Applications of surficial mapping to forest management in New Brunswick

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Joint investigations of the Geological Surveys (G.S.B.) and Timber Management (T.M.B.) branches of the New Brunswick Department of Natural Resources and Energy during the past ten years have demonstrated a well-defined relationship between forest productivity for different species with several geologic and climatic parameters. A method referred to as regolith mapping developed by the G.S.B. has enabled the T.M.B. to evaluate these geologic parameters in forest productivity. The growth curves for certain tree species on soils that formed on different regolith systems are discussed. The results of this work have been incorporated in long-term forest management plans.

Les études conjointes menées par les divisions des études géologiques et de l'aménagement du bois du Ministère des Ressources Naturelles et de l'Énergie du Nouveau-Brunswick durant les dix dernières années ont montré une relation bien définie entre la productivité forestière de différentes espèces et plusieurs paramètres géologiques et climatiques. Une méthode, appelée la cartographie du régolite et développée par la division des études géologiques, a permis à la division de l'aménagement du bois d'évaluer les paramètres géologiques reliés à la productivité forestière. Les courbes de croissance de certaines espèces d'arbres poussant sur des sols développés sur différents régolites sont discutées. Les résultats de cette étude ont été incorporés dans les plans de gestion forestière à long terme.
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Introduction

Till covers 90% of New Brunswick, whereas the remaining 10% represents residual regolith or bare rock. Growth rates on various tills are thus of special interest for forest management. The effect of bedrock and overlying regolith on forest productivity was the subject of a pilot study carried out by van Groenewoud and Ruitenberg (1982). In this study height and volume growth of black spruce plantations on different regolith systems was compared for areas of similar exposure and slope. A regolith system is the combination of *in situ* bedrock and residual or transported surficial materials that form the surface blanket of unconsolidated material that determines the nutrient potential and textural characteristics of the soil. One recommendation of the pilot study (van Groenewoud and Ruitenberg, 1982) was the extension from plantations to natural stands. Subsequently the T.M.B. set out to develop a forest site classification system for the entire province as support for long term supply/harvest forecasting.

During the development stages of the forest site classification system the provincial Geological Survey Branch was carrying out a regolith mapping project in the northern Miramichi Highlands/Chaleur Uplands. Outputs of this project included detailed regolith maps at a scale of 1:50,000. Several of the map areas overlapped the Northern Uplands and the Upsalquitch site classification regions of the T.M.B. Field checks of regolith units were conducted by personnel of both branches.

This paper outlines the methodology, the underlying principles, and the potential implications of the New Brunswick Forest Site Classification System.

The New Brunswick Forest Site Classification System

The first level in the system is the Climatic Region: a region having a distinctive climate delineated by multivariate statistical analysis of meteorological data. The amount of rainfall, sunshine, number of frost days, etc., are of extreme importance for forest productivity. The second, third, and indirectly, the fourth level, all reflect geology (Table 1). The second level, the Geomorphologic District, is the surface expression of a major bedrock formation or group. This parameter provides first order control on the drainage, topography, mesoclimate and nutrient supply. The Regolith System is the third level, and determines the landform (till, outwash, residual bedrock ridges, etc.) and the lithologic/

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Table 1. Levels of a proposed site classification system (after van Groenewoud and Ruitenberg, 1982).

Unit	Description	Remarks
1. Climatic Region	A region having a distinctive climate delineated by multi-variate statistical analysis of meteorological data.	These parameters constitute a broad control on forest growth and form the framework for meso- and microclimatic description.
2. Geomorphologic District	The surface expression of a major bedrock formation or group, modified by glaciation and fluvial erosion.	These parameters provide the first-order controls on drainage, topography, mesoclimate and nutrient supply.
3. Regolith System	a) Form and texture of landforms such as lodgement till, ablation till outwash, alluvial deposits etc. b) Lithologic-mineralogic composition (including percentage of material derived from different rock units and their secondary products) and structure (cleavage and fracturing) of the regolith material.	These parameters greatly affect drainage and limit nutrient availability within the regolith
4. Site Type	a) Soil profile characteristics b) Microdrainage c) Slope d) Position on slope e) Aspect f) Microclimate etc.	All of these parameters influence soil chemistry and/or soil physical properties and/or local climate, and hence influence forest growth at the individual tree and stand level.

mineralogical composition and structure of the material. These all greatly affect the nutrient availability and the soil texture. The last level is the Site Type, and includes soil profile characteristics, microdrainage, position on slope, aspect, and microclimate. The combination of these parameters determines the soil chemistry and soil physical properties that influence tree growth at the site and stand level. These may determine the timing of thinning, variability in root growth, and the need for enhancing soil texture or fertility. Some of the physical properties may also result in site constraints, such as the effect of bouldery ablation till on planting, thinning or harvesting equipment.

