MICROPEDOLOGICAL STUDIES OF ORTHIC BLACK, ORTHIC DARK GREY AND ORTHIC GREY WOODED SOIL PROFILES

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ABSTRACT

Micropedological studies were conducted on the horizons of Orthic Black, Orthic Dark Grey, and Orthic Grey Wooded profiles. Descriptions and interpretations are given for the micromorphological studies which were conducted by means of thin sections. The difference in profiles was due to vegetation with associated microclimate and position on the slope. The illuvial horizons were characterized by an increase in plasma, an increase in ped density, and the presence of cutans. Thin-section studies are beneficial in the characterization of soils, and in evaluating pedological factors and processes.

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INTRODUCTION

Podzolization of soils with concurrent formation of eluvial and illuvial horizons has received wide attention in pedological studies. The explanations of associated physical phenomena - such as platiness and coatings on peds - has until recently been a matter of conjecture. The introduction of the polarizing microscope to the study of soil, principally by Kubiena, has assisted greatly in the study and interpretation of these pedological features. Microscopic investigation of soil (micropedology) encompasses the study of shape and form of soil micro-features (micromorphology) and mineral identification. Micromorphological studies, which also include the relationship between various soil particles, has led to a better understanding of soil-forming processes. These studies are rapidly gaining a place of importance in soil investigations, particularly in the study of structural features. Kubiena (26) has used micropedological studies quite extensively in the characterization of European soils.

In the present investigation, micropedological studies were carried out on the various horizons of three soil profiles namely: Orthic Black, Orthic Dark Grey, and Orthic Grey Wooded. The principal objectives of the investigation were:

(1) to describe the micromorphological features,

(2) to interpret these features with respect to the genesis of the soils, and,

(3) to assess the intensity of weathering of the soil minerals in the various horizons.

REVIEW OF LITERATURE

I. The Growth and Objectives of Micropedology

The study of soils, whether directed towards soil classification or the interpretation of soil genesis, involves the description and determination of a great number of soil characteristics. While these descriptions and determinations were at first few and simple, with the realization that soils are extremely complex materials, they became progressively more detailed and complicated. Concomitant with this development was the introduction of new techniques, many of which were perfected by other scientific disciplines. One such introduction was the study of soils by means of thin sections and the polarizing microscope, a technique long used by petrographers in the study of rocks.

The main reason for the delay in using thin-sections for the study of soils was the inability to make sections from friable materials. This problem was not overcome until suitable impregnating materials and techniques had been devised. This was a major step forward in the study of soils as it allowed for the manipulation and study of soils without disturbing the natural features. The first major attempt to study soils by means of thin-sections was made by Kubiena (25) in 1938. His book Micropedology provides an excellent foundation for the study of soils through the medium of thin-sections. However, the growth of micropedology was slow, with only a few workers in the early years. In more recent years, a large number of workers, from all countries, have used thin-sections studies *per se*, and as a supplement to other studies.

The objectives of micropedology are essentially those of pedology - the study of the soil as an entity. More specifically they are study and interpretation of the megascopic features with respect to cause and effect. Microscopic investigations are used in the identification of primary and secondary particles and pedogenic features. Consideration of the pedogenic features, with emphasis on shape, form, and distribution, is extremely useful in genetic interpretations and in the explanation of physical characteristics exhibited by a soil. Brewer (6) stated that pedology has three phases "the characterization of soils, the study of soil genesis, and the classification of soil materials and soils". He went on to say that petrographic studies were invaluable in these considerations.

II. Terminology and Definitions

Micromorphology differs from macromorphology not only in the size limits, but also in the diagnostic features and in the concepts of description. Therefore, a new set of terms was desirable. The first major step in this direction was that of Kubiena (25) in 1937. More recently Brewer and

Sleeman (10) have added considerably to the description of micromorphological features. Both Kubiena (25) and Brewer and Sleeman (10), in describing and applying terms to distinguishing micropedological features drew quite heavily from geological petrographic works.

Two main constituents of the soil were recognized (25), skeleton, "which consists mainly of the residues of rock minerals and organisms not decomposable, or which are only slowly decomposing", and plasma, which is "more easily moved, changed in composition and shape, and redeposited". "The arrangement of the constituents of a soil in relation to each other", was called soil fabric, which Kubiena (25) said is a result of the dynamics of the soil system. The arrangement within the individual aggregates he called "elementary fabric", and the arrangement of the aggregates "fabric of higher order". Some of the factors Kubiena (26) attributed to influencing fabric are degree of flocculation of the plasma, work of alkalis and acids, action of eluvial and illuvial processes and wetting and drying.

Brewer and Sleeman (10), using essentially the same concepts, expanded somewhat on Kubiena's work. One exception was the introduction of "structure". This tended to encompass, at least partially, Kubiena's "fabric of higher order".

Some terms for the description of fabric (after Kubiena (25)).

Intertextic - the plasma occurs as intergranular braces linking the skeleton grains

(a) Chernozemic-plasma is dark brown to black and there may be dark humus films around the skeleton grains.

Plectomictic - Mineral grains are coated and united by intergranular braces.

Porphyropeptic - coated mineral grains are embedded in a dense groundmass.

Porphyropectic - bare mineral grains are embedded in a dense groundmass.

Spongy - globular-like aggregates are connected by plasmic braces, (this is a higher order fabric which falls partially within the definition of structure).

Some further basic definitions are:

1. Ped - "an individual natural soil aggregate consisting of a cluster of primary particles and separated from adjoining peds by surfaces of weakness which are recognizable as natural voids, or by the occurrence of cutans" (39).

2. Pedological features - "recognizable units within a soil material which are distinguishable from the enclosing material for any reason such as origin, differences in concentration of some fraction of the plasma, or differences in the arrangement of the constituents (fabric)" (10). Pedological features may be found within the peds (inped) or assoc-

iated with the interpedal voids (exped).

(a) Plasma concentrations - "are concentrations of any of the fractions of the plasma in various parts of the soil material, due to soil formation" (10).

(b) Plasma separations - "are features characterized by a significant change in the arrangement (fabric) of the constituents, rather than a change in concentration of some fraction of the plasma" (10).

(c) Cutans - "a modification of the texture, structure, or fabric at natural surfaces in a soil material due to concentration of particular components, or *in situ* modification of plasma" (7).

Cutans are subdivided by Brewer (7) on interpreted processes of formation into:

(a) Illuviation cutans - which are "true coatings due to movement in solution or suspension and subsequent deposition";

(b) Diffusion cutans - which are "concentrations at the surface due to diffusion; and

(c) Stress cutans - which are "*in situ* modifications of the plasma due to differential forces, such as shearing".

3. Structure - "the physical constitution of a soil material as expressed by the size, shape, and arrangement of the solid particles and associated voids, including both the

primary particles to form compound particles and the compound particles themselves" (10). Brewer and Sleeman (10) separated and defined several levels of structure. Secondary structure was defined as "the size, shape, and arrangement of the primary peds, interpedal voids, and associated interpedal pedological features", and will be used herein as being synonymous with the word "structure".

Size: after Brewer and Sleeman (10).

extremely fine..................	< 0.005 mm.
very fine.......................	0.005 - 0.02 mm.
fine............................	0.02 - 0.10 mm.
medium..........................	0.10 - 0.50 mm.
coarse..........................	0.50 - 2.0 mm.
very coarse.....................	2.0 -10.0 mm.
extremely coarse................	> 10.0 mm.

Shape: after Zingg (1935) as quoted by Pettijohn (35)

Equant..................	b/a > 2/3;	c/b > 2/3
Prolate.................	b/a < 2/3;	c/b > 2/3
Tabular*................	b/a > 2/3;	c/b < 2/3

The following terms and subdivisions were applied to the shape classes, and will be used in this study;

Equant	blocky subangular blocky granular
Prolate................	prismatic
Planar.................	platy
Massive................	massive single grained

* It is felt that "Planar" would be a more appropriate term than "Tabular" in the study of soil, and it would have the mathematical limits b/a > 1/10; c/b < 1/10. Also, there should be an addition of a fourth shape, namely: "Massive", in which no axis is limited.

III. Application and Interpretation of Thin-Section Studies

For one to interpret genesis and/or classify soils it is necessary to understand the processes which are at work in a soil, and the degree to which each is affecting a particular soil. Kubiena (25) states that nearly every happening in a soil has left its picture in the fabric, and that it need only be interpreted. Thin-section studies are possibly the most important tool one has with which to study fabric, and hence aid in its interpretation. Brewer (6) states that thin-section studies of soil structure and fabric indicate the kind of experimental work needed to study soil-forming processes, and that they may be used to check the results of the experiments.

Studies have been conducted on many soil features both through the interpretation of thin-sections, and by experiments set up to duplicate the features in question. The following is a brief summary of some of the studies which have particular application to this work.

Kubiena (25) found that, in the surface horizons of Chernozemic and Steppe soils, dark brown to black plasma occurred as intergranular braces linking the skeleton grains, which had dark humus films around them. He called this arrangement of constituents chernozemic fabric. He attempted to duplicate this fabric by shaking quartz sand in an alkaline lignin mixture and allowing it to dry. Thin-section work showed that the insoluble lignin had been deposited in the intergranular spaces and that the grains were covered with a uniform humus film. Furthermore, the complexes formed were quite stable. This correlates very well with observations that soils exhibiting chernozemic fabric have a high base status, a high organic matter content, and a climate in which wetting and drying occurs.

An eluvial horizon is often characterized by a platy structure. Kubiena (25) described and proposed a genesis for one such type of structure which he called "banded fabric". He described horizontal layers alternately rich and poor in plasma, and proposed drying, with concomitant "capillary draught" to the evaporation surface, to be the main cause for such a formation. The plasma deficient zones would crack easily, giving the plates. McMillan and Mitchell (29) also noted banded fabric, with the plates exhibiting a gradation in color. However, they found that in many instances the bands had complete uniformity of skeletal and plasmic material, for which they suggested the term "isoband fabric" but did not propose any mode of formation.

