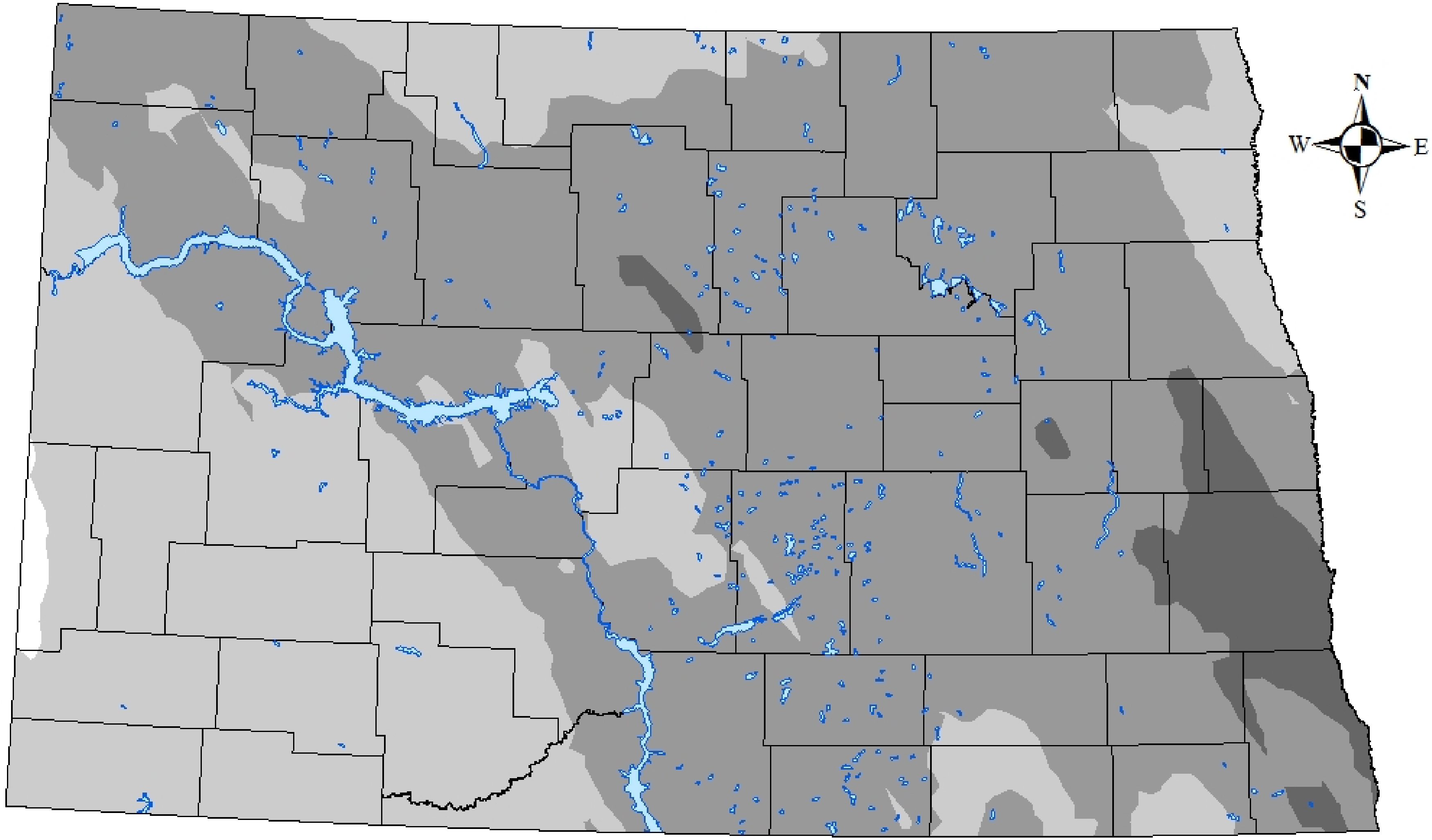
Smectite- (includes montmorillonite/beidelite)

Illite- 2-1 limited expanding clay

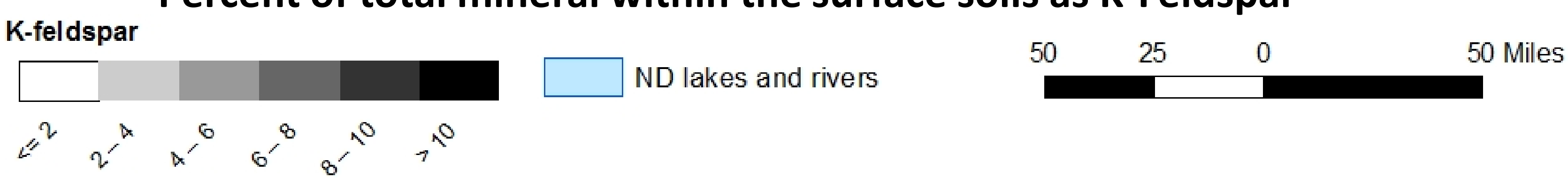
Kaolinite (1-1 non-expanding clays)

