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Grainy Gray Ped Coatings in Brunizem Soils[1]

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Abstract. The presence of light colored, granular material on structural units in the lower B horizon is considered to be an atypical morphological feature in the Brunizem soils of Iowa. This study indicates that there are appreciable areas of Brunizem soils, derived from Wisconsin loess and Iowan till, in eastern Iowa with such coatings in the lower B horizon. Because the grainy gray ped coatings cannot readily be accounted for by any soil-forming factor other than vegetation, and because they are similar to coatings in some associated Gray-Brown Podzolic soils, it is inferred that their presence is generally related to a prior influence of deciduous forest. Their proper classification needs further attention.

Smith et al. (1, p. 169) in their comprehensive report of Prairie soils, mention areas of loes-derived Tama soils in eastern Iowa and northwestern Illinois in which ". . . the B horizon has moderate to heavy coatings of light gray silt on structural aggregates." Since their report in 1950 additional observations have been made on Brunizem soils containing "grainy gray" or "Silica" coatings on structural unit or ped surfaces in the B horizon (2, 3, 4). These are not considered typical of modal Brunizems.

It is thought that Brunizem soils have developed wholly under the influence of prairie. Accumulation of humified organic matter results in a darkening of the soil to depths of 6 to 20 inches. They are said to have mollic epipedons (7). Subsoil or B horizon colors are brown, yellowish brown, or grayish brown. The A and B horizons are not sharply separated, but have diffuse boundaries usually several inches thick (1, 5).

Within the same region most soils formed under deciduous forest are called Gay-Brown Podzolic soils (1, 5). They have thin A1 or ochric horizons (7) and have sharper A-B horizon boundaries than the associated Brunizem soils. Intergrades between these two great soil groups have been recognized for many years at the series level (2, 6).

In the 7th Approximation soil classification scheme most Brunizems and some of the intergrades mentioned are now placed in the order of Mollisols (7). The mollic epipedon centers on a thick, dark surface layer saturated dominantly with bivalent cations, with a narrow carbon-nitrogen ratio and with moderate to

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strong granular structure. Color, structure, and thickness—three of the seven defined properties—can easily be determined in the field.

Most Brunizems with lower solum grainy ped coatings have surface layers that qualify as mollic epipedons. The presence of the grainy ped coats introduces problems of genesis and proper classification. The present study is concerned mainly with the degree of expression of grainy coatings and the areal distribution of Brunizem soils that have such coatings.

Data Collection

Sixty-nine sites from a random subsample of a previously drawn random sample of quarter-sections (4) were visited in the Cresco-Kasson-Clyde (CKC), Kenyon-Floyd-Clyde (CC), and a part of the Tama-Muscatine (TM) soil associations (Fig. 1). At each site observations were made of the type, color and thickness of epipedon and the presence, degree of expression, and depth of occurence of grainy gray ped coatings. The kind of soil material and the natural drainage class of each soil was also noted.

