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PAPER 68-6

GUIDE TO THE DESCRIPTION OF TILL

(Report and 5 figures)

J. S. Scott and D. A. St-Onge

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CONTENTS

Appendix

FOREWORD

This report results from a suggestion made at a conference on the geologic, hydrologic and engineering properties of till. The conference was held in Edmonton, in 1962, under the auspices of the Pleistocene Subcommittee of the National Advisory Committee on Research in the Geological Sciences.

The advice of many persons, covering a broad spectrum of interests, has been sought at various stages of the preparation. The authors gratefully acknowledge the constructive criticism thus received.

In order to proceed with this project an advisory committee was set up. The make-up of this committee was as follows:

Chairman: Dr. J. S. Scott - Geological Survey of Canada

Advisory Board: Mr. F. L. Peckover - Engineer of soils and foundations, Canadian National Railways.

Mr. C. B. Crawford - Head, Soil Mechanics Section, National Research Council.

Dr. J. A. Elson - Department of Geology, McGill University.

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Mr. S. C. Zoltai - Department of Forestry and Rural Development, 25 Dafoe Road, Fort Garry, Winnipeg 19, Manitoba.

GUIDE TO THE DESCRIPTION OF TILL

INTRODUCTION

This manual outlines a standard method for describing the essential features of till which distinguish it from other sediments and which permit objective comparisons between tills. It is primarily intended for field use and therefore the procedures and measurements have been kept as simple as possible. However, a field description alone is not sufficient, and consequently appropriate laboratory tests are also listed.

The methods suggested in this manual provide the basic data about till required by all disciplines. Widespread use of these methods will eventually permit critical comparisons and a more precise definition and classification of till.

DEFINITION OF TILL

Till is here defined as a sediment of diverse texture and structure deposited by direct glacier action. Because till is "fragmentary or such that some individual particles may be readily separated by agitation in water of a dried sample" (Natl. Res. Council, 1955) it forms part of a wide variety of materials commonly referred to as "soil" by engineers (Peck et al., 1957). However, not all tills are classified as soils by engineers. Very compact and cohesive tills are commonly referred to as hardpans or, more rarely, as tillites (Am. Geol. Inst., 1960). From the standpoint of their physical properties such materials have the characteristics of rock.

The definition includes stratified material incorporated within till but excludes deposits derived primarily from glacial meltwater. No sharp distinction exists between till and stratified drift which may intergrade in some localities. Where such intergradation exists it is suggested that the general term 'glacial drift' be applied (Flint, 1957).

PARAMETERS THAT CHARACTERIZE TILL

The most outstanding characteristic of till is its lithologic and physical heterogeneity. It may be cohesive and compact or loose and friable depending upon its texture, mineral composition and post-depositional history. However, it is characteristically compact, poorly sorted, and unstratified. Detailed investigation has shown some order in till despite its generally heterogeneous nature. Thus Dreimanis and Vagners (1965), who studied the till-bedrock lithologic relationship in the Great Lakes region, found that frequency distribution of particle sizes in till was bimodal near each bedrock source, and that the mode of the finer particle sizes tended to become predominant farther away from the source.

Project 620325
Manuscript received 6 December 1968.

STUDY OF TILL

Field and laboratory examinations are required to evaluate the essential features of till because some are a function of the mass of the material in situ whereas others pertain to its component parts.

The following chart lists the field and laboratory observations and measurements which must be made for an adequate description of till.

	FIELD (See Fig. 1, Appendix)	LABORATORY (See Fig. 2, Appendix)
Location Factors	Location	
	Physiographic setting	
	Outcrop description	
	Stratigraphic relations	
'primary' parameters	Grain-size distribution (coarse)	Grain-size distribution (fine)
	Shape of clasts	
	Fabric of clasts >4mm	Fabric of clasts <2mm
	Lithology + mineralogy >4mm	Mineralogy <4mm (includes clay minerals, heavy minerals, trace elements and calcite/dolomite ratio)
	Structures (fissility, joints, slip surfaces, etc.)	
'secondary' parameters	Weathering (oxidation + leaching)	
	Colour (Munsell notation)	
	Dilute HCl reaction	
	Unconfined compressive strength + compactness (penetrometer)	
		Atterberg limits
		Plasticity Index and Activity
		Dry density
		Porosity and void ratio
	Seismic velocity	
		Permeability
		pH

Field Studies

Field description of a till should begin with its geographical location and physiographic setting. Its occurrence as a component of a landform or stratigraphic unit must be clearly recorded as well as its relationship to associated sediments. In the case of a large outcrop it is important to record the dimensions, form and structure of the till and of other exposed materials.

