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GEOLOGIC VARIABLES ASSOCIATED WITH HEIGHT OF YELLOW-POPLAR STANDS IN THE BALD MOUNTAINS OF NORTH CAROLINA

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Abstract: Quartz grain size and mylonitization, geologic variables determined from rocks on sites, were associated with total height of yellow-poplar (*Liriodendron tulipifera* L.) stands and may be of value as independent variables in modeling tree growth from site characteristics. A predictive model containing quartz grain size and stand age accounted for about 54% of the variation in total height of yellow-poplar stands in the Bald Mountains of western North Carolina. These and other geologic variables may also be of value in classifying forest sites for species composition and productivity.

Key Words: geologic variables; mylonitization; quartz grain size; ***Liriodendron tulipifera;*** yellow-poplar; tree height growth.

INTRODUCTION

Geologic variables have sometimes been included in models for predicting tree growth from measurable characteristics of forest sites. Based on studies in British Columbia, Warren and Matheson (1949) reported that productivity was higher for forests on sites over sedimentary rock than on those over igneous rock. Geology is entered at the upper levels in hierarchical site classification schemes for the interior South (Smalley, 1984) and the Southern Appalachians (McNab, 1987). In addition, the species composition of forest stands has been related to geologic formations (Hack and Goodlet, 1960; Leak; 1978; and Rohrer, 1983).

The reasons for links between geologic variables and forest site productivity are not well understood. In many cases, the association appears to be indirect through the soils that have formed from the rock formations. Several studies have shown an advantage from stratifying soils by geologic parent material (Graves and Monk, 1985; Yawney, 1964). Soil series alone is not sufficient to predict growth of black oak ***Quercus velutina*** Lam. (Carmean, 196 1) and yellow-poplar ***Liriodendron tulipifera*** L. (Van Lear and Hosner, 1967). Physical characteristics of soils, such as texture and depth, are typically found to be more significant to forest growth than the taxonomic series (Mowbray and Oosting, 1968).

Direct relationships between geologic variables and forest site productivity are useful supplements to soils maps which are often less than adequate in forested areas. They also may be useful in evaluating forest productivity over broad areas.

The study described here was designed to determine how much of the variation in forest site quality could be accounted for by geologic variables in a small portion of the Southern Appalachians. This study is part of a larger effort to explain variations in site productivity in the mountains.

THE STUDY AREA

Forest stands were studied along a 48 km section of the Bald Mountains in the Blue Ridge physiographic province of western North Carolina about 40 km northwest of Asheville (Fig. 1). The region's climate is relatively uniform and may be characterized as humid-temperate with short mild winters and long warm summers. Weather records for Hot Springs, the nearest weather station (elevation 406 m) and about centrally located in the study area, show a mean annual temperature of 13.7°C, a mean daily August maximum of 25.5°C, and a mean January daily minimum of 2.9°C. Mean annual precipitation is about 114 cm of which about 60% occurs during the growing season. February is the wettest month; the driest is September.

Forest vegetation on mesic sites in the Bald Mountains is typical for the Southern Appalachian region and is strongly affected by topography. Our study was restricted to moist sites where yellow-poplar predominates. Besides yellow-poplar, other common deciduous overstory species include sweet birch *Betula lenta* L., northern red oak *Quercus rubra* L., and black locust *Robinia pseudoacacia* L., Red maple *Acer rubrum* L., flowering dogwood *Cornus florida* L., and sourwood *Oxydendrum arboreum* (L.) DC. formed a large proportion of understory tree species. Two coniferous species, eastern hemlock *Tsuga canadensis* (L.) Carr. and eastern white pine *Pinus strobus* L., are occasionally found in the understory. *Rhododendron maximum* L. is the principal shrub species, particularly near streams.

Rock units in this region have not been thoroughly studied. The Bald Mountain region is underlain by metamorphic rocks of igneous and sedimentary origin. Small-scale geologic mapping (North Carolina Geological Survey, 1985) indicates that the region consists of metagranites and gneisses of the Middle Proterozoic Era and metasedimentary rock units in the Ocoee Supergroup of the Late Proterozoic Era (approximately 600 million years old). Several thrust faults are present in the region, but the contact between the metamorphosed igneous and sedimentary rocks is variable and often difficult to distinguish, especially where the local area has been deformed. Oriel (1950) and others have intensively studied the geology of the Hot Springs window, a 140 km² area consisting of four different thrust faults and a number of thermal springs. We selected the Bald Mountains for study because of the great variety of rock types occurring within a relatively small area.