Also, fifty sites in Cedar and Scott counties and fifty-eight sites

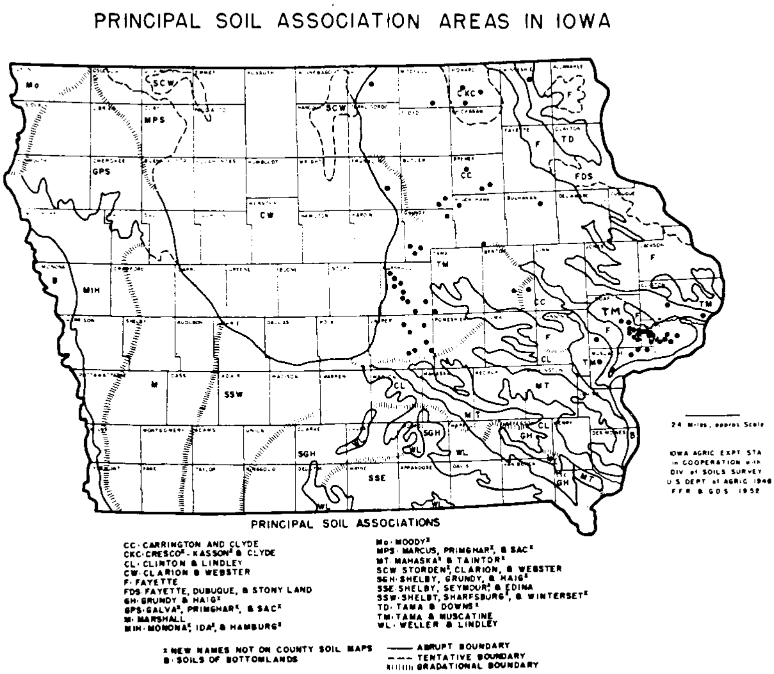

Figure 1. Map showing location of Brunizem soils with grainy gray ped coats in their subsoils (each dot represents such a soil).

in Jasper and Marshall counties were examined for more information on Tama and Muscatine soil series.

In other parts of the state observations were made either by special trips or as a part of usual soil survey work.

Distribution and Extent

The general location of Brunizem soil sites with observed grainy gray ped coatings are shown in Figure 1. These sites occur in the Iowa drift and adjacent loessial areas in eastern and northeasert Iowa, principally the Kenyon-Floyd-Clyde (CC) and the Tama-Muscatine (TM) soil association areas shown in Figure 1. The Brunizem soils in this area exhibit minimal to medial development of textural B horizons and their solums do not contain free carbonates. This area presently has an average annual rainfall of 30 to 35 inches, 45 to 50° F. mean annual temperature, a frost-free growing season of about 160 days, and frost penetration of 30 to 40 inches in the winter (5).

The Brunizem soils throughout the rest of Iowa characteristically do not have grainy ped coatings in any part of the solum. However, coatings have been observed at depths greater than 30 inches in some Brunizems located adjacent to major streams. Such sites are on loess-covered stream terraces or elevated alluvial fills and commonly trees are nearby. This suggests that trees, present or past, may be related to the presence of coatings at these sites (4). Also, coatings may occur in Brunizems that intergrade to Gray-Brown Podzolic soils. Observations in Taylor and Lucas Counties revealed that grainy gray ped coatings may be present in the B1 or B21 horizons but rarely in the lower B subhorizons.

The results of the random sampling in northeast Iowa (Table 1) indicate that up to 60 percent of the better drained soils with mollic epipedons may contain grainy gray ped coatings in their subsoils. Based on estimates of 1.4 to 1.8 million acres of well and moderately well drained Brunizem soils in the Cresco-Kasson-Clyde and Kenyon-Floyd-Clyde soil associations, it is inferred that similar ped coatings may occur in approximately one million acres of Brunizem soils in northeast Iowa (4).

In the Tama-Muscatine soil association approximately 75 percent of the soils in the eastern region and 35 percent of the soils in the western region may contain recognizable zones of grainy gray ped coatings (Table 4). A projection of these estimates indicates that about 900,000 acres of such soils *may occur in this* soil association. Their common occurrence and strong expression in Cedar and Scott counties is evident.

Table 1. Number of soils in the random sample having selected soil properties.

Kind of epipedon	Occurrence of ped coats Present W*	M	I	P	Absent W	M	I	P	Total
Mollic	8	9	3	..	6	6	8	5	45
Ochric	14	3	..	..	3	4	..	..	24
Totals	22	12	3	..	9	10	8	5	69

* The letters W, M, I, and P refer to the estimated natural drainage classes called well, moderately well, imperfect, and poor, respectively.

Table 2. Percent of soils with selected properties in depth distribution classes of grainy gray ped coats.

Type of epipedon	Drainage class	Profile distribution class A	B	C	D	E	No. of profiles
Mollic	Well	..	..	9	91	..	11
	Moderate	..	27	9	37	27	11
	Imperfect	19	..	..	36	45	11
Ochric	Well	20	..	80	..	..	5
	Moderate	..	10	30	40	20	10
	Imperfect	..	..	75	25	..	4

Table 3. Average measurements of selected soil features of some soils with grainy gray ped coatings in the Kenyon-Floyd-Clyde soil association.