Iron concretions are another distinct pedological feature which may be found in eluvial horizons. Round shaped concretions, interspersed with mineral grains, have been described (25,29) and named "invasion amygdali" (29). McMillan and Mitchell (29) found that in platy eluvial horizons these amygdali tended to be concentrated at the bottom of the plates.

Their explanation was that as the soil dried out, aeration would begin at the bottom of the plates resulting in a precipitation condition and then iron oxides would diffuse to the nuclei formed at the aeration surfaces.

Illuvial horizons which have an accumulation of clay have been of particular interest. Frei and Cline (17), in their study of the Gray-Brown Podzolic-Brown Podzolic sequence of soils, proposed that the increase in clay content in the B horizons may be accounted for in three ways:

(1) Clays may move downwards in suspension;

(2) Weathering products from the A and B horizons may be synthesized into clay minerals. This has received a good deal of attention in European literature (18,24,34), but there is no real evidence to support it; and

(3) Removal of constituents, such as calcium carbonate, may concentrate the residual clay.

To this may be added:

(4) *In situ* weathering of primary constituents which may yield clay minerals (25,5,31)

In most instances this accumulation of clay occurs, at least in part, as coatings on mineral grains, around voids, or along conducting channels. These "clay skins" have been reported in many soils including Brown Podzolic (17,28), Grey-Brown Podzolic (12,17,28), Solodized Solonetz (5), and

Humic Eluviated Gleysol (1). They have also been reported in several European soils (18,24,34). It was noted that most of the clay skins were optically oriented, and this has been accepted by many as being indicative of an illuvial origin. Frei and Cline (12), McCaleb (28), and others (5,31) proposed that oriented clay was a result of deposition from suspensions of percolating water, under the influence of surface tension. While agreeing with this, Buol and Hole (12) suggested that oriented clay may also be formed by <u>in situ</u> weathering, or mechanical pressure, as did Brewer (5) and Minashina (31). Brewer (5) felt that soil properties such as bulk density, porosity, and particle size distribution should be taken into account when attempting to assess the genesis of clay skins, as those formed by <u>in situ</u> weathering, for example, should show little or no change in bulk density or porosity.

Several workers (9,2,13) have produced optically oriented clay skins by passing clay suspensions through sand columns. In one such study, Brewer and Haldane (9) found that the saturating cation had no effect on the orientation of the clay, that clay illuviation could be accomplished by the upward movement of particles in suspension with concomitant clay skin formation, and that silt size particles had a disrupting effect on clay orientation. Bartelli and Odell (2) noted that wetting and drying accentuated the formation of oriented clay, as did Minashina (31).

The features described as clay skins frequently contained varying amounts of material, other than clay, such as organic matter and iron (19,20,25,2). Therefore, the term "clay skin" appeared in many cases to be a misnomer. This, along with the realization that these clay coatings could have different geneses, and could be associated with different soil entities such as mineral grains or conducting channels, led Brewer (7) to introduce the term "cutan" (as defined on page 7). Clay skins would fall into different categories, under the general heading of cutans, depending on their composition, occurrence and interpreted genesis.

Another pedological feature which has been used in interpretive studies (25,17,40,1,6) is the size, shape, and number of pores and voids. From them were inferred such things as permeability, density of peds and the soil mass, the state of the plasma (flocculent or disperse), and eluvial and illuvial processes.

From the preceding studies it can be seen that a petrographic study of the totality of fabric and structure, with associated pedological features, can lead to more soundly based interpretations of genesis, the influence of soil forming processes, and a more thorough characterization of a soil.

IV Mineral Analyses

A petrographic mineral analysis limits the size of grains under study to within the approximate diameters of 0.5 to 0.05 mm. The size fractions are separated into groups based on specific gravity. Normally, one separation is made which results in two mineral fractions - "light", with a specific gravity less than 2.89, and "heavy" with a specific gravity greater than 2.89. The light mineral fraction, dominated by quartz and the feldspars, generally accounts for greater than 95% by weight of the size fraction. The heavy mineral fraction contains such species as the iron oxides, garnet, zircon, amphiboles, pyroxenes, epidote kyanite, and apatite.

Petrographic studies of mineral grains are normally conducted for two reasons - to prove or disprove homogeneity of soil material, and to estimate the degree of weathering within a profile.

It is known that minerals vary in their resistance to weathering. Many attempts have been made to evaluate the relative stability of minerals (30,35). Milner (30) divided the more common minerals into three stability classes; stable, moderately stable and unstable. Quartz fell into the first class, as did orthoclase, while microcline, albite, and andesine were classed as moderately stable, and the calcic feldspars were unstable. Cann and Whiteside (14) point out that the lower percentage of plagioclase feldspars in the upper horizons of a profile indicates their lower stability. Therefore, a study of the relative proportions of species of different stabilities could give a qualitative estimation of weathering, if the upper horizons are compared to the parent material.

The provenance of any sedimentary material is reflected in the minerals present. This is particularly true of the heavy minerals. Because they are present in relatively small quantities, any significant change in the percentage of one or more species is readily discernable. Some heavy mineral - such as tourmaline, garnet, and zircon - are very resistant to weathering and will, therefore, remain in constant proportions in the soil for prolonged periods of time. If a semi-quantitative study of resistant heavy minerals shows no significant change in the mineral suite throughout the profile, there is proof of homogeneity of soil material within the profile (27). This may be expanded to include uniformity of parent material between profiles. By similarity in heavy mineral suites Seale (38) concluded that for the project area, the "sand fractions have a common origin". From heavy mineral studies in conjunction with particle size distribution considerations, Sawhney _et al_. (37) felt that there was a slight disconformity of parent material in the soils they were studying. Yassoglou and Whiteside (40) using heavy minerals, in particular magnetite - garnet ratios, reached a similar verdict for one profile in Michigan while concluding from the same considerations that two other soils had uniform parent material. Bayrock (3), working in Alberta, showed that tills could not be differentiated using heavy minerals as the only criterion because of the proximity of the Canadian shield from which the majority of the minerals were derived.

V. Technology

1. Thin-section Preparation

Kubiena, (25) in 1923, developed a method for impregnating friable materials without destroying the natural fabric. He experimented with bakelite, Canada balsam, and kollolith, as impregnating materials. The latter proved to be the most satisfactory.

With the growth of the plastic industry a large number of new synthetic plastics and resins became available as impregnating materials. Several of these, Lakeside Number 70C thermoplastic cement (15,40), glycol thalate (21), and Castolite have been used with satisfactory results. Bourbeau and Berger (4) were among the first to use Castolite, which has rapidly gained popularity as an impregnating agent. They used pure Castolite with castolite hardener and impregnated the soil samples under vacuum. McMillan and Mitchell (29) used essentially the same procedure as did Buol and Hole (12), while Acton (1) used 80% Castolite and 20% styrene, Bartelli and Odell (2) used 45% castolite and 55% styrene, and Buol and Fadness (11) used 50 per cent castolite with 50 per cent styrene. In all cases Castolite hardener, a cumene hydroperoxide, was added to aid in the polymerization of the castolite. Styrene was added to lower the viscosity of castolite and thus facilitate impregnation. Buol and Fadness (11) and Brewer (4) found that initial impregnation was more complete if the samples were evacuated prior to the addition of the impregnating material. Curing time for castolite varies from 12 hours at 100°C (11) to five to seven days at room temperature followed 30 minutes heating at 82°C (29).

Mounting and grinding techniques are essentially the same in all instances. Kerosene has been most commonly used for lubrication and cooling during the grinding procedure. Water, or any other polar liquid, tends to disperse and/or swell the clay constituents and therefore cannot be used. Dry grinding (25,8) has also been employed, but gives rise to cooling problems.

Sections of appropriate thickness are cut from the impregnated sample and trimmed to fit on a glass slide. For this mounting Lakeside 70 has taken precedence in recent years over Canada balsam. Sections are then ground using Alundum or Carborundum grinding compounds to a thickness of 30μ to 50μ as judged by interference colors using a polarizing microscope. The final grinding, which is quite critical, is done by hand on a glass plate. Acton (1) attached a cork to the slide, on the opposite side, and the end away from the specimen, as a control aid during grinding. After the ground section has been cleaned, a cover slip is affixed, usually with Canada balsam, although some workers are now using Caedax. Caedax has the advantage of not darkening with age and can be redissolved. Xylene is the most commonly used solvent for cleaning the completed thin section.

2. Mineral Mounts

Petrographic mineral analyses are usually preceded by specific gravity separations. Separations may be made with bromoform (specific gravity 2.89), tetrabromethane (specific gravity 2.90), or other heavy liquids (30).

The light minerals are usually mounted in Canada balsam or Caedax. Heavy minerals may be mounted in the above mentioned or in Aroclor Number 4465 which has a refractive index of 1.664 - 1.667 (3, 37). Aroclor has the advantage of an index of refraction which facilitates the identification of heavy minerals.

Staining techniques are very useful in light mineral separates for the rapid identification of quartz, potash feldspars, and plagioclase feldspars. Mineral grains are etched using hydrofluoric acid, either by exposing them to the fumes (22) or by totally immersing them in the acid (36). The acid will attack the feldspars, but not the quartz, and expose elements reactive to specific stains.