Properties of till that are best determined in the field are distribution, shape, orientation and lithology of particles larger than 4 mm in diameter; structure, depth of weathering and leaching; assessment of compactness; and seismic velocity.

Grain-size analysis of the coarse fraction of till can be accomplished by determining the number per cent of pebbles, cobbles, and boulders present on a representative till face. The Wentworth classification (Wentworth, 1922), is used with the lower limit of pebbles, cobbles, and boulders at 4, 64, and 256 mm, respectively. A minimum of 100 particles larger than 4 mm in diameter are collected from an exposed face which has been selected as containing a representative distribution of coarse particles. The particles are then separated into the three grade classes with the aid of a simple measuring device consisting of a sheet of metal containing holes of 4 mm, 64 mm, and 256 mm in diameter. Particles that will not pass through the 4 mm opening but pass through the 64 mm opening are classed as pebbles; the classification of the larger particles is accomplished by a similar procedure. A histogram based on number per cent is then prepared from a count of the particles in each grade size. The approximate volume per cent of coarse fragments in a till exposure can be quickly determined by using comparison charts for visual estimation of percentage composition (Terry and Chilingar, 1958, see Appendix, Fig. 3).

A lithologic count of the pebbles, cobbles and boulders should accompany the grain-size analysis of the coarse fraction of the till.

In the usual method of analysis, till fabric is determined by measuring the orientation and the plunge of one hundred pebbles and plotting on a polar equal-area net (Harrison, 1957, see Appendix, Fig. 4). Ideally the ratio of length to width of the pebbles should be at least 2 to 1 and the general axial ratios of the pebbles should be recorded.

Alternatively, till fabric can be determined for particles 4 mm in length by collecting an oriented sample in the field and measuring particle orientation in the laboratory. The simple method suggested below has been found effective. A horizontal till surface is cleaned and a tin can (10 x 6 cm), open at one end, is pushed vertically into the till until the closed end is even with the surface. Absolute orientation is indicated by scratching a north arrow on the closed end of the can and by notches on the rim of the can. The tin can is then dug out. In the laboratory the tin cover is removed and the orientation of elongated particles is studied under a binocular microscope as the till is extruded from its container. Particle orientation is measured with a protractor mounted in the microscope eyepiece.

The plunge of pebbles or coarse particles is an important aspect of fabric analyses as it may indicate direction of ice movement. Data pertaining to orientation and plunge can be shown on the polar equal-area net (Harrison, 1957, see Appendix, Fig. 4).

The amount and depth of weathering are important criteria and may be determined by noting the colour differences and the dilute HCl reactions between the weathered and unweathered portions of the till.

Compactness is the degree to which the particles are packed together. It embodies concepts of cohesion, consolidation, shear strength and, because of the range in grain size of till, also relative density and consistency. In engineering usage, the latter two concepts are applied to sands and clays respectively. The pocket penetrometer provides a simple means of estimating the compactness of till through which a large number of readings on the compressive strength of the material can be made quickly and the average value retained as typical of the particular unit being studied. Penetrometer readings should be obtained from a fresh exposure of till and care should be taken to avoid striking particles larger than the penetrometer head.

Another indication of the compactness of till is given by its seismic velocity which is determined with portable equipment using a hammer impact as the energy impulse (Fahnestock, 1961). The seismic velocity is probably directly proportional to the compactness of till but sufficient data upon which to base an empirical relationship are presently unavailable.

Bulk density measurements, in which the weight of a known volume of material is determined, provide another indication of compactness. The volume of the sample to be weighed is best measured by the use of commercially available volumetric apparatus such as the "Volumeasure" CN-980 available from Soiltest Incorporated.