Estimated drainage class	Surface thickness (inches)	Depth to till (inches)	Depth to coats (inches)	Thickness of coated zone (inches)
A. Soils with mollic epipedons				
Well	13.3	27.1	26.0	19.0
Moderately well	12.5	21.7	25.2	24.0
Imperfect	11.4	22.4	25.1	13.9
Average	12.4	23.7	25.4	19.0
B. Soils with ochric epipedons				
Well	7.3	22.7	18.0	10.0
Moderately well	5.5	22.2	19.4	23.0
Imperfect	6.3	19.3	17.0	27.7
Average	6.4	21.4	18.1	20.2

Table 4. Comparisons of soils in the eastern and western regions of the Tama-Muscatine soil association.

	Western region (Jasper and Marshall Counties)	Eastern region (Cedar and Scott Counties)
Number of Brunizem soil sites observed	58	50
Soils with grainy gray coat zones in subsoil	20	38
Coating expression		
Very strong	1	26
Strong	6	12
Weak	9	..
Very Weak		
a. In a zone	4	..
b. Isolated, not in a zone	13	3
Average depth to coated zone (inches)	34.3	28.6

Nature and Expression of the Grainy Gray Ped Coatings

The grainy gray coatings consist dominantly of concentrations of uncoated silt and sand size quartz and feldspar mineral grains, and seem similar to the "neo-skeletans" of Brewer and Sleeman (8). In the field they are best identified when the soil is in the moist to dry state. They may be observed in a soil profile pit, though undisturbed cores of 1- to 3-inch diameter are also suitable. If present they usually occur at a depth of 24 to 36 inches on surfaces of either blocky or prismatic peds. A low power hand lens aids in examination, and individual grains of coarse silt or sand are more easily seen. The coatings vary in thickness and abundance. In loess the coats are of coarse silt size and in glacial till they are mainly of fine to medium sand sizes. When dry they give to the ped a light gray to whitish color. The individual grains are quite free of stains, indicating low iron oxide.

Kenyon-Floyd-Clyde soil association

Because of the similarity of the soils in the Cresco-Kasson-Clyde soil association to those of this association, they are included in the following discussion. Many of the soils in these areas are developed in two-story parent materials (3). The upper material is better sorted than the lower and has been considered at some sites to be loess and at others to be glacial wash or pedisediment (9). The lower material is loamy, slightly firm to firm till, presumed to be Iowan till (9).

Several relationships between the underlying till surface and zones of grainy gray ped coatings were noted from information on about 52 profiles compiled from random samples, theses, and other published descriptions, and are depicted schematically in Figure 2. The letters designate a class and have no other significance. Though five depth distribution patterns of grainy gray ped coat zones can be distinguished, their significance is not understood at present.

The relative frequencies of soils of specified drainage among these depth distribution classes are shown in Table 2. It is in-

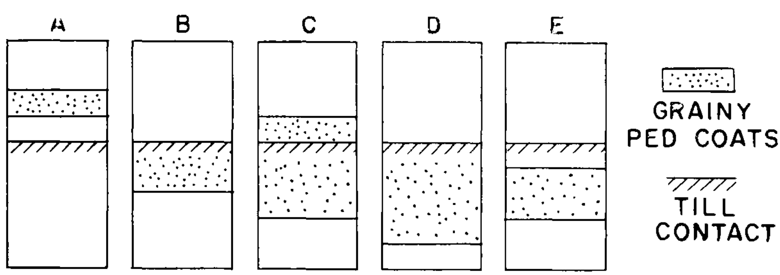

Figure 2. Schematic depth distribution patterns of grainy gray ped coats of some soils in the Kenyon-Floyd-Clyde soil association.

ferred that moisture supply and movement in these soils are involved in the development of the grainy ped coated zones. As more information concerning the type of coatings present is obtained, it may indicate the magnitude of the processes involved and the relationship to the moisture region in these soils.