Height growth/year does not neccessarily reflect marketable volume. In natural stands the site index, i.e., the height growth of free-growing dominant individuals at a specified age (in this case 50 years at breast height) is the preferred productivity measure. Height growth is easily measured and it is relatively unaffected by density. In contrast density is not easily measured. But in terms of forest ecology the treatment units described below closely approximate a site's productive capacity (Collin Bowlin, oral communication, 1989).

NUTRIENT PROPERTIES OF COMMON ROCK TYPES

The production of plant nutrients from a particular rock type is a complex interaction between weatherability of the rock (how fast or slow a rock will break down to release nutrients) and chemical composition of the rock (inherent fertility).

The major plant nutrients are K, Ca, Mg, P, which are also major rock forming elements. All felsic rock types are high in potassium and low in calcium and magnesium, whereas the mafic and ultramafic rocks are high in calcium and magnesium and low in potassium. Rocks throughout the felsic-mafic range all have similar phosphorous concentrations. Sedimentary rocks are comprised of components of above mentioned rocks and thus have a wide range of plant nutrient concentrations. Silicious sandstones or quartzites are generally poor nutrient sources. Arkosic ones are somewhat richer because they contain more feldspar and micas. Greywackes and mudstones contain a great variety of plant nutrient-bearing minerals and they have a relatively large percentage of fine-grained matrix.

Fine-grained rocks generally leach more readily, and produce fine-grained soils that have better water holding capacity, and a higher cation exchange capacity (CEC) depending on the clay mineralogy. Tills comprised of calcareous and mafic rocks generally support soils with higher pH, which in turn promotes higher nutrient turnover rates and tree growth. Some structural characteristics such as cleavage also affect weatherability and leachability of rocks (see also Fig. 1), because the surface area subject to leaching is greater than in non-foliated rocks.

Most soil parent materials in New Brunswick are surficial deposits composed of more than one rocktype. The source and depositional history of the surficial deposit determine the nutrient content, soil texture and landform (drainage, slope, etc.). The different genetic till types, and other glacigenic deposits have very distinct textural characteristics and lithologic compositions.

Nutrient potential and soil moisture conditions, in combination with vegetation types, divide forest stands into treatment units (Fig. 2), which require certain treatments at specific times, and will likely produce the forecasted volume of marketable wood. Each treatment unit (TU) is characterized by soil moisture conditions (dry, dry-moderate, moderate, wet), soil nutrient potential (very poor, poor, moderately poor, moderately rich, rich, very rich), and cover type (pine dominated softwood, mixed softwood, cedar dominated softwood, shade intolerant species mixed wood, shade tolerant species mixed wood). Each of these TU's also has predicted site conditions in relation to site preparation and erosion, compaction, and frost heave hazards. The method is quantified by the arbitrary assignment of points to site parameters. These include, slope, forest floor thickness, texture, soil drainage, constricting layer and surface stoniness, which have different qualifying points. Points from all different characteristics will be added to obtain a trafficability index. Thus a TU will have indexes for trafficability and site regeneration, which includes species selection, competition, and soil preparation measures (e.g., scarification).

SURFICIAL MAPPING AND REGOLITH SYSTEMS

The New Brunswick Geological Survey Branch initiated a surficial mapping project under the Canada-New Brunswick Mineral Development Agreement (MDA) in 1985. Outputs of this project include 1:50,000 regolith maps with information on landforms and lithological composition of the surficial deposits (Pronk, 1986, 1987; Pronk and Parkhill, 1988). Some of the surficial units correspond to Geological