Laboratory Studies

Laboratory studies are directed toward analysis of the fine fraction or matrix of till. Grain-size analysis of the till matrix should follow a standard method to permit meaningful comparison of samples. Approximately 50 grams of till are required for this purpose; a 1,000 gram sample (2 lb.) is sufficient for the grain-size analysis and other laboratory tests listed on the Till Laboratory Data Sheet (see Appendix, Fig. 2). Plotting of the grain-size data as a cumulative curve on arithmetic probability paper as shown on Figure 5 (see Appendix) permits comparison of different tills either by visual comparison of the curves or by determination of sorting coefficients, frequency distribution, grain-size fraction ratios, or other comparative measures (Folk, 1966). The weight per cent scale on the left of the graph (Fig. 5) permits recalculation of the data in the form of a histogram (Washburn et al., 1963).

Several grain-size classification systems are in use. In North America pedologists generally use the U.S. Bureau of Soils system (U.S. Dept. Agr., 1951), whereas geologists commonly use the Wentworth or modified Wentworth system (Wentworth, 1922). Because of the differences between these systems, care should be taken to record the classification system being used when referring to grade sizes by name, particularly in the case of material finer than 0.25 mm.

Grain-Size Classifications

U.S. Bureau of Soil	(mm)	Wentworth (mm)	
Medium gravel	10-4	64-4	Pebbles
Fine gravel	4.0-2.0	4.0-2.0	Granules
Very coarse sand	2.0-1.0	2.0-1.0	Very coarse sand
Coarse sand	1.0-0.5	1.0-0.5	Coarse sand
Medium sand	0.5-0.25	0.5-0.25	Medium sand
Fine sand	0.25-0.10	0.25-0.125	Fine sand
Very fine sand	0.10-0.05	0.125-0.062	Very fine sand
Silt	0.05-0.002	0.06-0.0039	Silt
Clay	<0.002	<0.0039	Clay

The mineralogical composition of a till is, of course, an important parameter. For routine studies the light and heavy minerals should be identified in the fine sand fraction (<.250mm>.125mm) and results presented in the form of tables, histograms or frequency curves. Trace elements may be of potential economic interest (Bayrock and Pawluk, 1967), but their identification requires complex laboratory techniques. Determination of carbonate content in the fine fraction of tills is performed on a routine basis by the Chittick method in many laboratories. This test involves the fraction <.200mm.

The clay-sized fraction of till, although it may be quantitatively minor, exerts a strong influence on such properties as plasticity, permeability, moisture retention and shear strength. X-ray analysis of the clay-sized fraction is desirable but requires special equipment. An indication of the mineralogical composition of the clay fraction can be obtained from the Plasticity Index (Lambe,1951) and the Activity (Skempton, 1953) in which the Plasticity Index and clay-sized fraction are related. If the clay-sized fraction is composed mainly of non-clay minerals or kaolin, both Plasticity Index and Activity will have low values. On the other hand presence of montmorillonite or other expanding lattice clay minerals will tend to produce values for the Plasticity Index higher than 30 and values of Activity greater than 1.5.

The till under study can be further defined by determining its compactness ratio. Compactness ratio is the ratio between bulk density and void ratio. As mentioned under field studies, bulk density measurements are relatively simple to carry out. The computation of void ratio is more complicated because it is normally based on the specific gravity of the sample and this involves complicated laboratory manipulation. However, satisfactory results can be obtained by measuring porosity by liquid displacement techniques, and using the formula:

$$n = \frac{Vp}{Vt} \ (100)$$

where n equals porosity, Vp equals volume of pore space and, Vt equals total volume of the sample.

Vp can be determined by subtracting the volumes of the solids Vs from the total volume. This merely involves measuring the volume of liquid displaced in a graduated cylinder by the addition of a known volume of a dried sample which gives the volume of solids, Vs.

$$\text{Thus } n = \frac{Vt - Vs}{Vt} \ (100)$$

Porosity can then be converted to void ratio by the formula

$$e = \frac{n}{1 - n}$$

where e equals void ratio, and n equals porosity.

Admittedly liquid displacement techniques contain built-in errors such as the additional absorption of water by hydrous minerals. However, in spite of these possible errors, the accuracy is suitable for the purpose of calculating compactness ratio.