Average values of surface soil thickness, depth to till, depth to and vertical thickness of these grainy ped coated zones are given in Table 3. There is a tendency for the till contact and the zones to occur at greater depths in those Brunizems which have thicker mollic epipedons and a tendency for thicker zones to occur in the moderately well drained soils.

Tama-Muscatine soil association

The grainy gray ped coatings are more widespread, more strongly expressed, and tend to occur at shallower depths in the soils in the eastern region than in the western region (Table 4).

In the sites examined in Scott and Cedar counties the soils often have weak mottling in their subsoils, are considered to be moderately well drained, and generally have a better developed textural B horizon than similar soils in the western region. Although the more strongly sloping soils may have less mottling, they do not have the bright brown colors free of mottles as do the soils on comparable landscape positions in the western region of the association. Consequently no separations were made for estimated drainage classes.

The ped coatings in the eastern region are generally strongly expressed and occur in definite zones, whereas those in the western region are weakly expressed even where in zones and often occur only at patches on ped surfaces.

Pedogenetic Evaluation

Grainy gray ped coatings in subsoils are known to occur in some of the Brunizem soils of the Kenyon-Floyd-Clyde, Cresco-Kasson-Clyde and Tama-Muscatine soil associations in Iowa.

The following general relationships between grainy gray ped coatings and other soil features have been noted:

1. The coatings were not observed in poorly drained soils with thick, dark surface layers, as the Garwin and Clyde series (5), or in calcareous soil materials.

2. Grainy gray ped coatings are more commonly observed on vertical faces of prismatic and blocky structural units than on horizontal faces.

3. The coatings in the Brunizem soils studied are associated with an A1-A3-B upper solum horizon sequence. An A2 horizon is *not present*. In some soils the B horizon adequately qualifies

as an argillic[4] or textured B horizon, but may be a weak argillic to cambic or color-structure B horizon in other soils. In some soils there appears to be a double B sequence as A1-A3-B-B'-C with the grainy ped coat zone at the juncture of the B-B' horizons, somewhat like the bisequal forest-influenced, loess-derived soils reported in southern Illinois (10). The grainy lower solum zones have not been observed in Brunizem soils with strongly developed argillic horizons.

4. Grainy gray ped coatings are common in forest-formed Gray-Brown Podzolic soils which generally have an A1-A2-B-C. In these soils the coatings are most strongly expressed in the upper part of the argillic horizon.

In a consideration of the soil feature-grainy gray ped coat relations in Brunizem soils the following genetic factors, if taken individually, fail to account for the coatings.

1. Macro-climate. Brunizem soils with and without coatings may be observed in the same climatic region in eastern Iowa. However, the Brunizem soils in western Iowa where there is less rainfall generally do not contain the coatings. It is inferred that climate may provide some necessary condition, such as its effect on vegetation, but does not itself determine the presence of grainy gray ped coats in soils.

2. Parent material. Coatings are known to exist and to be absent in soils derived from similar kinds of loess and till in eastern Iowa. Those soil materials usually are medium textured. Coatings have not been observed in sandy materials but may be present in more clayey materials. Grainy gray ped coats have not been observed in calcareous materials but may or may not be present in leached soil materials. Other than being sandy and/or calcareous, the parent material appears to have little influence on the presence of these ped coatings.

3. Topography and drainage. Coatings are not known to exist in poorly drained prairie-formed soils and are thought to be either absent or of minor extent in excessively drained prairie-developed soils. Soils in northeastern Iowa considered to be imperfectly, moderately well, and well drained may or may not contain these ped coatings. As many topographic or landscape positions are included within the observed drainage classes, it appears that topography is not solely responsible for the grainy gray ped coats.

[4] An argillic horizon is equivalent to a textural B horizon in which there is detectably more clay than in the A horizon (7). A cambic horizon is a slightly altered layer measured by change of color or structure or by loss of carbonates but which has not changed enough to qualify as another diagnostic horizon. An albic horizon is a layer in which clay and oxides have been removed or segregated until color is due to uncoated sand and silt grains.