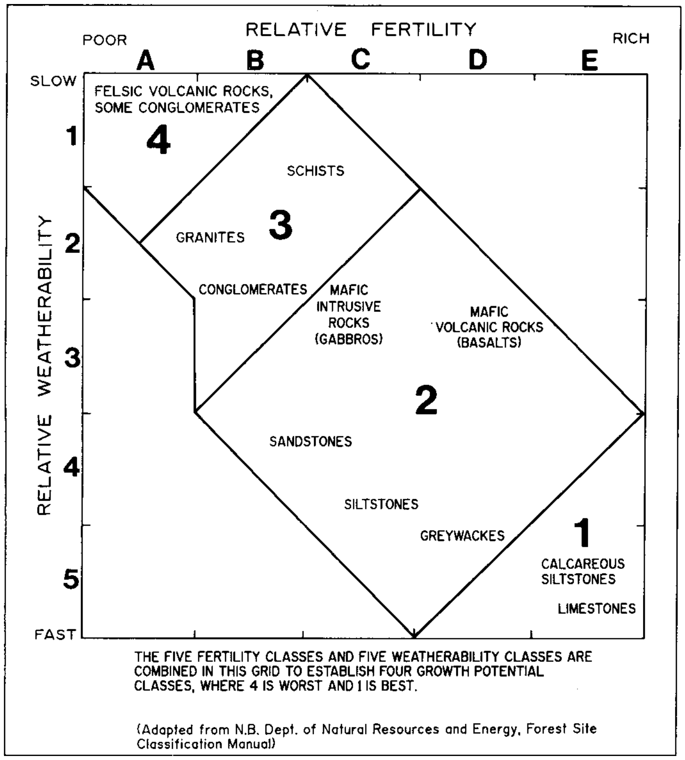

Fig. 1. Simplified quality rating grid for regolith systems. All major rock groups and formations are placed within this grid and given a quality rating, 1 is best, 4 is worst (Timber Management Branch, 1985).

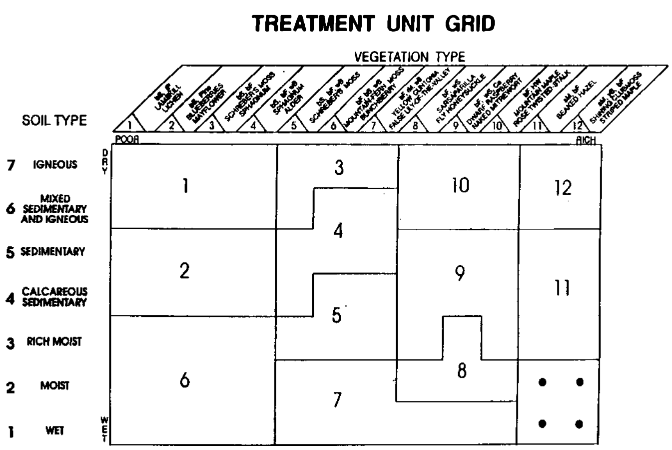

Fig. 2. The quality rating grid of Figure 1 is replaced by a Treatment Unit grid in each site classification region. Each site region has keys to determine both soil type and vegetation type. Soil type is largely determined by geology and drainage. This example is from the Upsalquitch Site Region.

Districts of the pilot project for the province wide site classification, which was being evaluated in the survey area. Nutrient availability and site characteristics such as soil moisture retention are clearly reflected in the height growth curves (Fig. 3a, b, c).

Typical height growth curves for three regolith systems characterized respectively by Benjamin Formation volcanic rocks, Tetagouche Group metabasalts and Tetagouche Group quartz-feldspar schist are compared in Figure 3a. The Benjamin Formation consists of mostly felsic volcanic rocks, but is closely associated with mafic volcanic and sedimentary rocks of Late Silurian age. Its growth curve matches the one for the metamorphosed basalts of the Tetagouche Group. The growth curve of fir on the quartz-feldspar schist regolith of the Tetagouche Group shows lower productivity reflecting nutrient poor conditions.

Height growth curves for black spruce on regolith systems characterized by Matapedia, Benjamin and Northpole formations show similar growth for the first two, but extremely delayed growth for the last (Fig. 3b). This delayed "take-off" is probably due to lower water holding capacity of soils on the coarse-grained granite. As a result deeper rooting hardwoods compete favorably with shallower rooting black spruce. After rooting depth has been established (about 30 years), growth rates are similar to those on the other two regolith systems. Van Groenewoud (oral communication, 1985) found that Northpole regolith systems in the Trousers Lake area (Fyffe and Pronk, 1985) showed highly increased growth rates when small percentages of mafic intrusive and/or sedimentary rocks were present. The early growth is made possible by higher nutrient availability and water holding capacity, which shorten the "release" time. Soil preparation and seedling care could counter the type of delayed growth on granitic till exhibited in Figure 3b.