Calculations based on void ratio and bulk density measurements indicate compactness ratios consistently higher for till than for glaciomarine drift. It thus seems likely that compactness ratio will prove a useful parameter to quantitatively differentiate till from other types of glacial sediments (Easterbrook, 1964).

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APPENDIX

(1) Sample No.

(2) Location: N. T. S. Map Sheet
Lat. Long.
Other

(3) Surface elevation

(4) Depth below surface

(5) Collector

(6) Date

(7) Sampling Method
(Test pit, auger, spoon, tube etc.)

(8) Map Unit

(9) Morphological Expression
(End moraine, drumlin etc.)

(10) Color
(Munsell Chart)

(11) Dilute HCl reaction
Depth of Leaching

(12) Percentage of coarse fragment (visual estimation using chart)

(13) Compactness:
a) Seismic Velocity Ft./sec.
b) Bulk Density Lb./ft.^{3}
c) Penetrometer Tons/ft.^{2}
(Avg. of 25 readings)

(14) Structure:
(Horizontal platiness, fractures etc.; Record attitude and spacing)

(15) Secondary features:
(Mineralization in fractures e.g. gypsum, carbonate cementation)

(16) Natural Stable Slopes:
Horizontal Component Hc ft.
Vertical Component Vc ft.
Slope ratio $= \frac{Hc}{Vc}$, i.e. 2:1

(17) Remarks: e.g. Use of material for construction purposes, type of earth moving equipment used, agricultural use of soils, drainage characteristics, underlying bedrock lithology, presence of permafrost.

Figure 1: Till field data sheet

Analysis of Till Matrix

(1) Moisture Content $W\% = \frac{\text{Wt. water evaporated}}{\text{Wt. oven dried (110°C) soil}} \times 100 =$ %

(2) Atterberg Limits Lw = % Pw = %

(3) Plasticity Index P.I. = Lw - Pw =

(4) Activity = $\frac{\text{P.I.}}{\% < 2u}$ =

<0.75 inactive
0.75 - 1.25 normal
>1.25 active

(5) Mineralogy (specify fractions and methods used):
- -Light minerals,
- -Heavy minerals,
- -Clay minerals,
- -Trace elements,

(6) Carbonate Content

Bulk density $d_b = \frac{Wt}{Vt}$ Compactness Ratio

(7) Compactness: $Cr = \frac{d_b}{e}$

Void ratio $e = \frac{n}{1-n}$

(8) Other Specify and List Results.