METHODS AND MATERIALS

I. Description of Soils

The soils used in this study are well-drained members developed on moderately calcareous boulder till of mixed limestone, shale and granitic rock origin. The texture is dominantly a clay loam. The topography is undulating to rolling. The elevation of the area is between 2000 and 2200 feet above sea level, with the Orthic Grey Wooded approaching the upper limit (16). Geographically the Orthic Grey Wooded was taken from a site within the Riding Mountains and had a slightly more humid microclimate as reflected by the forest vegetation. The Orthic Black and Orthic Dark Grey were from the southern slope of the Riding Mountains. Both were taken from the same knoll, with the latter being down slope and under aspen vegetation as compared to the former which was under tall grasses and associated shrubs.

The field descriptions were based on the National Soil Survey Committee of Canada Proceedings (32,33). The wet and dry colors were described using Munsell Soil Color Chart notations. Consistence was determined at field moisture. Photographs of representative profiles are shown in Plate V in the Appendix.

1. Orthic Black

Location: North center of section 33, township 16, range 18 west.

Vegetation: Tall grasses, rose, dogwood, with aspen and balsam poplar.

Drainage: Well drained.

Parent Material: Moderately calcareous mixed boulder till.

Topography: Undulating to rolling.

Horizon	Depth-inches	Description
L	2-1	Leaf litter
F-H	1-0	Partially to well decomposed organic matter.
Ah	0-5	Clay loam: black (10YR2/1 moist) very dark grey (10YR3/1 dry); moderate, medium granular; very friable; neutral; rich in well decomposed organic matter with abundant roots; boundary diffuse to:-
Ahe$\overline{j}$	5-9	Clay loam; very dark grey to black (10YR2.5/1 moist), very dark grey to dark grey (10YR3.5/1 dry); moderate, medium granular; very friable; neutral; rich in well decomposed organic matter with many roots; boundary clear and irregular to:-
Btj	9-15	Clay loam; grey brown to dark greyish brown (10YR4.5/2 moist), brown (10YR 5/3 dry); moderate, medium prismatic breaking to moderate, medium subangular blocky; firm; neutral; appears to be cutans on prismatic surfaces; boundary clear and wavy to:-
BC	15-18	Clay loam; brown (10YR4.5/3 moist); brown (10YR5/3 dry); weak, medium prismatic; friable; weakly calcareous; boundary clear and wavy to:-
C	18-36+	Loam; pale brown (10YR6/3 moist); very pale brown (10YR7/3 dry); weak, medium pseudo-prismatic; dry, slightly hard; moderately calcareous.

2. Orthic Dark Grey

Location: North center section 33, township 16, range 18 west.

Vegetation: Aspen, balsam poplar, dogwood, rose, tall grasses.

Drainage: Well drained.

Parent Material: Moderately calcareous mixed boulder till.

Topography: Undulating to rolling.

Horizon	Depth-inches	Description
L	3-2	Leaf litter
F	2-1	Partially decomposed leaf litter
H	1-0	Highly decomposed organic matter boundary clear and smooth to:-
Ahej	0-5	Clay loam; black (10YR2/1 moist), very dark greyish (10YR3/1 dry); weak, fine granular; very friable; neutral; rich in well decomposed organic matter with abundant roots; boundary gradual and irregular to:-
Aeh	5-7	Clay loam; very dark grey (10YR3/1 moist), dark grey (10YR4/1 dry); weak, fine subangular blocky; friable; neutral; rich in organic matter; tongues, in which the organic matter appears to be breaking down, go into the BA and Bt horizons; boundary gradual and irregular to:-
BA	7-10	Clay loam; very dark grey brown (10YR 3/2 moist), greyish brown (10YR5/2 dry); moderate, fine, subangular blocky with some weak, medium prismatic, firm; neutral; the top appears to be breaking down into Ae; boundary clear and wavy to:-
Bt	10-14	Clay loam; very dark greyish brown (10YR3/2 moist), dark grey brown (10YR 4/2 dry); strong, medium blocky with some weak, medium prismatic; very firm; neutral; cutanic formations well defined; boundary gradual and wavy to:-

Horizon	Depth-inches	Description
BC	14-18	Clay loam; dark greyish brown to very dark grey brown (10YR3.5/2 moist), greyish brown (10YR5/3 dry); weak, fine subangular blocky; firm; weakly calcareous; boundary gradual and irregular to:-
C	18-36+	Clay loam; dark greyish brown (10YR 4/2 moist), greyish brown to light greyish brown (10YR5.5/2 dry); weak, fine to medium subangular blocky to granular; dry, slightly hard; moderately calcareous.

3. Orthic Grey Wooded

Location: South east ¼ of section 26, township 21, range 19 west.

Vegetation: Aspen, birch, black spruce, hazel, dogwood, rose, vetch.

Drainage: Well drained.

Parent Material: Moderately calcareous mixed boulder till.

Topography: Rolling.

Horizon	Depth-inches	Description
L	2-1	Leaf litter; boundary clear and smooth to:-
F	1-0	Partially decomposed leaf litter; boundary clear and smooth to:-
H	0-1	Well decomposed organic matter, and mineral horizon; black (10YR2/1 moist); boundary gradual and smooth to:-
Ae	1-4	Loam; greyish brown to darkish brown (10YR5/2-4/2 moist), greyish-light grey (10YR6/1 dry); moderate, medium

Horizon	Depth-inches	Description
		platy; very friable; slightly acid; boundary clear and smooth-wavy to:-
BA	4-7	Clay loam; dark greyish brown (10YR 4/2 moist), greyish brown (10YR5/2 dry); moderate, fine subangular blocky; friable; slightly acid; boundary clear and smooth to:-
Bt1	7-10	Clay; very dark greyish brown (10YR 3/2 moist), dark greyish brown (10YR 4/2 dry); moderate, medium prismatic breaking down to moderate, fine to medium blocky; firm; slightly acid; pronounced cutans; boundary clear and smooth to:-
Bt2	10-13	Clay; very dark greyish brown (10YR 3/2 moist), dark greyish brown to dark brown (10YR4/2-3/3 dry); moderate, medium prismatic breaking down to strong, medium to coarse blocky; very firm; slightly acid; pronounced cutans; boundary gradual and irregular to:-
BC	13-17	Clay loam; dark greyish brown (10YR 4/2 moist), dark brown to brown to pale brown (10YR4/3-6/3 dry); moderate, fine-medium subangular blocky; firm; weakly calcareous; boundary gradual and irregular to:-
C1	17-34	Clay loam; brown (10YR5/3 moist), brown and light grey (10YR5/3 and 7/1 dry), pseudo-crumb; friable; strongly effervescent; calcium carbonate found throughout with pronounced deposition along root channels; boundary diffuse to:-
C2	34+	Loam; brown and light grey (10YR5/3 and 7/1 dry); pseudo-fragmental; dry, hard; moderate amounts of calcium carbonate throughout with pronounced deposition along root channels and cleavage planes.

II. Sampling

Pits were dug at the selected sample sites and several peds and clods were taken from each horizon. The peds were wrapped in paper towelling and their orientation was marked on the wrapping paper. The wrapped peds were placed in cartons in such a manner that the upper part of the soil sample was towards the top of the carton. Monoliths were also taken at each site for the provision of peds from specific locations in the profile, and as a permanent record of the profiles.

III. Thin-Section Preparation

Preliminary investigations were carried out to ascertain the most efficient method of impregnating. The results obtained are as follows:

1. The addition of styrene lowered the viscosity of Castolite. Heating had a similar effect.

2. Evacuation of the impregnating solution (about 7 mm of mercury (10), did not appear to have any detrimental effects on fabric and/or structure.

3. Any increase in efficiency of impregnation by pre-evacuation was outweighed by the convenience of evacuation after addition of the impregnating material.

4. The majority of samples were not sufficiently impregnated after the initial treatment.

5. An incorrect amount of Castolite hardener tended to promote cracking of the casts as did rapid curing at high temperatures.

6. Drying of incompletely impregnated samples for further treatment by heating above 50° centigrade resulted in swelling of the casts with concomitant cracking of natural structures.

With these findings in mind, the following method was adopted:

Samples, the approximate size of which was $1\frac{1}{2} \times \frac{1}{2} \times 1$ inches, were cut from air dry soil clods. This sample size sacrificed completeness of impregnation, but greatly facilitated the maintenance of orientation and ease of handling. The samples were placed in 7 ounce plastic coated "Pureflavor" hot drink cups#, the horizon and orientation being marked on the cups. Cup and sample were then placed into a 250 ml beaker. A 1:1 Castolite:styrene mixture was stirred with slight heating to ensure complete mixing and to lower the viscosity. Six drops of "Castolite hardener" were then added per 100 ml of solution under continued stirring. The resultant mixture was added to the samples in the cups until they were covered by 3/8 to $\frac{1}{2}$ inches of liquid.

Samples were then placed in a vacuum desiccator and evacuated. The evacuation system included the desiccator, a stopcock, a manometer, a cooled flask to condense styrene fumes, a $CaCl_2$ dryer and a vacuum pump in that order. The whole apparatus, with the exception of the pump, was placed in a fume chamber.

Evacuation was done at such a rate that no large bubbles- greater than about $\frac{1}{4}$ inch - came to the surface and broke. Large bubbles tended to disturb the sample and to cause spattering of the plastic. Approximately 29 inches of mercury

---

Crown Zellerback.

vacuum was applied and held for one hour. The moulds were then removed from the desiccator, placed in a dark fume chamber and covered. The plastic was allowed to harden for three days at room temperature. Then it was cured for one day at 40°C., one day at 70°C., and one hour at 80°C.

If, upon cutting, the soil was found to be insufficiently impregnated, sections, or grooved blocks, were washed in kerosene, dried at 40°C. and reimpregnated by the above procedure.

Using a diamond saw, sections of desired orientation, and about 3 mm thick, were cut from the impregnated soil. The sections were then trimmed to about 20 mm, by 20 to 40 mm leaving a rim of Castolite around them where possible. The smoother side of the section was ground as smooth as possible by hand using Alundum 600 grit grinding compound, washed in kerosene, dried, and buffed with a cloth. Kerosene was used in conjunction with all cutting and grinding procedures for lubrication and cooling.

