# MINERALOGY OF SOIL PROFILES: IREDELL AND DURHAM SOILS FROM THE PIEDMONT PROVINCE OF NORTH CAROLINA[1]

*By*

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## ABSTRACT

A comparative study of two soil profiles derived from a biotite-granite and from a metagabbro in the Piedmont Province of North Carolina was made. Intensive weathering of the granite has yielded a soil (Durham) with a clay fraction composed of a kaolinite-halloysite intermediate, mica, and quartz. Restricted weathering of the metagabbro has resulted in a soil (Iredell) with a clay fraction composed of a complex assemblage of chlorite, beidellite, vermiculite, interlayered talc-like minerals, and quartz.

The data indicate that the Durham soil is derived from the severe alteration of a granite and that it represents an advanced stage in soil formation. The Iredell soil has been derived from the less active weathering of a metagabbro and represents a retarded, youthful stage in soil formation. The clay mineral assemblage of the Durham is that of a comparatively stable end product of weathering; that of the Iredell is indicative of a complex, unstable early stage in weathering.

## INTRODUCTION

The Piedmont Province in North Carolina is geologically old with a mature physiography. Yet, the soils in this area are markedly different in appearance and properties. The basic source of distinction appears to lie in the parent rock.

The paper presents a study of the weathering products that have been derived from two different lithologies. The object was to compare the mineralogic changes in the weathering of a sialic versus a mafic rock. Two soils that are residual from Paleozoic rocks in the southern Piedmont Province were selected for this purpose: the Durham from a granite and the Iredell from a metagabbro.

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## SOILS AND PROCEDURES

The Durham soil is a representative member of the Red-Yellow Podzolic soil group. It occurs on nearly level to gently rolling upland. External and internal drainage are good and the native vegetation is mixed hardwood and short-leaf pine. The parent rock of the Durham profile studied is a medium-grained biotite-granite consisting chiefly of orthoclase, quartz, and biotite. The Iredell soil is considered a Planosol (Argipan) and is found on level to very gentle slopes. External and internal drainage are poor and the native vegetation is blackjack oak. The parent rock in the present study is a very fine-grained metagabbro composed of epidote, zoisite, and augite, with minor amounts of plagioclase and chlorite. Whereas the Durham soil is moderately erodible and of high agricultural value, the Iredell soil is very susceptible to erosion and is considered to be best utilized for pasture.

The sampling sites for the two soils are in the vicinity of Raleigh, North Carolina. The procedure described by Jeffries and Jackson (1949) was followed in the laboratory treatment of the soils. Examination of the particles finer than $43\mu$ was carried out mainly by means of x-ray diffraction, using filtered copper radiation with Geiger counter recorder. In addition, differential thermal analyses were made of the clay ($<2\mu$). Differential cation treatment, glycerol solvation, and heat were all used with x-ray diffraction to aid in distinguishing the several minerals (Walker, 1949).

## RESULTS AND DISCUSSION

The data in Table 1 indicate the concentration of clay and free iron oxide in the *B* horizons of both soils. The pH of the Durham surface layer is unexpectedly high in view of the fact that the area was in brush and apparently had never been cultivated. The high percentage of fine clay ($<0.8\mu$) in both profiles is significant. As a Red-Yellow Podzolic soil, the Durham may be expected to have developed after severe alteration of the parent granite, and the amount of fine clay in the profile is probably

TABLE 1. — PARTICLE SIZE DISTRIBUTION.