4. Time. Most exposed soils in Iowa are of Wisconsin or younger age and are thought to be generally less than 17,000 years B.P. (9). Soils in northeastern Iowa that are thought to be of the same age may or may not contain grainy gray ped coatings in their subsoils, so it appears that length of exposure or development does not necessarily control the coating development. However, a closer look at the time-topography factor expressable in the geomorphic surface age is needed not only to evaluate the time and topography factors but also to find out when the coats developed.

5. Vegetation. Most of the better drained soils thought to have formed under prairie grass vegetation do not have these subsoil coatings except the soils in eastern Iowa.

The effects of climate and vegetation are not easily separated on the better drained soil sites as the vegetation readily adapts to changes or shifts in the climatic regime. The presence or absence of grass or forest on these soil sites today may reflect a micro-climatic condition or a minor climatic fluctuation rather than the macro- or long-time climate of the region. It is inferred, therefore, that the presence of a particular vegetation type today is not in itself sufficient evidence as the controlling factor in the development of grainy gray ped coatings.

Concepts of the course and magnitude of soil genesis have been derived from numerous empirical relationships observed repeatedly in the field. Because of the recurring relations we look, therefore, at the soils thought to have developed under a particular vegetation and from the observed soil properties make inferences about the influence of vegetation on the soil.

Field observations in Iowa reveal that B horizon structural units in soils developed under forest vegetation usually are of stronger grade, firmer consistence, and of larger size than in soils developed under grass vegetation. If sufficient time has passed for the pedogenetic processes active under the influence of deciduous forest to bring about changes in the soil materials, the common horizon assemblage consists of a thin ochric epipedon over an albic horizon that overlies an argillic horizon. Usually portions of the albic and upper argillic horizons contain material that may be considered as grainy gray ped coating material.

Based on our observations, we infer that the formation of these coatings in the better drained soils is more closely related to the soil system under deciduous forest than to the soil system under prairie vegetation.

The coatings may develop primarily as alteration features in argillic horizons under the influence of forest vegetation, and as such, their presence in the subsoils of Brunizem soils is thought to generally be a relict feature and not related to pedogenesis influenced by prairie grass.

Discussion

There are several interesting problems of soil genesis and geography associated with the development of the Brunizem soils with lower solum grainy ped coatings, or X-Brunizem soils as we have labeled them in Figure 3. The X-Brunizem soils have an upper solum horizon sequence of A1-A3-B characteristic of typical Brunizems (1, 4). They may also lack a decrease of clay content in the A1 horizon normally associated with the so-called transition Brunizem-Gray Brown Podzolic soils (1, 6) designated as G.B.P.-Brunizems in Figure 3.

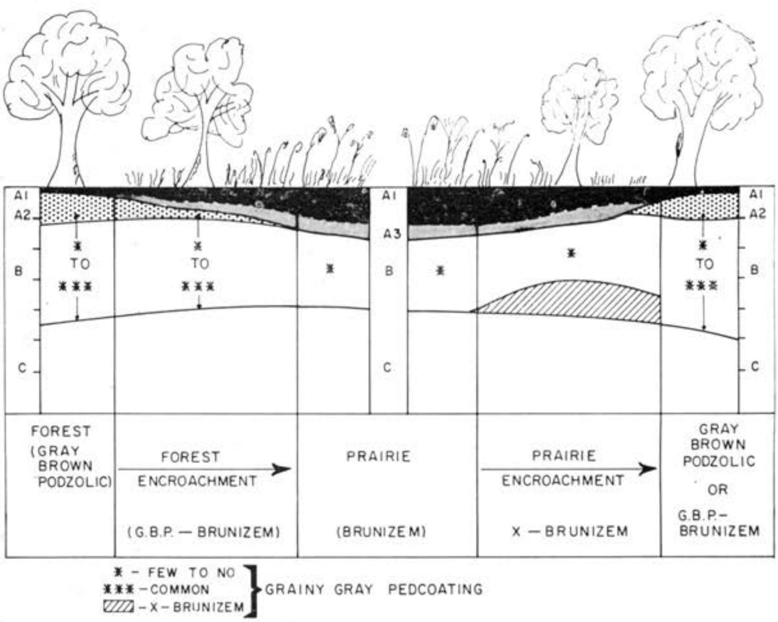

Figure 3. Schematic diagram of transition from Gray-Brown Podzolic to Brunizem, and of course of vegetation on X-Brunizems (Brunizems with grainy gray ped coatings).