METHODS

Field Sampling

Field plot location depended on presence of suitable stands of yellow-poplar, a particularly site-sensitive species, and not on geologic parameters. Sixty 0.62 ha plots were located in even-aged stands with no sign of recent disturbance and with yellow-poplar comprising over half of the overstory. The preferred range in stand age was between 35 and 75 years, which includes the physiological period

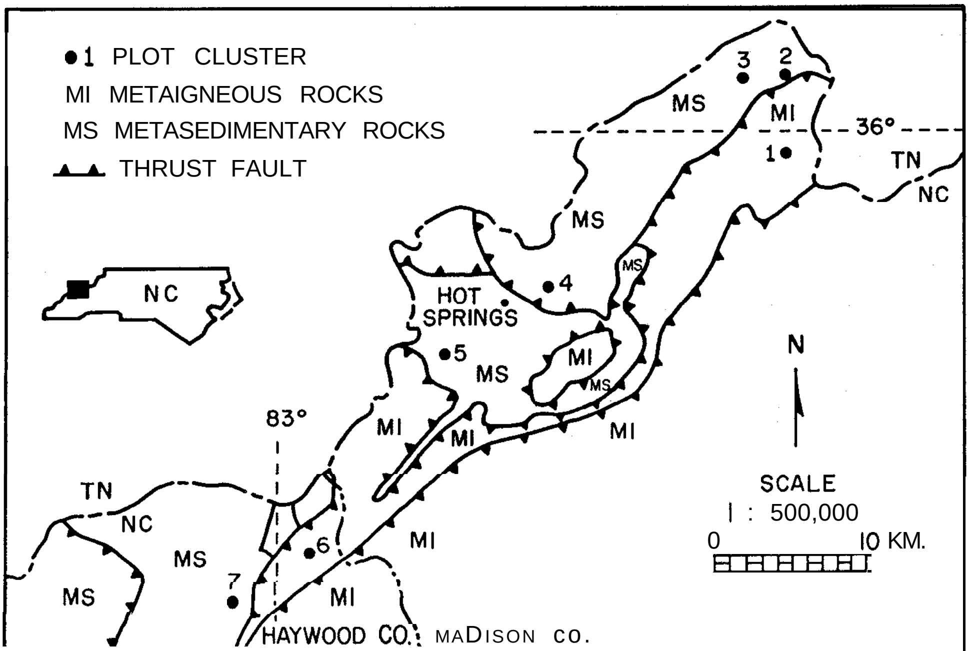

FIG. 1. Location of seven study sites in the Bald Mountains of the Unaka Range in Haywood and Madison Counties, NC (NC Geological Survey, 1985).

of relatively rapid height growth. From three to five dominant or codominant yellow-poplar trees were sampled on each plot to determine average age and average total height. Forest site quality was expressed as the mean total height of the dominant and codominant yellow-poplars on the plot.

From 5 to 10 plots were clustered at each of 7 sample locations. Plots within a cluster were generally within 100 m of one another. Stands were sampled over a broad range of topographic conditions: elevations from 549 to 1,158 m, aspects from 6 to 359" azimuth, and slope gradients from 9 to 66%. About 53% of the 60 stands were in cove landforms and 82% were on mesic, north-facing slopes. The few stands on southerly, more xeric, aspects were on colluvium on lower footslopes. Available soil mapping (Goldston et al., 1942 and 1954) for Madison and Haywood Counties shows most sites consisting of rough stony land, typically in the Porters or Ransey series. Soils data were not collected for this study, but al1 sites were on colluvium.

Rock types underlying the plots were determined through examination and extrapolation from existing geologic maps and by field investigations of the plots. Al1 sites were underlain by crystalline metamorphic rocks derived from either originally igneous or originally sedimentar-y rocks. The following rock types were observed at the sample sites: feldspathic granule metaconglomerate, feldspathic metasandstone, quartzose sandstone, metasiltstone, metashale, metagranite, biotite granite, and granodiorite. More than one rock type occurred at most sites because the various rock types are commonly interlayered. Rocks were classified based on the following mineralogical and physical geologic parameters and corresponding qualitative field estimates:

Table 1

Geologic characteristics of metamorphosed rock groups occurring on plots sampled in the Bald Mountains of Haywood and Madison Counties, NC.