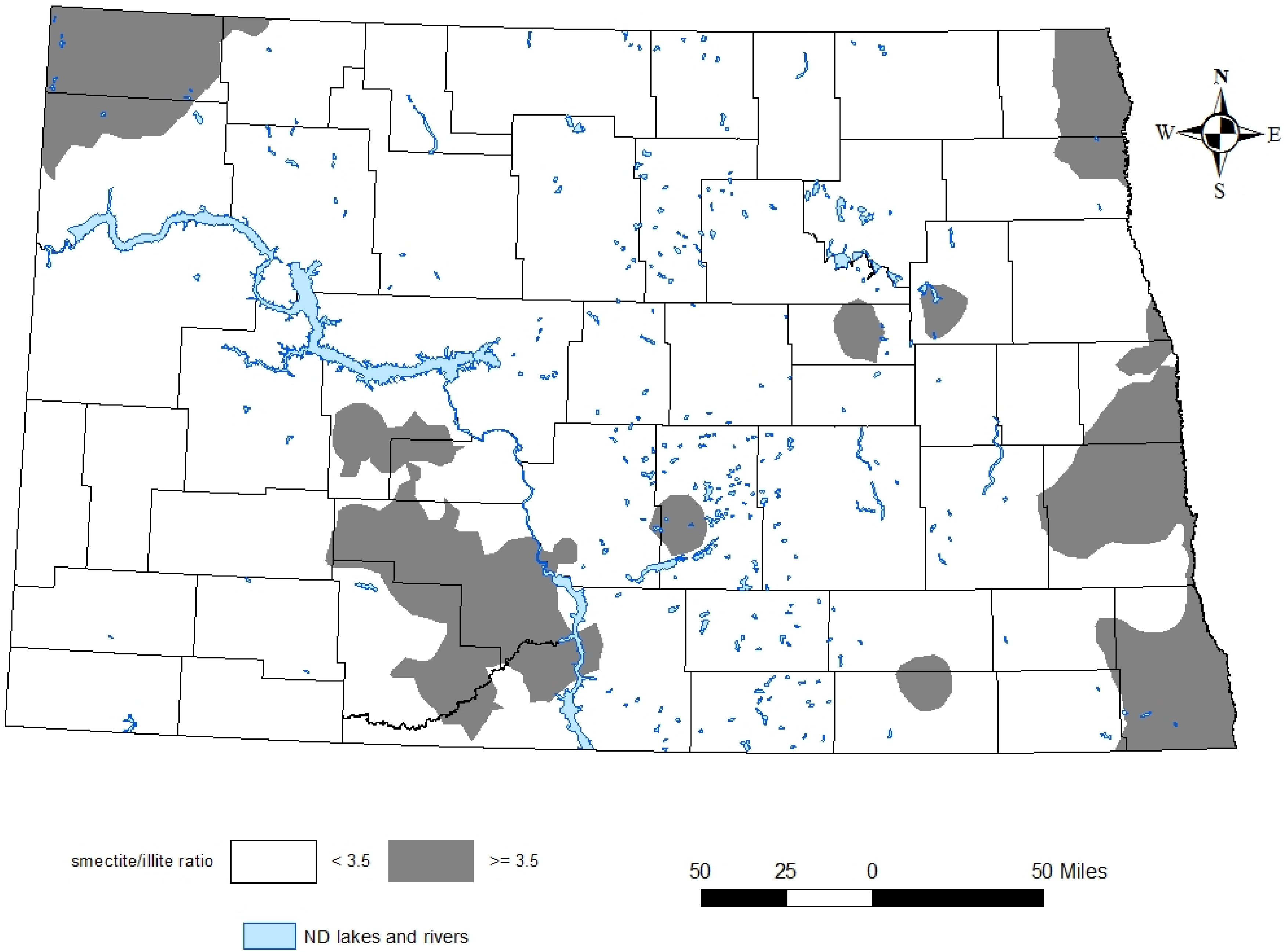
Chlorite (3-1 non-expanding clays)