Figure 2: Till laboratory data sheet

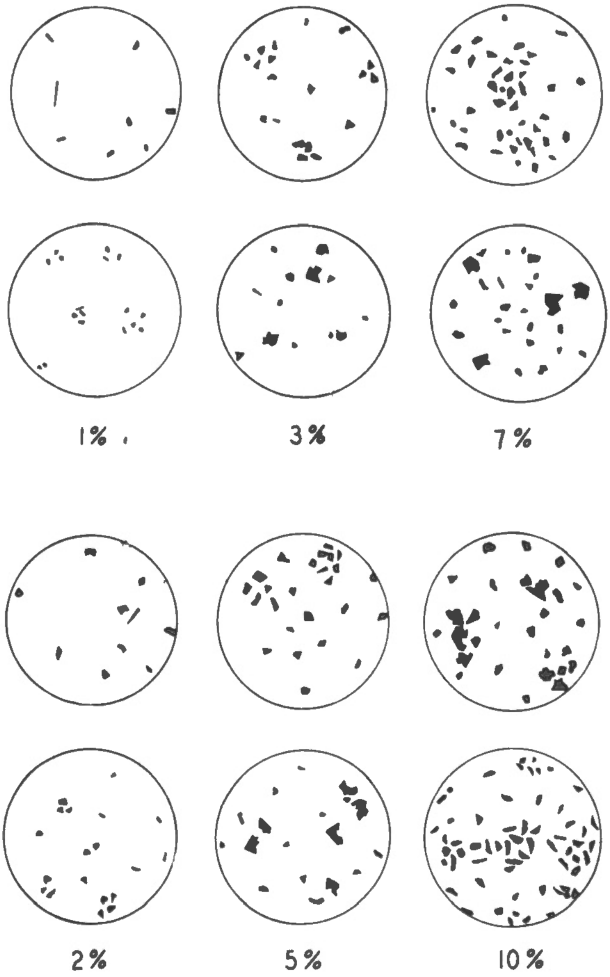
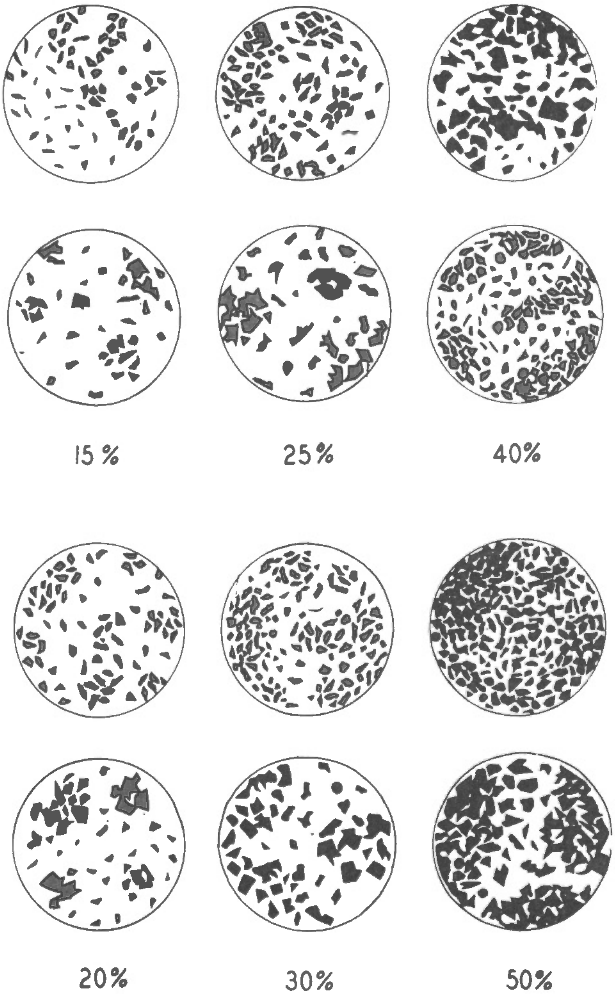


Figure 3. Comparison charts for visual estimation of percentage composition.



Prepared by Richard D. Terry and George V. Chilingar,
Allen Hancock Foundation, Los Angeles, Calif.
Reprinted from Jour. Sed. Petrol., vol. 25, No. 3,
pp. 229-234, Sept. 1955.

TILL FABRIC PROJECT

Station ____________ Date ____________ Personnel ____________

No. of stones: ________

Location:

Depth below ground surface: ______

Surface slope:

Direction: ______

Amount: ______

Stone shape restrictions:

Description of till:

Remarks:

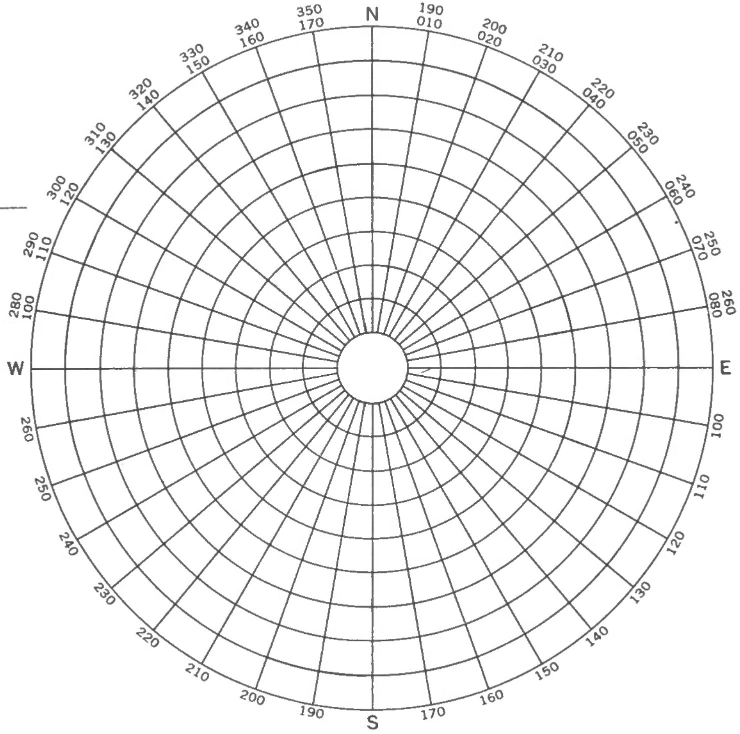


Figure 4. Fabric analysis data sheet

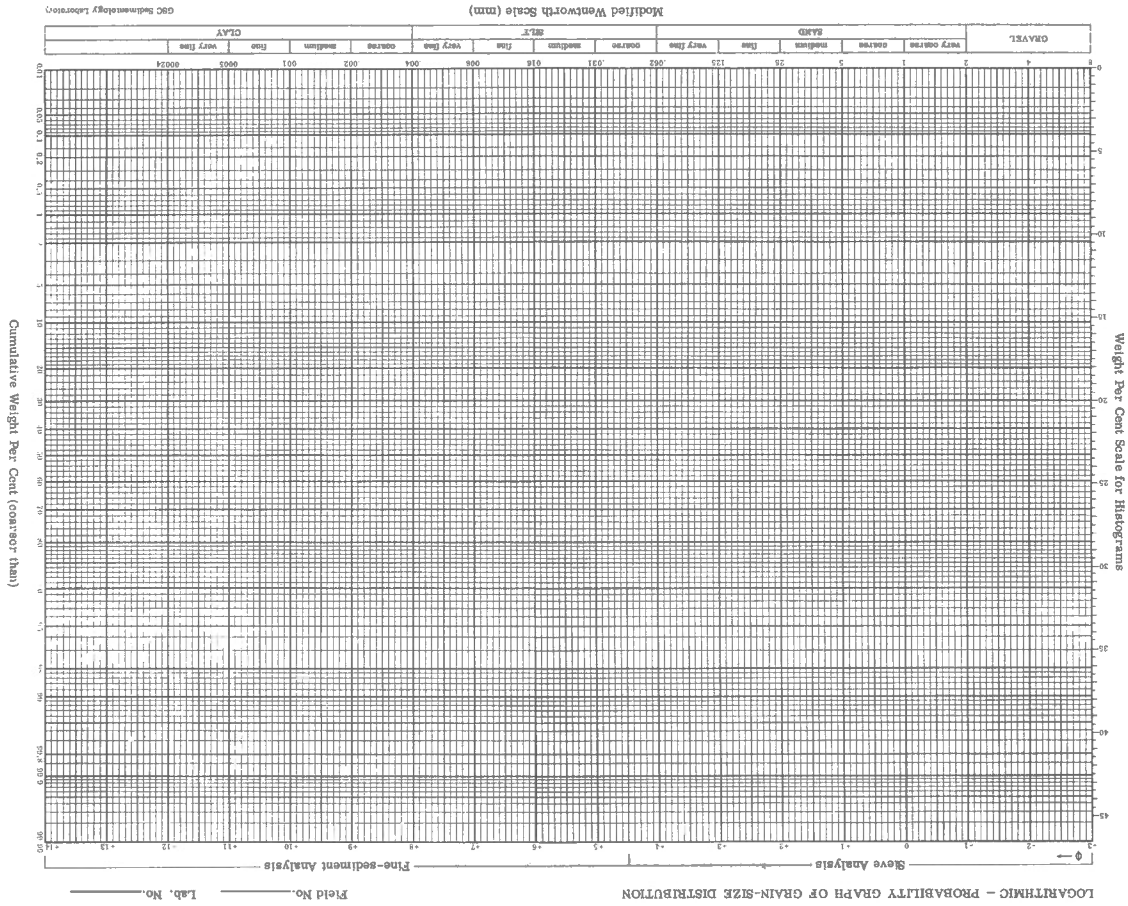


Figure 5. Cumulative grain size analysis data sheet.