| Horizon and depth of sample (Inches) | | pH | Percent Free $Fe_2O_3$ | Percent Organic Matter | Size distribution in mm (percent by weight) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Sand | | | Silt | Clay | | Total Clay |
| | | | | | Medium 1.0-.074 | Fine .074-.043 | Very Fine .043-.020 | .020-.002 | Coarse .002-.0008 | Fine <.0008 | <.002 |
| | | | | | *DURHAM SOIL* | | | | | | |
| A | 0-12 | 6.4 | 0.7 | 2.6 | 63.1 | 6.1 | 5.8 | 16.3 | 4.35 | 0.65 | 5.0 |
| B | 12-35 | 5.2 | 2.6 | 0.3 | 32.6 | 7.9 | 3.4 | 18.6 | 4.5 | 30.0 | 34.5 |
| C | 35+ | 4.9 | 0.7 | 0.04 | 41.9 | 8.1 | 7.6 | 27.7 | 1.3 | 12.6 | 13.9 |
| | | | | | *IREDELL SOIL* | | | | | | |
| A | 0-5 | 5.8 | 1.4 | 1.1 | 44.3 | 13.6 | 12.0 | 18.8 | 1.9 | 6.7 | 8.6 |
| $B_{21}$ | 5-8 | 5.5 | 3.4 | 0.44 | 14.5 | 4.1 | 1.5 | 13.8 | 3.1 | 59.1 | 62.2 |
| $B_{22}$ | 8-32 | 5.5 | 3.8 | 0.44 | 19.1 | 2.5 | 1.0 | 12.3 | 3.0 | 57.7 | 60.7 |
| C | 32-45 | 6.2 | 1.9 | 0.23 | 26.3 | 8.7 | 4.8 | 20.4 | 4.1 | 33.4 | 37.5 |

the result of such weathering. The Iredell, on the other hand, belongs to the Planosol group within which weathering is presumed to be restricted. The high percentage of fine clay in the Iredell profile is related to the original fine-grained texture of the parent metagabbro; weathering has merely produced a finer-grained soil. The overall fineness of the texture of the Iredell soil, combined with a podzolic environment, has resulted in a soil of low permeability.

The mineral composition of the very fine sand fractions is shown in Table 2. Quartz, mica, and feldspar are prominent in both profiles. A member of the kaolin group, intermediate between kaolinite and halloysite, occurs in the Durham *A* and *B* horizons. A 7 A chlorite and a talc-like mineral are present in the Iredell profile.

The data in Table 3 indicate the differences in mineral composition of the silt fractions. Quartz has a similar distribution in the Durham and Iredell profiles, starting with a trace in the *C* horizons and becoming strong at the surface. Kaolin intermediate and a 10 A mica are prominent

TABLE 2. — X-RAY DIFFRACTION DATA: 0.043-.020 mm SIZE SEPARATES. Prominent spacings (d) and relative intensities (I).

| "d" in A | Horizons and depths of sampling | | | | Mineral |
|---|---|---|---|---|---|
| | *DURHAM SOIL* | | | | |
| | A 0-12 inches I | B 12-35 inches I | | C 35+ inches I | |
| 11.48 | — | — | | 3 | mica intermediate |
| 10.65 | — | — | | 4 | mica intermediate |
| 10.04 | 10 | 10 | | 4 | mica |
| 8.58 | 6 | 5 | | 6 | ? |
| 7.25 | 6 | 10 | | — | kaolin |
| 4.44 | 6 | 10 | | — | mica |
| 4.25 | 10 | 10 | | 10 | quartz |
| 3.54 | 5 | 10 | | — | kaolin |
| 3.35 | 10+ | 10+ | | 10+ | quartz, mica |
| 3.19 | 7 | 7 | | 7 | feldspar |
| | *IREDELL SOIL* | | | | |
| | A 0-5 inches I | $B_{21}$ 5-8 inches I | $B_{22}$ 8-32 inches I | C 32-45 inches I | |
| 10.04 | ) | 7 | 6 | 5 | mica |
| 9.61 | ) 3vb | 7 | — | — | talc ? |
| 9.21 | ) | 7 | 7 | — | talc ? |
| 8.34 | — | 7 | 7 | 6 | epidote ? |
| 7.37 | — | 7 | 6 | 6 | chlorite |
| 4.25 | 10 | 10 | 10 | 4 | quartz |
| 3.72 | 1 | 7 | 7 | 6dbl | chlorite |
| 3.35 | 10+ | 10+ | 10+ | 10+ | quartz, mica |
| 3.18 | 5 | 9 | 10+ | 10+ | feldspar (plagioclase) |