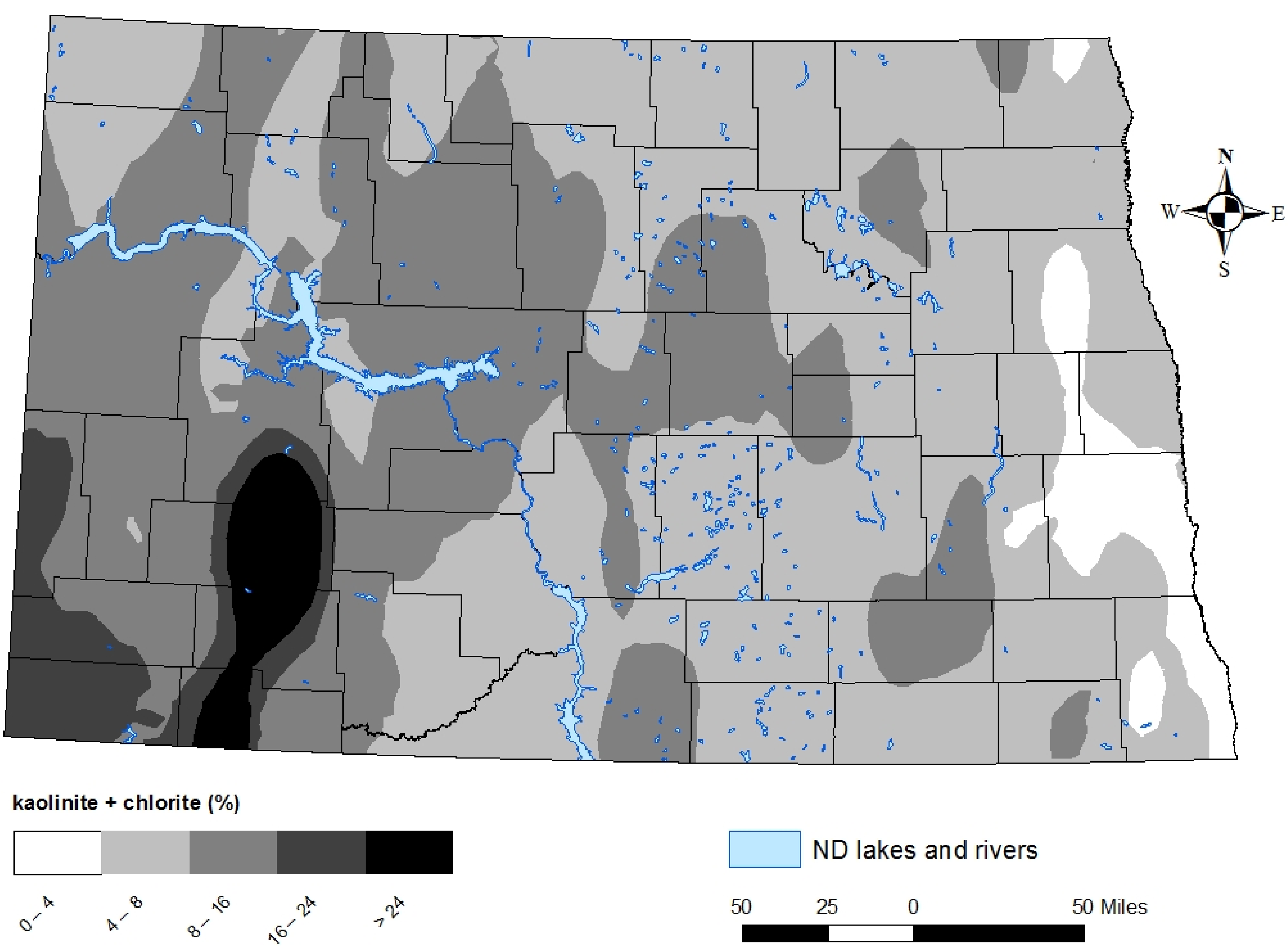
Potassium feldspar



Percent of total mineral within the surface soils as K-Feldspar




N
W
E
S
smectite/illite ratio
< 3.5
>= 3.5
ND lakes and rivers
50
25
0
50 Miles


N
W
E
S
kaolinite + chlorite (%)
0 – 4
4 – 8
8 – 16
16 – 24
> 24
ND lakes and rivers
50
25
0
50 Miles

New North Dakota critical K levels-

For corn, alfalfa-

Smectite/illite > 3.5 200 ppm

Smectite/illite < 3.5 150 ppm

For sugar beet-

>3.5 150 ppm

< 3.5 120 ppm

For spring wheat/durum/winter wheat

> 3.5 150 ppm

< 3.5 100 ppm