A 25 x 75 x 1 mm glass slide was placed on the hot plate and prewarmed to 115-120°C. A bar of Lakeside 70 thermoplastic cement pressed against the slide until the required amount had melted off, and allowed to sit until all the bubbles had disappeared from the cement. The chip, smooth side down, was placed on the Lakeside 70 and pressure applied until the cement had reached all edges of the section, upon which the slide was removed from the heat and pressure continued until the Lakeside

70 cooled. Care was taken to avoid any lateral movement of the chip during the cooling procedure. If entrapped bubbles were present the chip was removed and remounted. The profile, horizon and orientation was then scratched into the glass slide.

To facilitate subsequent grinding, a cork was affixed to the slide on the end away from, and on the opposite side to, the specimen.

Coarse grinding was done on a lapidary using Alundum 240 grit grinding compound until a thickness of about 0.1 mm was attained, taking care to keep the slide even. All thicknesses were estimated by the interference color of quartz. The section was then washed in kerosene making sure that all coarse grinding compound was removed.

Final grinding was done by hand on a double diamond glass plate using Alundum 600 grit grinding compound. Frequent checks on thickness were made until the section was 0.03 to 0.05 mm thick.

Upon completion of grinding, the cork was removed, the section washed, dried and buffed, and a label with profile, horizon and orientation marked on it was affixed.

A small drop of Caedax, which has essentially the same properties as Canada balsam, was placed centrally on the cold section. An appropriate cover slip was gently placed on top of it. The whole assembly was placed on the hot plate, prewarmed to about 65°C., and allowed to sit until the Caedax had reached all corners of the cover slip. The cover slip was then pressed gently, any bubbles "pushed" or "worked" out, and left on the hot plate for about one hour. The slide was cooled and any excess mounting medium wiped off with a Xylene dampened cloth. The thin-section was now completed and ready for petrographic investigations.

A minimum of two thin-sections, one oriented parallel and one perpendicular to the ground surface, were made from each horizon.

IV. Mineral Grain Preparation and Mounting.

1. Preparation of Samples

The preparation of samples for heavy mineral separation was carried out by the method proposed by Jackson (23). Samples were ground and passed through a 2 mm sieve. Carbonates were destroyed using sodium acetate buffered at pH5. Organic matter was decomposed with hydrogen peroxide. Iron was removed by sodium dithionite and sodium citrate.

A 300 mesh sieve was used to collect the sand fraction which was the dried from acetone, and the very fine, fine, and medium sands were separated using a set of screens based on U.S.D.A. size limits.

2. Heavy Mineral Separation and Mounting

Heavy minerals from the selected sand fractions were separated with bromoform (S.G.2.89), using the method set out by Milner (31). The separates were dried, weighed and heavy minerals calculated as a percent of the total weight of the particular sand fraction.

The heavy minerals were mounted in Aroclor, a thermoplastic cement, as follows:- A glass slide was placed on the hot plate set at 120°C (250°F) and a bar of Aroclor was pressed against it until the required amount had melted. A representative sample of 250-300 grains was added, and stirred to attain uniform distribution. The cover slip was put on by first placing one edge down and then gradually lowering onto the cement, followed by gentle pressure to force out excess cement. The slide was allowed to cool and excess Aroclor removed with kerosene.

3. Light Mineral Staining and Mounting

The method used for staining light minerals was that of Reeder and McAllister (36) with a few modifications.

Reagents:

Sodium cobaltinitrite solution: - One gram of sodium cobaltinitrite was dissolved per 4 ml. distilled water.

Hematein solution:- 0.05 gm. of hematein was dissolved in 100 ml. of 95% ethanol.

Buffer solution:- 20 gm. of sodium acetate was dissolved in 100 ml. of distilled water, to which 6 ml. of glacial acetic acid were added and the solution diluted to 200 ml. The resultant solution was approximately 0.5 N in acidity and buffered at pH 4.8 (37).

The selected light mineral grains were placed in a polyethylene container, and 49% hydrofluoric acid was added until the grains were covered. After one minute the acid was immediately diluted and siphoned off. The grains were spread over the bottom of the container, covered with sodium cobaltinitrite solution for 1-1½ minutes, and washed by dilution and siphoning. The sample was covered with a 2:1 hematein: buffer mixture, shaken well for approximately one minute, and allowed to stand for about ten minutes. The grains were then washed once with 95% ethanol, twice with acetone, and allowed to dry.

A few drops of Caedax were placed on a glass slide on the hot plate set at 65°C. and a representative 250-300 grains stirred in. A cover glass was put on as outlined in the heavy mineral mounting, the slide labelled, and placed in an oven, set at 65°C. for 5 hours. Upon cooling, the grain mounts were ready for examination.

V. Photomicrography

An Exacta 35 mm. reflex camera, with a microscope adapter was employed with a Zeiss "Junior Pol" microscope. A milliammeter, with a photocell probe, was used in conjunction with a variable voltage transformer attached to the light source, so that the intensity of light, as determined at the microscope eyepiece, was constant. This meant that for a particular film, only one exposure time needed to be used. In the illuminating system a light blue filter was used with a clear ground glass filter. Anscochrome duplicating film was used for color slides and Panatomic X for black and white.

RESULTS AND DISCUSSION

I. Mineral Grain Studies

1. Heavy Mineral Fraction

The percentage of heavy minerals was fairly constant in all horizons of the three profiles, with values ranging from 2.40% to 3.18%. The data appear in Table I (Appendix). The Orthic Black and Orthic Dark Grey profiles tended to have more micaceous minerals. Apart from this, the mineral species present and the proportions of each was very similar between profiles as well as within the respective profiles. The heavy mineral suite present in the fine sand fractions of the major horizons is given in Table II (Appendix).

From the similarity in the percentage of heavy minerals and in the species present, it was concluded that the parent materials were similar. The dominance of amphibole indicated a paucity of post-glacial chemical weathering.

2. Light Mineral Fraction

Stained mineral mounts were examined and 250-300 grains were counted per slide. This was done for the medium, fine, and very fine sand fractions from the master horizons of each profile. The results of this study may be found in the Appendix (Table III).

The results indicate that quartz is dominant in the finer sand fractions. The percentage plagioclase in the medium sand is fairly constant between the horizons of the respective profiles. The fine sand fraction shows a decrease in plagioclase in the A and B horizons, with respect to the C horizon for the Orthic Dark Grey and Orthic Grey Wooded profiles. In the very fine sand fraction all profiles have less plagioclase in the solum than in the parent materials. These results indicate that chemical weathering is taking place, and that the breakdown of primary minerals is more pronounced in the more strongly degraded profiles.

II. Micromorphological Descriptions

The prepared thin-sections were examined using a polarizing microscope. They were described by means of the following characteristics; fabric - using the defined description terms; structure - using the defined size and shape classes; porosity - voidal space within the peds, inped porosity, and the size of the interpedal voids, exped porosity (where the peds were very poorly defined, or did not exist, only one figure is given); pedological features - description of plasma orientations or concentrations. Percentage figures are estimations of the area of the slide covered by any specific feature.

1. Orthic Black

Ah (Plate I photograph 1)

Fabric: - Chernozemic, with a tendency to be spongy.

Structure: Poorly defined, very coarse to extremely coarse subangular blocky.

Porosity: (a) Inped - 25%

(b) Exped - very irregular voids, 0.02 to 2 mm in cross section.

Pedological features: Extremely fine to fine rounded iron amygdali were disseminated throughout the horizon. Under medium power, random streaks and flecks of yellowish oriented plasma, likely organic matter, were seen within the ped. Around the skeleton grains and most voids, this plasma was weakly separated and tended to become oriented parallel to the edges, thus forming cutans.

Remarks: The horizon was impregnated with a high percentage of very dark organic matter which tended to be globular in nature.

Ahej

Fabric: Chernozemic and spongy.

Structure: Poorly defined, coarse to very coarse granular which appears fragile.

Porosity: (a) Inped - 30%

(b) Exped - irregular voids 0.02 to 0.5 mm, in cross-section.

Pedological features: Similar to those in the Ah horizon with the amygdali being somewhat smaller and the voidal cutans a little more pronounced.

Remarks: Some limestone grains were noted.

Btj (Plate II, photograph 1)

Fabric: Porphyropeptic to intertextic.

Structure: Well defined, coarse to very coarse, subangular blocky within extremely coarse (10-15 mm) prismatic.

Porosity: (a) Inped - 10%

(b) Exped - inter-prismatic voids are 0.1 to 0.5 mm in cross-section, and the inter-subangular blocky voids are 0.02 to 0.1 mm in cross-section.

Pedological Features: Extremely fine to medium iron amygdali (3%) were present, with the medium ones frequently along voids. Streaks of birefringent plasma which tended to parallel the edges of skeletal grains occurred throughout the slide. Plasmic concentrations, particularly along large exped voids, were present and had diffuse inped boundaries. The plasma, in these concentrations, appeared to consist chiefly of humus with some clay and iron oxides.

Remarks: In many cases the cutans appeared to be plasma separations. The main illuvial constituent appeared to be organic matter. The major skeletal mineral was quartz with some microcline and plagioclase, the latter exhibiting surface weathering.

BC

This horizon appeared to be similar to the Btj horizon with very poorly developed structure, if any; a little less organic matter; more iron concretions; and a trace of limestone.

C

Fabric: Porphyropectic to plectomictic (some grains are coated)

Structure: Massive.

Porosity: 10%

Pedological features: Iron concentrations were less prevalent than in above horizons. The grain cutans were weathering rims (particularly noticeable around impure limestone grains).