The G.B.P.-Brunizem soils have an upper solum horizon sequence of A1-A2-B generally interpreted as reflecting the encroachment of forest on a former prairie (1, 2). Such soils are now recognized by means of the mollic prefix in several subgroup classes of the Alfisol order as, for instance, the sub-group class "Mollic Typudalf" (7) to which the Downs series (2) can be assigned.

The X-Brunizem soils, however, are more readily conceived as having been under prairie vegetation in the more recent course of their formation. Current concepts are that the surface layers (A1 and A3) of a typical Brunizem could form in about 300 to 500 years (11) and that the A1-A2 horizon sequence of a Gray-Brown Podzolic soil can form in about the same number of years (12). One suspects, however, that textural differentiation of uniform parent material into an A2-Bt horizon sequence takes considerably longer time, perhaps 8 to 10 times more, than the formation of either the A1-A3 or A1-A2 color and structural horizon sequence.

Perhaps more important than the time element is the question whether a reversion of an A2-Bt textural sequence to an A1-A3-B textural sequence can occur under prairie vegetation. The possibility of this type of reversion needs to be explored for many of the X-Brunizem soils observed in the present study. Although reversion processes are recognized (13), there is no current hypothesis that the reversion mentioned above can take place by any continuing soil-forming processes in soils occurring on landscape sites which have been stable for a considerable time.

Tree throw is a possible mechanism (13) to consider, but it evidently has not prevented textural A2-Bt horizon sequences in Gray-Brown Podzolic and forest-on-prairie soils such as the Fayette and Downs series in eastern Iowa (2, 6). Increased activity of earthworms (14) resulting in soil homogenization has not been observed in the Gray-Brown Podzolic or X-Brunizem soils in Iowa.

Several alternate hypotheses, which are more likely to the authors, assume that forest occurred on the X-Brunizem soil sites for some time before prairie became established and took over as the dominant vegetational influence. The forest cover would need to have been of sufficient duration to develop a griny gray ped zone, but not of such duration to develop an appreciable, non-revertable, textural A2-Bt horizon sequence.

As currently conceived, an A1-A2 horizon sequence could develop in about 300 to 500 years. Whether appreciable textural A2-Bt differentiation could occur in this time span is not known, but probably it is too short. If such hypotheses are correct in assuming that the X-Brunizem soils have relict forest influence, as evidenced by the presence of lower solum grainy gray ped coatings, current knowledge of the geomorphic development and associated vegetative history of these soils is not sufficiently refined to place the time or duration of forest occupancy.

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Comparison of Various Commercial Hydrated Lime for Reducing Soil Plasticity[1]

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Abstract. Atterberg limits tests were performed on mixtures of gumbotil soil and the various chief chemical compounds found in hydrated limes. The results were then checked with commercial hydrated limes of varying chemical compositions.

Results indicate that among the major constituents of hydrated limes $Ca(OH)_2$ is most effective in reducing soil plasticity. MgO shows a moderate effect, but $Mg(OH)_2$ and $CaCO_3$ show practically no effect.

There is, however, practically no difference between different types or between the same type of commercial hydrated limes for the reduction of soil plasticity. The choice of lime for soil-lime stabilization should, therefore, be dictated by the relative price and pozzolanic strength characteristics of the lime.

Hydrated lime, usually calcium hydroxide, mixed with wet clay soils quickly reduces their plasticity, i.e., brings about a change from sticky to crumbly texture. Such lime modification is useful for "drying up" mud holes for support of construction equipment, or for pre-treatment of clays to aid later pulveriza-

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