vb — very broad
dbl — double

TABLE 3. — X-RAY DIFFRACTION DATA: .020-.002 mm SIZE SEPARATES. Prominent spacings (d) and relative intensities (I) with different solvations.[1]

| "d" in A | Horizons and depths of sampling | | | | | | | | Mineral |
|---|---|---|---|---|---|---|---|---|---|
| | *DURHAM SOIL* | | | | | | | | |
| | *A 0-12 in* | | *B 12-35 in* | | *C 35 in+* | | | | |
| | *Mg* | *Li* | *Mg* | *Li* | *Mg* | *Li* | | | |
| | I | | I | | I | | | | |
| 14.03 | 4 | — | 3 | 2 | 6 | — | | | vermiculite |
| 12.11 | 5 | — | — | — | — | — | | | mica intermediate |
| 10.78 | — | — | — | 5 | — | — | | | mica intermediate |
| 9.9 | 7 | 7 | 4 | 6 | 10+ | 10 | | | mica |
| 7.25 | 8 | 8 | 10 | 10 | 10 | 5 | | | kaolin |
| 4.25 | 10 | 10 | 5 | 4 | 3 | 1 | | | quartz |
| 3.71 | 4 | 4 | — | — | — | — | | | vermiculite, kaolin |
| 3.57 | 6 | 4 | 9 | 7 | 7 | 3 | | | kaolin, vermiculite |
| | *IREDELL SOIL* | | | | | | | | |
| | *A 0-5 in* | | *$B_{21}$ 5-8 in* | | *$B_{22}$ 8-32 in* | | *C 32-45 in* | | |
| | *Mg* | *Li* | *Mg* | *Li* | *Mg* | *Li* | *Mg* | *Li* | |
| | I | | I | | I | | I | | |
| 14.25 | — | 2 | 10+ | — | — | 5 | 10+ | 8 | chlorite, vermiculite |
| 11.48 | — | 4 | — | 10+ | 10 | 5 | — | 10+ | mica intermediate |
| 9.61 | 3 | 4 | — | 8 | — | — | — | — | talc ? |
| 7.3 | 6 | 4 | 9 | 10 | 5 | 10 | 10 | 10+ | chlorite |
| 4.25 | 10 | 10 | 7 | 7 | 7 | 9 | 3 | — | quartz |
| 3.6 | — | — | — | — | 4 | — | 6 | 6 | chlorite, vermiculite |
| 3.56 | — | — | 5 | 5 | — | 6 | — | 6 | chlorite, vermiculite |

[1] Mg—1*N* Mg acetate in $H_2O$ Li—1*N* Li chloride in $H_2O$

in the Durham. Also present in the Durham profile are weathered forms of mica, including a vermiculitic mineral. Only the prominent reflections were tabulated but the x-ray pattern from the Durham silt fraction was sharp and clear in contrast to the diffuse pattern obtained from the Iredell silt. The complexity of the Iredell mineralogy becomes apparent in this table. A 7 A chlorite, similar to halloysite in x-ray characteristics, is prominent in the profile. Differential thermal analyses, to be described later, aided in this distinction. Differential cation treatments indicate that the Durham silt contains hydrated forms of mica, whereas the Iredell silt in composed of a complex arrangement of hydrated, interlayered talc-like minerals.

The silt samples were heated at 600°C for two hours in an effort to distinguish the kaolin from the chlorite minerals (Brindley and Robinson, 1951, p. 188). However, instead of reinforcing the chlorite reflections and removing those of the kaolin, the heat treatment destroyed both. This indicates that the soil chlorite present in the Iredell is unstable and unlike the mineralogical specimens previously described in the literature.