Remarks: This horizon contained about 20% limestone which was present in two distinct forms, cryptocrystalline with clay and iron impurities and clear crystalline, which could be recrystalized metamorphic or authigenic in origin. The former may be seen in the upper right hand corner of photograph 3, Plate IV, and the latter in the upper left hand corner of the same photograph. Plagioclase grains still exhibited surface weathering. There was distinctly less plasma present than in the above horizons.

2. Orthic Dark Grey

Ahej

Fabric: Chernozemic and spongy.

Structure: Moderately expressed coarse to very coarse granular, to spongy.

Porosity: (a) Inped - 40%

(b) Exped - very irregular voids, 0.02 to 0.5 mm. in cross-section.

Pedological features: A large number of very fine to medium iron amygdali were present. Around the grains are plasma separations with orientation parallel to the grain edges.

Remarks: There was a significant amount of undecomposed organic remains which was birefringent and had extinction parallel to the "grains".

Aeh (Plate I, photograph 2).

Fabric: Chernozemic and spongy.

Structure: Medium to coarse granular to spongy with a tendency to be extremely coarse platy.

Porosity: (a) Inped - 25%

(b) Exped - quite irregular voids 0.02 to 0.5 mm in cross-section.

Pedological features:- Iron amygdali were found throughout; flecks and streaks of strongly oriented plasma, (probably organic matter and/or micaceous material) were found throughout the ped and formed weak cutans around grains and voids.

Remarks: Some plagioclase was very highly weathered while some was clear. That much of the source rock is metamorphic is evidenced by the presence of mica schists, greisen, and strongly strained quartz. At least part of the oriented plasma is due to in situ weathering as the original mineral outline can still be seen in some cases.

BA

Fabric: Porphyropeptic to plectomictic.

Structure: Well developed coarse subangular blocky to extremely coarse prismatic.

Porosity: (a) Inped - 10%

(b) Exped - the voids were 0.02 to 0.5 mm in cross-section.

Pedological features: Many very fine to fine iron concentrations were noted. The matrix was quite dense with streaks and flecks of well oriented plasma throughout. The inped voids had strongly separated and oriented cutans as did the skeletal grains, while the cutans along the interpedal voids ranged from non-existant to very strongly separated and oriented.

Remarks: The plasma was quite highly stained with organic matter and/or iron.

Bt (Plate II, photograph 2)

Fabric: Porphyropeptic to plectomictic

Structure: Massive.

Porosity: 15% - many roundish to oblong voids connected by fine cracks.

Pedological features: Iron concretions similar to those found in the BA horizon were present (4%). Neither the oriented plasma in the matrix nor the grain cutans were as well developed as in the BA horizon. Voidal cutans however, were more continuous and exhibited a high degree of separation and orientation.

Remarks: There was less staining of the matrix than in the BA horizon. A significant amount of limestone was present.

BC

Fabric: Porphyropeptic to plectomictic.

Structure: Coarse to very coarse subangular blocky, the peds are well separated with many of the aggregates not appearing to be natural.

Porosity: Total-about 20%.

Pedological features: Fewer iron concretions were present than in the BT horizon. A few poorly separated and oriented flecks of plasma were present in the matrix as well as some weakly expressed grain cutans; A slight but definite concentration of darker colored plasma was noted along the major interpedal voids.

Remarks: There was almost as much weathering of the plagioclase as in the surface horizons. About 15% limestone was present.

C. (Plate IV, photograph 3).

Fabric: Porphyropectic to porphyropeptic.

Structure: Massive to coarse granular.

Porosity: 10%

Pedological features: Iron concretions present were similar to those in the BC horizon, There were no plasma concentrations other than weathering rims around some limestone grains.

Remarks: There was a different "texture" to the fabric, which appeared fluffy. This could be due to the flocculent nature, and lack of orientation of the plasma. Many of the exped voids did not appear to be natural and could be shrinkage cracks caused by drying. Limestone (15%) was present in the two forms mentioned in the Orthic Black profile. The presence of schistose grains was noted.

3. Orthic Grey Wooded.

Ae (Plate I photograph 3).

Fabric: Intertextic to porphyropeptic.

Structure: Very coarse platy.

Porosity: (a) Inped - 15%

(b) Exped - voids appeared to be somewhat sinuous, 0.02 to 0.5 mm in cross-section.

Pedological features: Fine to coarse iron amygdali (5%) had a slight tendency to form near the planer surfaces. Some of the grains had thin coatings of iron and/or organic matter. There was little, if any, oriented plasma.

Remarks: The plagioclase was moderately weathered and some of the hornblende exhibited bleaching.

BA (Plate III, photograph 1)

Fabric: Porphyropeptic to plectomictic.

Structure: Moderately defined, coarse to very coarse subangular blocky within weakly defined, very coarse to extremely coarse platy.

Porosity: (a) Inped - 10%

(b) Exped - peds are well separated by 0.02 to 0.5 mm conducting voids.

Pedological features: The larger iron concretions (about same amount as in the Ae) had diffuse boundaries. Grain cutans were only weakly expressed as was oriented plasma within the peds. Interpedal void cutans were weak, except when skeletal material was close to the ped surface.

Remarks: The ped interior was quite dense and quite strongly stained with iron, particularly in the vicinity of amygdali. Quite a large number of undecomposed plant roots were present.

Btl (Plate III, photograph 2).

Fabric: Porphyropeptic.

Structure: Well defined, coarse to very coarse, subangular blocky.

Porosity: (a) Inped - 5-10% (look like old exped voids, crack-like).

(b) Exped - voids were 0.5 to 0.1 mm in cross-section

Pedological features: Fewer iron concretions were present than in the above horizon, particularly the larger ones. Streaks and flecks of oriented plasma were found throughout; Definite plasmic concretions with broad diffuse inped boundary, were found peripherally and along inped voids. Grain cutans were weakly to strongly expressed with inped void cutans being very strongly expressed. The interpedal void cutans appeared to be compound, with an extremely fine well separated and oriented clay cutan on the outside and a very fine to fine reddish-brown (probably clay highly impregnated with iron and organic matter) cutan, with a gradual to diffuse inner boundary, on the inped side.

Remarks: There appeared to be no preferred surface, vertical or horizontal, for cutan formation. The inner component of the compound cutans has a large number of skeletal grains embedded in it, giving the impression that there had been inward diffusion of this plasmic material.

Bt2 (Plate III, photograph 3; Plate IV, photographs 1 and 2).

Fabric: Porphyropeptic to plectomictic.

Structure: Coarse to very coarse subangular blocky.

Porosity: (a) Inped - 15% (round, oblong, and irregular cracks).

(b) Exped - voids were 0.02 to 0.5 mm in cross-section.

Pedological features: Iron concretions were more prevalent than in the Btl horizon. They appeared somewhat dendritic. Inped streaks of oriented plasma were present, but in lesser amounts than in the Btl horizon. Cutans around inped voids were strongly separated and oriented, with grain cutans being weakly expressed except when near voids. The compound nature of the interpedal void cutans appear even more distinct in this horizon than in the Btl with the darker colored "inner cutan" being strongly separated as well.

Remarks: There was a slight tendency for cutans to be more strongly pronounced on vertical surfaces. Distinctly different from the Btl horizon in that there are more inped voids, less inped oriented plasma and more strongly expressed voidal cutans.

BC

Fabric: Porphyropectic to plectomictic.

Structure: Weakly defined very coarse granular, to massive.

Porosity: Total - 15%.

Pedological features: Iron concentrations were smaller and more dentritic than in above horizons. Very little oriented plasma was noted; under high power grain cutans and some very weakly expressed channel cutans were detected.

Remarks: Some iron staining occurred as blotches. About 15% limestone, was present with both the microcryptalline and cryptocrystalline types. The plasma appeared more flocculent.

C.

Fabric: Porphyropectic to porphyropeptic.

Structure: Massive with irregular fine cracks.

Porosity: Total - 10%.

Pedological features: Iron was present more as concentrations than concretions. Plasma appeared somewhat denser along some voids.

Remarks: There was some iron staining, flocculent plasma, and about 20% limestone.

III. Micropedological Interpretations

1. Orthic Black

The large amount of organic matter, with associated chernozemic fabric indicates that the addition of organic matter to the surface horizon is a very significant process. The weakly eluviated Ahej and weakly illuviated Btj horizons, coupled with the poor expression of structure and the presence of carbonates in the solum, indicate that leaching and eluviation is not pronounced. The similarity in degree of weathering in the A, B and C horizons as seen in thin-section and mineral grain studies, suggests that post-glacial chemical weathering is not significant in this profile.

2. Orthic Dark Grey

The high concentration of organic matter in the surface horizons implies that addition is a major process. However, eluviation and illuviation are present to a degree which in thin section study approaches the addition process in significance. This may be inferred from the platy tendency of the Ahej horizon; the quite dense BA with well developed structure, and oriented plasma present as inped streaks and as voidal cutans; the strongly expressed interpedal void cutans in the Bt; the indication of some illuvial plasma in the BC.

A study of the plagioclase, in thin sections and in the light mineral separates, indicates that some post-glacial weathering of primary minerals has taken place in the solum.

3. Orthic Grey Wooded

The presence of the eluviated Ae horizon, and the absence of an Ah horizon, makes it clear that the addition of organic matter is not a significant process.

The combined impressions of a rather dense BA horizon, which appears to be breaking down; a very dense Btl with well expressed cutans and an abundance of oriented plasma; very strong interpedal void cutans in the Bt2; and some illuvial plasma in the BC, all indicate that eluviation and illuviation are the dominant processes in this profile, and that it is continuing.

The post-glacial weathering of primary minerals in the upper solum relative to the parent material is greater than in the previous profiles.