Although Benjamin and Matapedia Formation materials (see Fig. 1) are on the opposite ends of the quality rating diagram, growth curves for black spruce on tills characterized by these lithologies are very similar. This may reflect the fact that hardwoods continually suppress the growth of softwoods on soils developed on regolith composed of Matapedia Formation rocks. On Benjamin sites black spruce will be the dominant species, whereas on Matapedia black spruce is not dominant in natural stands.

Balsam fir on Benjamin regolith systems invariably outgrows black spruce (Fig. 3c). This is quite common on most regolith systems, except the nutrient poor ones. One of the reasons for planting black spruce instead of balsam fir is the high susceptibility of balsam fir to spruce budworm damage. The budworm favors balsam fir needles.

These curves are replaced in the fieldguides for the New Brunswick Forest Site Classification System by volume growth curves that reflect the underlying bedrock and surficial geology. The specific vegetation/soil units that make up the TU's (Fig. 2) and have a specific volume growth curve, are indeed determined largely by soil parent material. This relationship is not so obvious as in the more basic curves used in this study. For a more detailed description of the TU deriviation from regolith units see Bowling and Zelazny (1991).

Summary and Conclusions

The surface expression of major bedrock formations and groups, modified by glaciation and fluvial erosion, provide

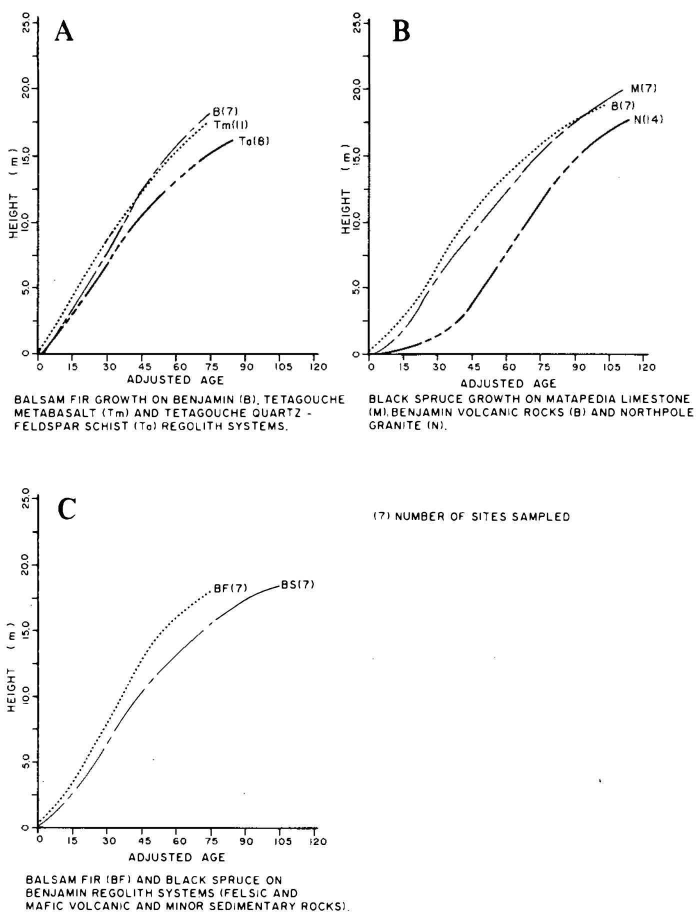

Fig. 3. Growth curves for different species on several of the mapped regolith units in the Upsalquitch and Northern Uplands site regions.

first order controls on drainage topography and mesoclimate. The lithologic composition, texture and structure of regolith overlying the bedrock greatly affect drainage, and set limits on nutrient supply. Surficial maps that delineate the geological parameters affecting forest productivity are therefore essential in efficient forest management. These maps can also be used to delineate areas with high potential for agriculture.

Chemical analyses of soils, rocks and plants cannot explain all relations between growth and parent materials. The logical next step is to examine the mineralogy of soil parent materials and their secondary products.

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