TABLE 4. — X-RAY DIFFRACTION DATA: <.002 mm SIZE SEPARATES.
Prominent spacings (d) and relative intensities (I) with different solvations.[1]

| "d" in A | Horizons and depths of sampling | | | | | | | | Mineral |
|---|---|---|---|---|---|---|---|---|---|
| | *DURHAM SOIL* | | | | | | | | |
| | *A 0-12 in* | | *B 12-35 in* | | *C 35 in +* | | | | |
| | *Ca* | *Li* | *Ca* | *Li* | *Ca* | *Li* | | | |
| | I | | I | | I | | | | |
| 13.8 | 7 | — | 1 | — | 3 | — | | | vermiculite |
| 10.04 | 4 | 10 | 1 | 2 | 9 | 10 | | | mica |
| 7.19 | 10 | 9 | 10 | 10 | 10+ | 10 | | | kaolin |
| 4.25 | 4 | — | 2 | — | — | — | | | quartz |
| 3.57 | 10 | 6 | 10 | 6 | 10 | 6 | | | kaolin |
| | *IREDELL SOIL* | | | | | | | | |
| | *A 0-5 in* | | *$B_{21}$ 5-8 in* | | *$B_{22}$ 8-32 in* | | *C 32-45 in* | | |
| | *Ca* | *Li* | *Ca* | *Li* | *Ca* | *Li* | *Ca* | *Li* | |
| | I | | I | | I | | I | | |
| 17.0 | — | — | 7 | 4 | 2 | 2 | 8 | 4 | beidellite |
| 13.8 | 10 | — | 7 | — | 2 | — | 4 | — | chlorite, vermiculite |
| 12.6 | — | 10 | — | — | — | — | — | — | mica intermediate |
| 11.95 | — | — | — | 8 | 4 | 7 | 6 | 10 | mica intermediate |
| 9.21 | 8 | — | 8 | — | 6 | — | 7 | — | talc ? |
| 7.25 | 8 | 8 | 10+ | 10 | 10 | 10 | 10 | 10 | chlorite |
| 4.25 | 8 | 7 | 5 | 3 | — | — | — | — | quartz |
| 3.63 | 5 | — | 8 | — | 7 | — | 10 | — | vermiculite, chlorite |
| 3.57 | 6 | 7 | 10 | 10 | 7 | 10 | 9 | 10 | vermiculite, chlorite |

[1] Ca — 1*N* Ca acetate in glycerine Li — 1*N* Li chloride in $H_2O$

The mineralogy of the clay fractions ($<2\mu$) is shown in Table 4. Again, the x-ray patterns for the Durham were clear with sharp peaks in contrast to the diffuse pattern for the Iredell. The data indicate that the Durham soil clay is a comparatively simple assemblage of a kaolin mineral and mica with trace amounts of quartz and weathered mica (vermiculite). The Iredell soil clay, on the other hand, is characterized by the complexity of the mineral composition. The mixed-layer nature of this assemblage is indicated by the presence of reflections greater than 9.6 A, and absence of 10 A mica. The Iredell clay fraction is composed of a montmorillonoid (beidellite), chlorite, vermiculite, and a mixture of talc-like interlayered minerals. Quartz is present in trace amounts. Heating the clay fractions of both soils at 600°C for two hours yielded the same results as with the silts. All 7 A reflections were destroyed.

Further investigation of the clay fraction was made by studying the mineral composition of the coarse (2-0.8$\mu$) and fine ($<0.8\mu$) clays with the x-ray spectrometer. In the Durham soil, quartz is restricted to the coarse clay whereas the kaolin and mica are equally divided between the two sizes. Surprisingly, in the Iredell soil, the beidellite is restricted to the coarse clay whereas the chlorite is prominent in the fine. Quartz appears only in the coarse clay, along with the beidellite.