4. Discussion of Specific Features

The surface horizons of the profiles studied exhibited a drastic change in properties from the Chernozemic fabric expressed in the Ah horizon of the Orthic Black (photograph 1, Plate I), through the moderately degraded and slightly platy Aeh horizon of the Orthic Dark Grey (photograph 2, Plate I), to the plasma deficient, strongly platy Ae horizon of the Orthic Grey Wooded (photograph 3, Plate I). The platy structure of the eluvial horizons of the Orthic Dark Grey and Orthic Grey Wooded profiles corresponds to the "isoband fabric" of McMillan and Mitchell (29). The "invasion amygdali" noted in the Ae horizon of the Orthic Grey Wooded profile had no definite mode of occurrence, in contrast to their concentration at the bottom of the bands as was reported by McMillan and Mitchell (29).

The major illuvial horizons also show a distinct gradation of properties between soils. In the Orthic Black, eluviation is not marked, and the chief illuvial constituent appears to be organic matter. The only cutans present are around skeleton grains (photograph 1, Plate II) and they appear to be plasma separations with orientation caused by physical forces - probably freezing and thawing and/or wetting and drying. Inped oriented plasma is likely of similar genesis. The Orthic Grey Wooded, by comparison, has a higher concentration of plasma and somewhat denser peds (photograph 2, Plate III), and very strongly expressed interpedal void cutans which are undoubtebly of illuvial origin (Photograph 3, Plate II; photograph 1, Plate IV). The illuvial horizon of the Orthic Dark Grey (photograph 2, Plate II) occupies an intermediate position. Structure also had a gradational tendency, being better defined in the more strongly degraded profiles.

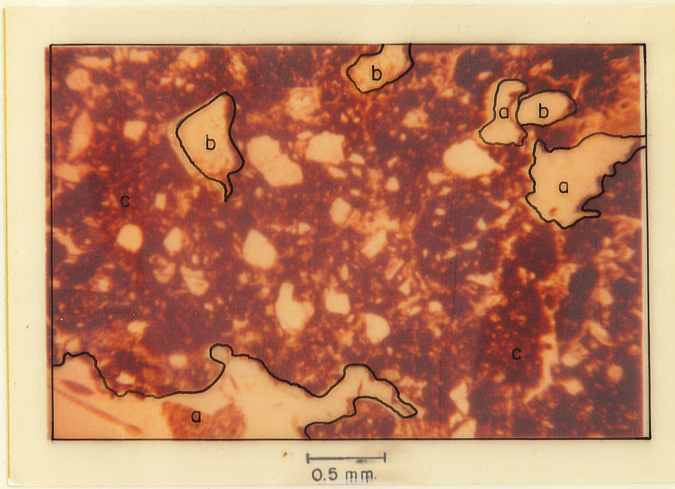
Another gradation may be found within the illuvial horizons of the Orthic Dark Grey and Orthic Grey Wooded profiles respectively. Using the Orthic Grey Wooded as an example (photographs 1,2,3, Plate III), it can be seen that the Bt1 horizon is the most highly impregnated with plasma, while the Bt2 has the least plasmic material within the peds. The Bt2 horizon, on the other hand, has the most strongly expressed interpedal void cutans. Buol and Hole (12), and

PLATE I

Schematic diagram of prints on plate I

a.) Void
b.) Large mineral grains
c.) Matrix - plasma and small mineral grains
d.) Iron amygdali

1



↑ Ah-Orthic Black

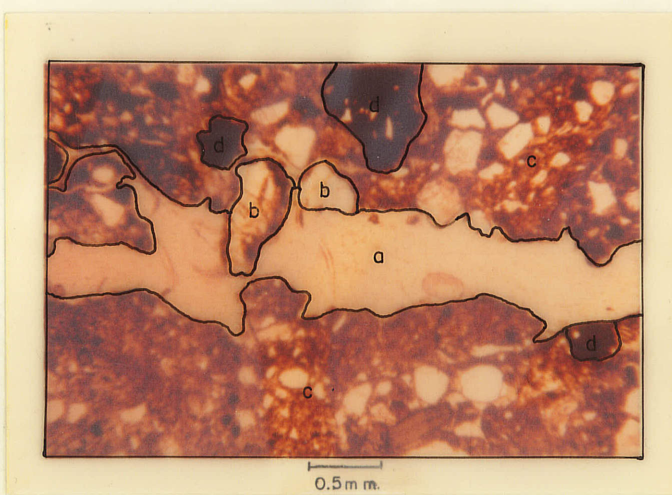
plane polarized light

2

↑ Aeh-Orthic Dark Grey

plane polarized light

3



↑ Ae-Orthic Grey Wooded

plane polarized light

PLATE II

Schematic diagram of prints on plate II

LEGEND:

a.) Void

b.) Large mineral grains

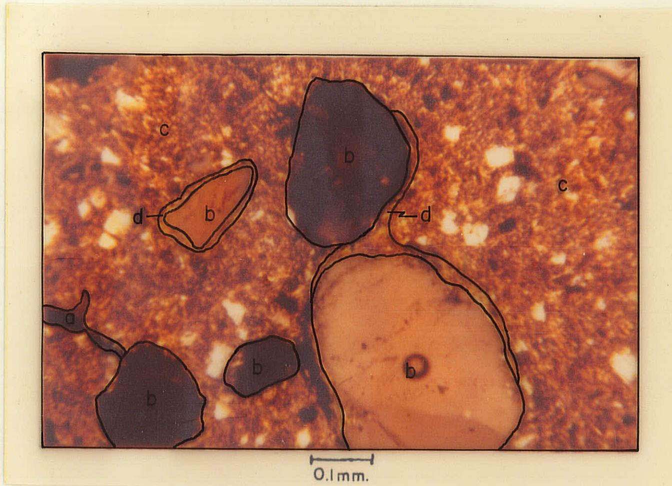
c.) Matrix – plasma (some oriented) and small mineral grains

d.) Grain cutans

e.) Void cutans

f.) Iron amygdali

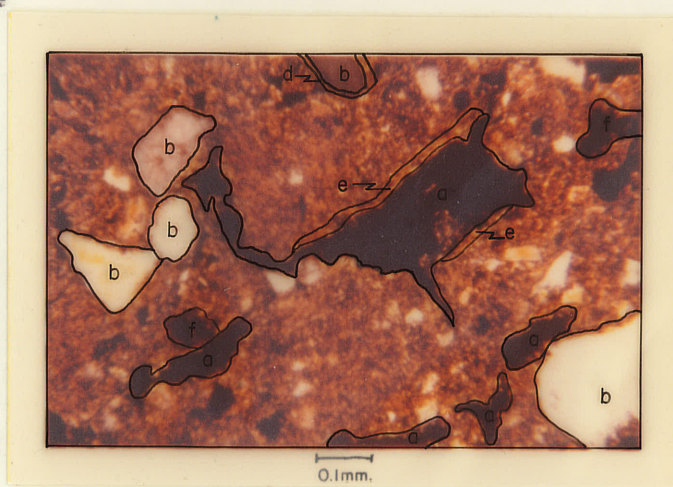
1



↑ Btj-Orthic Black

x-nicols

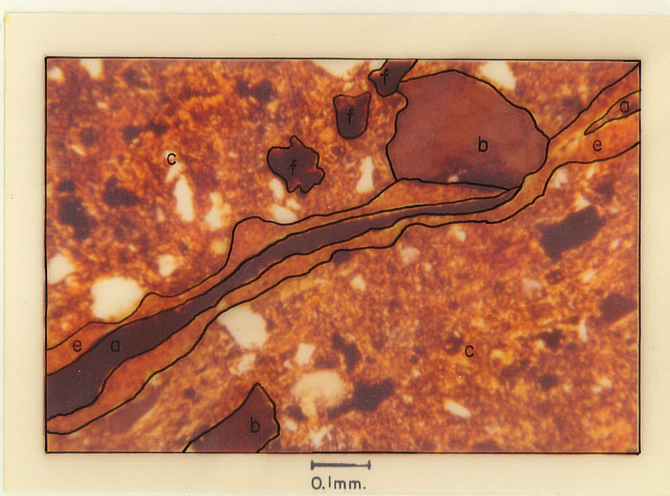
2*



↑ Bt-Orthic Dark Grey

x-nicols

3



\+ Bt2-Orthic Grey Wooded

x-nicols

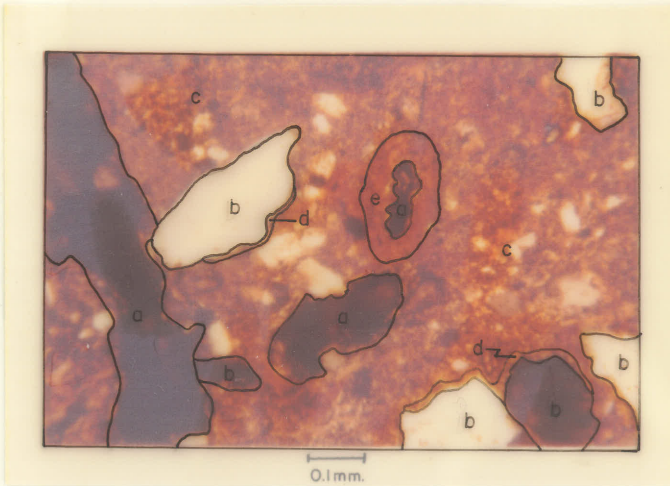
* This photograph was taken with a heavy blue filter in the system.

PLATE III

Schematic diagram of prints on plate III

LEGEND:
a.) Void
b.) Large mineral grains
c.) Matrix - plasma (some oriented) and small mineral grains
d.) Grain cutans
e.) Void cutans

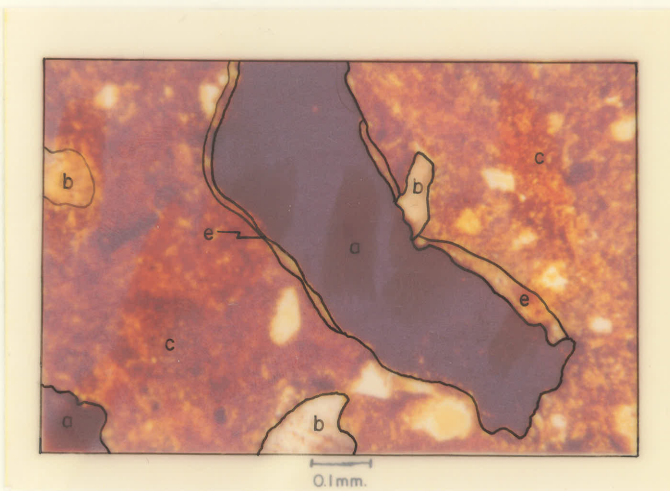
1



BA-Orthic Grey Wooded

x-nicols

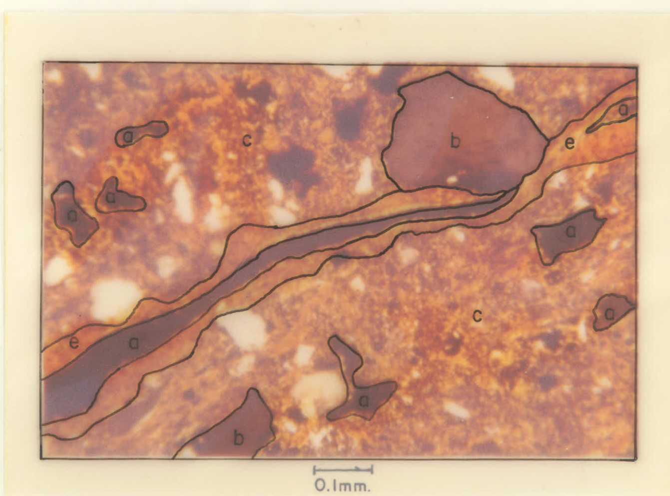
2



Bt1-Orthic Grey Wooded

x-nicols

3



Bt2-Orthic Grey Wooded

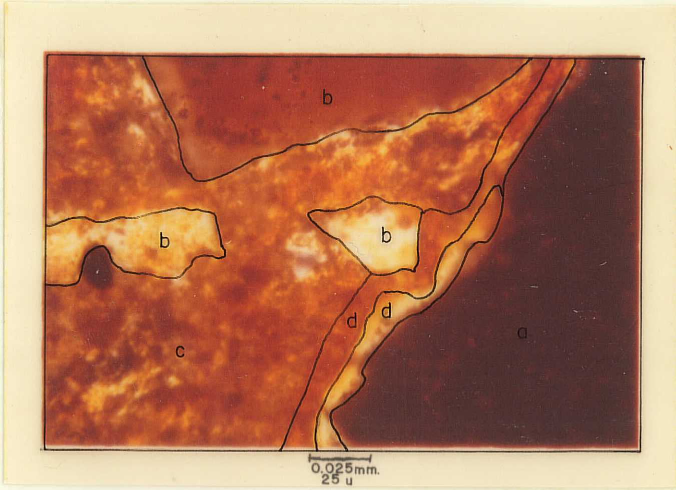
x-nicols

PLATE IV

Schematic diagram of prints on plate IV

LEGEND:
a.) Void
b.) Large mineral grains
c.) Matrix – plasma and small mineral grains
d.) Void cutans
e.) Limestone

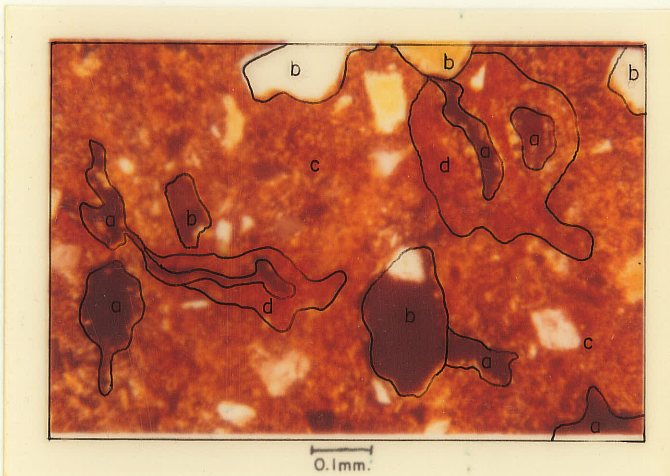
1



Bt2-Orthic GreyWooded

x-nicols

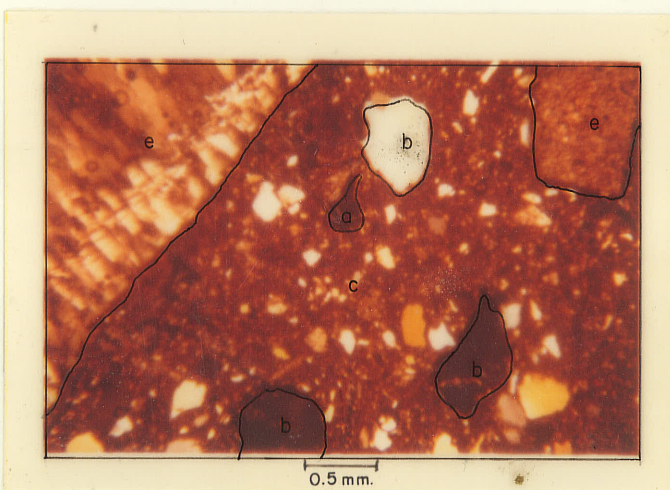
2



Bt2-Orthic Grey Wooded

x-nicols

3



C-Orthic Dark Grey

x-nicols

Fridland (19) suggested mechanical disturbance as the cause of this phenomenon. They reasoned that disturbance by such forces as freezing and thawing, wetting and drying, and root pressure, would be greater near the surface. This would engender the breaking down of old peds and the formation of new ones, with the concomitant exposure of new surfaces. This seems to be a valid explanation for the dense plasmic state of the upper illuvial horizons. It also explains the more strongly expressed interpedal void cutans in the lower part of the solum, where ped disturbance would be much less.

A well expressed interpedal void cutan can be observed on the right side of photograph 1, Plate IV. The compound nature of the cutan is quite clear (also note photograph 3, Plate III). The sharp, clear boundaries of the outer cutan indicate its illuvial nature. The color both under crossed nicols (yellow to white) and under plane polarized light (clear to dusky) implies a composition of clay. The yellow-brown to red-brown inner cutan suggests contamination by iron and organic matter. This in conjunction with its smooth outer boundary implies an illuvial origin for this cutan as well. Only in the more strongly expressed cases do the cutans appear to be compound.

Noted in all horizons affected by illuviation was the diffuse inner boundary of the clay-organic matter-iron void cutans (photograph 2, Plate IV). This suggests impregnation of the ped by these substances. Frei and Cline (18) recorded the same phenomenon. The author feels that there is sufficient evidence to support the addition of a variant of illuviation cutans to cover this case. The proposed variant would be an "infusion cutan". It could be distinguished from a diffusion cutan by its composition - which is foreign to the parent material - and occurrence, both of which would mark it as an illuviation cutan. A definition of an infusion cutan could be "an illuviation cutan with a diffuse inner boundary."

CONCLUSIONS

As the parent materials are similar, post-glacial weathering does not appear to be significant, the age of the soils and the macro climate are similar, the only soil-forming factors responsible for differences in the profiles studied are vegetation and soil climate.

The illuvial horizons are characterized by an increase in plasmic material, leading to an increase in the density of well defined peds; a decrease in porosity (but not necessarily a decrease in permeability); the presence of voidal cutans, inped streaks of oriented plasma, and some invasion amygdali.

Petrographic examinations are extremely useful in evaluating pedological factors and processes, as to kind and degree, as interpreted from micromorphological considerations.

Thin section studies are beneficial in the characterization of soil. They correlate quite well with chemical data.