## DIFFERENTIAL THERMAL ANALYSES*

The clay fractions from the two soils were studied by means of differential thermal apparatus. Examination of the thermograms indicates that the Durham clay is composed of a kaolin mineral intermediate between kaolinite and halloysite along with amorphous iron oxides and trace amounts of quartz. The kaolin mineral produced the characteristic endothermic reaction below 600°C and the accompanying exothermic reaction at 950°C. The mica mineral, easily distinguished by x-ray diffraction, was not recognizable by this thermal technique, its reactions probably being masked by those of kaolin.

Study of the thermograms of the Iredell clay indicates the presence of beidellite, chlorite, and amorphous iron oxides. The vermiculitic and talc-like minerals, indicated by x-ray diffraction, are not discernible on the thermogram. The absence of the characteristic kaolin exothermic reaction at 950°C indicates that the 7 A mineral is probably a member of the chlorite family and not a kaolin. Chlorites with weak 14 A reflections have been previously reported, especially those rich in iron (Brindley and Robinson, 1951, p. 187). The Iredell soil chlorite is probably either rich in iron or a member of the 7 A antigorite group.

## CONCLUSIONS

Previous studies of weathering of rocks in the Piedmont province of North Carolina have been made. Cady (1950) studied the mineralogy of an Iredell profile that had developed from the weathering of a metagabbro. He reported that the principal mineral in the clay fraction was halloysite along with a little goethite, chlorite, and montmorillonite. The contrast between his results and the author's may be attributed to the difference in mineral composition of the parent rocks. Cady reported a dominance of green hornblende and plagioclase feldspar (labradorite) in the parent rock of the soil profile that he studied, whereas an epidote complex is dominant in the parent rock of the Iredell in the present paper. Ross and Hendricks (1945) reported that Iredell soils, formed from the weathering of diabase intrusives in the Triassic basins of North Carolina, contained clays that are predominantly of the montmorillonite type. It is of interest to note that Ross and Hendricks doubted the possibility of montmorillonite development from epidote. The restricted clay-mineral development in the present Iredell profile may be the result of the dominance of epidote in the parent rock.

Sand (1952) concluded that halloysite in residual kaolins in the southern Appalachian region forms from the intense weathering of feldspar and that subsequent alteration leads to kaolinite. This is in accord with the results of the present study. The parent rock of the Durham is dominantly

* M. C. King, Petrographic Laboratory, U. S. Bureau of Reclamation, Denver, Colorado, made the thermal analyses.

orthoclase and has been intensely weathered. The clay mineral formed is a kaolinite-halloysite intermediate.

Grim (1953) has stated that the composition and texture of the parent rocks are important in initial stages of weathering but that their importance decreases as the duration of weathering increases. The composition and texture of the granite underlying the Durham were susceptible to rapid weathering and, in accord with the principle in Grim's statement, their importance decreased rapidly. The aphanitic texture of the metagabbro underlying the Iredell combined with the basic mineral composition to produce a finer-grained soil of low permeability. Weathering has been restricted by the lack of active leaching, and the effect of texture and composition is therefore still important. It is difficult to believe that the poor internal drainage in the present Iredell profile may be attributed in large part to the mineralogy of the clay fraction. Rather, it appears that the texture of the *B* horizon with its high content of fine clay is sufficient to impede percolation.

The need for corroborative procedures in clay mineralogy has been recognized. The present study brings out forcibly the dangers inherent in the reliance on a single method of diagnosis. The 7 A mineral in the Iredell profile seemed to be a member of the kaolin group on the basis of its x-ray diffraction properties until differential thermal analysis excluded this possibility.

The field work for this report was done in the summer of 1952. The samples were examined and this report prepared in the laboratory of the Geological Survey at Colorado A & M College at Fort Collins, Colorado. The work incident to this investigation was carried out under the general direction of R. W. Davenport, Chief, Technical Coordination Branch, U. S. Geological Survey.

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