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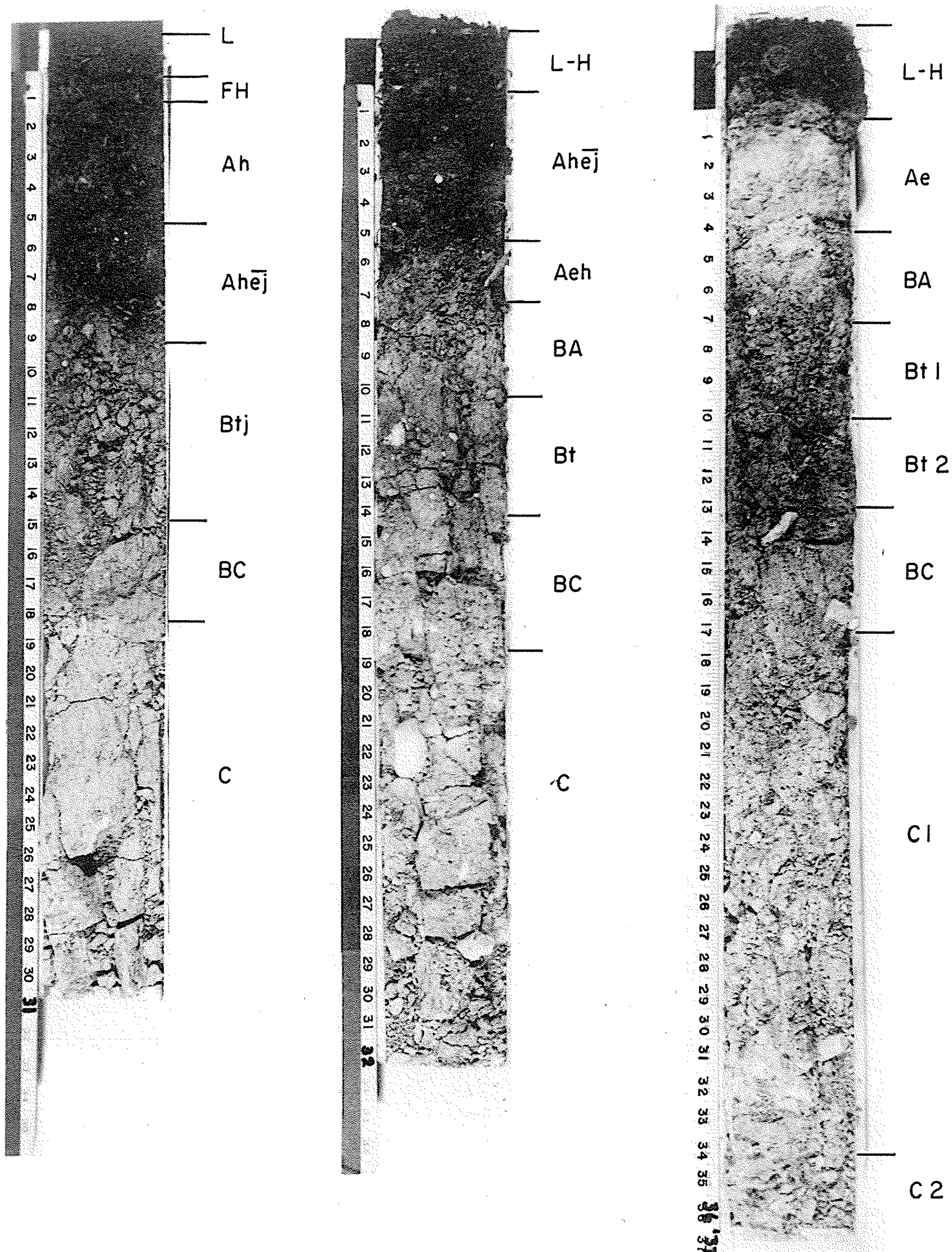
APPENDIX

PLATE V

Representative Profile Types



Orthic Black

Orthic Dark Grey

Orthic Grey Wooded

TABLE I

Percentage of Heavy Minerals in the Major Horizons of the Profiles Studied

Profile	Horizon	Sand Fraction	% Heavy Minerals
Orthic Black	Ah	MS	1.75[1]
		FS	2.93
		VFS	3.05
	Btj	MS	0.48
		FS	2.40
		VFS	2.69
	C	MS	0.76
		FS	2.58
		VFS	2.46
Orthic Dark Grey	Aeh	MS	0.93
		FS	2.60
		VFS	2.49
	Bt	MS	1.60
		FS	2.60
		VFS	3.51
	C	MS	1.54
		FS	2.85
		VFS	4.25
Orthic Grey Wooded	Ae	MS	2.41
		FS	3.18
		VFS	4.08
	Bt2	MS	1.85
		FS	2.52
		VFS	3.22
	C2	MS	2.02
		FS	2.84
		VFS	3.96

[1] As the weight of heavy minerals in the medium sand fraction was quite small, there could be a large percentage error involved.

TABLE II

Heavy Mineral Suite Present in the Profiles

Dominant	-	amphibole (dark blue-green hornblend, and traces of tremolite-actinolite and orthoamphibole).
	-	garnet
Abundant	-	staurolite
	-	epidote
Scarce	-	mica
	-	opaque (hematite, magnetite, limonite, ilmenite, pyrite).
	-	kyanite
	-	sillimanite
	-	hypersthene
	-	apatite*
Trace	-	rutile
	-	zircon
	-	topaz
	-	tourmaline
	-	pyroxene

* The preparation procedure destroyed the carbonates and the majority of the phosphates (23).

TABLE III

Percentage of Quartz, K Feldspar and Plagioclase in the Light Mineral Fractions of the Three Profiles

Profile	Horizon	MS Quartz	MS K Feldspar	MS Plagioclase	FS Quartz	FS K Feldspar	FS Plagioclase	VFS Quartz	VFS K Feldspar	VFS Plagioclase
Orthic Black	Ah	57	14	29	64	14	22	90	3	7
	Btj	66	10	24	74	8	18	92	2	6
	C	56	13	31	78	7	18	79	1	20
Orthic Dark Grey	Aeh	59	13	28	76	8	16	93	1	6
	Bt	64	13	23	85	6	9	93	3	4
	C	65	9	26	69	9	22	86	3	11
Orthic Grey Wooded	Ae	49	16	35	82	7	11	93	3	4
	Bt2	52	13	35	85	5	10	91	4	5
	C2	59	13	28	71	2	27	67	2	31

TABLE IV

Some Physical and Chemical Analyses

of the Profiles Under Study*

Profile	Horizon	% sand	% silt	% clay 2-0.2 μ	% clay <0.2 μ	% clay total	% O.M.[1]	% Fe_2O_3[2]
Orthic Black	Ah	36.34	33.62	9.78	20.25	30.02	4.21	1.004
	Btj	22.91	43.06	9.84	24.18	34.02	1.23	1.004
	C	35.79	43.45	6.85	13.89	20.74	0.61	0.946
Orthic Dark Grey	Aeh	33.54	37.28	9.82	19.32	29.14	6.75	0.839
	Bt	33.71	30.23	11.24	24.80	36.04	0.80	1.0315
	C	32.72	34.30	13.78	19.18	32.96	0.69	0.957
Orthic Grey Wooded	Ae	51.09	38.08	6.20	4.62	10.82	1.05	0.621
	Bt2	31.07	24.45	11.80	32.67	44.47	1.28	1.175
	C2	40.62	35.14	9.65	14.56	24.21	0.37	1.232

* G.J. Beke- unpublished data
1. Dichromate method.
2. Na-citrate extraction.

I. Some Physical and Chemical Properties of the Materials Used.

1. Castolite (A)

Castolite belongs to the thermosetting class of plastics. It is a polyster resin derivative.

The following are a few of the more important qualities of finished Castolite:

Color: It is tinted a light bluish-green, which fades into transparent water-white when cured.

Color Stability: Practically no change under ordinary indoor lighting conditions. Slight yellowing upon prolonged exposure to the sun.

Outdoor Weathering: slight yellowing. Will not craze on the surface even after long exposure. Will not crack due to rapid and frequent temperature changes.

Structural Stability: No distortion under light loads, even at above-room-temperature.

Refractive Index: Liquid - 1.5378 at 77°F. Solid-1.5591 at 77°F.

Viscosity: 300 to 500 Centipoises.

Shrinkage During Cure: By volume 7.5% (average). This is equivalent to 2.5% linear shrinkage.

Heat Stability: Can be boiled in water without losing its shape. Castolite does not melt.

Machining Properties: Will not gum on high speed tools. Machined pieces are readily buffed.

Effect of Chemicals: Water, soaps, weak acids, vegetable and mineral oils, alcohol and carbonated beverages: no effect. Acetone, carbon tetrachloride, alkalis and cleaning fluids - softening.

Solvent: No known solvent for cured Castolite. Will slowly disintegrate in acetone or methylethyl ketone.

Burning Rate: slow.

Specific gravity	-	1.22 gm. per cc.
Tensile strength	-	4000 psi.
Flexural strength	-	10,000 psi.
Flexural modulus	-	550,000 psi.
Impact strength	-	0.2 ft.lbs.
Heat distortion	-	180°F (ASTM)
Power Factor	-	0.016 at 60 cycles.
Hardness	-	Barcol Value - 40 - 45 Rockwell (M) Value - 115 Moh's Scale - 2.5 - 3#
Dielectric strength	-	350 volts per mil.
Dielectric Constant	-	3.35 at 60 cycles.
Loss Factor	-	0.05 at 60 cycles.

Author's estimate.

The hardening catalyst "Castolite Hardener" is a cumene hydroperoxide.

2. Lakeside 70C(B)

Lakeside 70C is a thermoplastic cement. It is a combination of a number of natural resins.

Color: Colorless in thin films - pale yellow in thicker sections. No apparent polymerization with age.

Refractive Index: Solid - 1.54. No material change over protracted periods of time and at elevated temperatures.

Effect of Heat: melts quickly above 80°C, flows freely at 140°C; above 155°C. it is apt to burn. No baking is required. It chills very quickly to a solid state upon removal from heat.

Solubility: It is insoluble in mineral oils, soluble oils, and water. Strong mineral acids (except HCl) and bases will attack it. It is soluble in acetone, xylene, toluene, chloroform, and only slowly soluble in alcohol.

Machining Preoperties: It can be sawed, drilled or sanded wet without sticking or picking up abrasive. Dry machining can be employed if due care is taken to prevent joint heats above 80°C.

Other Characteristics: It has a hardness of about 2.5 on Moh's scale #, and is somewhat brittle. It gives a firm bond with vitreous or polished metal surfaces. It is not toxic.

3. Caedax (C)

Caedax is an absolutely neutral, synthetic mounting media.

Caedax is a synthetic resin dissolved in xylol with a refractive index of 1.55. It is used in the same manner as Canada Balsam, and is preferred to the latter since it is absolutely neutral and has little coloring of its own.

Caedax does not mix with even small traces of water. Preparations, therefore, have to be dehydrated carefully. After mounting, the cover glasses usually set in a few hours. Caedax does not polymerize even over a period of years. Therefore, it may be dissolved again in Xylol.

A. Obtained from The Castolite Co. Woodstock, Illinois.

B. Obtained from Hugh Courtright & Co. 7652 Vincennes Ave., Chicago 20, Illinois.

C. Obtained from Ward's Natural Science Est. In., 1712 Rochester N.Y.

Author's estimate.