Rock Group	Rock Class	Feldspar Content	Quartz Grain Size	Mica Content	Mylonitic
I	Metaigneous	High	Medium	Some	No
II	Metaigneous	High	Fine	Some	Yes
III	Metasedimentary	Low	Fine-to-medium	None	No
IV	Metasedimentary	Moderate	Coarse	None	No
V	Metasedimentary	Low	Very fine	Moderate	No
VI	Metasedimentary	Moderate	Fine	None	Yes

(1) Rock class: metaigneous or metasedimentary.
(2) Feldspar content: low, moderate, or high.
(3) Quartz grain size: very fine ($\frac{1}{16}$–$\frac{1}{8}$ mm diameter), fine ($\frac{1}{8}$–$\frac{1}{4}$ mm), fine to medium ($\frac{1}{8}$–$\frac{1}{2}$ mm), medium ($\frac{1}{4}$–$\frac{1}{2}$ mm), or coarse ($\frac{1}{2}$–1 mm).
(4) Mica content: none, low, or moderate.
(5) Mylonitization: absent or present.

Each plot was then placed in one of six rock groups (Table 1). It is important to note that these parameters are typically used by geologists to characterize rocks during routine field observation. This information is also usually included in published geologic maps.

Characteristics of the tree stands associated with each rock group are shown in Table 2. Tree heights for rock groups 1 and IV were less than average partly because the mean stand ages were younger-about 47 years compared to about 59 years for the other groups. Except for groups II and VI, each rock group was represented at several sampling locations. Field plots were well distributed among rock groups, but only 11 plots (locations 6 and 7) were sampled where rocks were mylonites.

Data Analysis

Data were analyzed in two phases using multiple regression techniques. Mean stand age is included in the regressions to account for differences among sample

Table 2

Distribution of sample plots and characteristics of yellow-poplar stands by rock group in the Bald Mountains of N.C. Plot cluster location is keyed to Fig. 1.

Rock Group	Cluster Location	Plots Sampled	Stand Height Mean	Stand Height Range	Stand Age Mean	Stand Age Range
		No.	m	m	Years	Years
1	1, 6, 7	14	35.0	31.7-38.7	48	39-58
II	6	8	38.7	34.7–40.8	53	48-61
III	4, 5	13	38.4	34.7-43.3	58	44-77
IV	3, 5, 7	12	34.4	29.6-41.1	46	32-71
V	2, 4, 7	10	38.1	35.0–41.1	62	55-84
VI	7	3	38.4	36.0-41.4	62	60-65

plots and for the increase in tree size with time. All geologic variables were nonmetric and were coded as dummy variables after being simplified into two classes as follows: feldspar content (1) low and moderate or (2) high; quartz grain size (1) very fine to medium or (2) medium to coarse; mica content (1) none or (2) low to moderate. Rock class and mylonitization were measured in two categories. Homogeneity of variance in the dependent variable stand height was obtained by logarithmic transformation (base 10). The first phase involved applying the following model to stand heights (HT) for each sample plot:

$$\log HT = b_0 + b_1x_1 + b_2x_2 \qquad [1]$$

where:

b_0 = constant
b_1–b_2 = regression coefficients
x_1 = 1/tree age (years)
x_2 = geologic variable.

This analysis provides an indication of the relative usefulness of each geologic variable in accounting for variation in mean tree height.

In the second phase of the analysis all geologic variables were used in the following model:

$$\log HT = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n \qquad [2]$$

where:

b_o = constant
b_1–b_n = regression coefficients
x_1 = 1/tree age (years)
x_2–x_n = geologic parameters.

A backward elimination procedure was used to develop an appropriate model with nonsignificant independent variables removed until all remaining were significant at the alpha = 0.05 level or better. This analysis provided a quantification of the effect of the significant geologic variables on mean total height of yellow-poplar. Because model [2] was not developed with the intent of predicting tree heights, no attempt was made to validate the model and the coefficients are not presented.

RESULTS AND DISCUSSION

The relative effects of geologic variables on tree height, after the effects of tree age were removed, are presented in Table 3. Age alone accounted for about 48% of the total variation in stand height. After this source of variation was removed, only quartz grain size and mylonitization accounted for a statistically significant proportion of variation in stand height. Based on these regression relationships at the overall mean stand age of 54 years, trees growing over rocks with very fine to medium quartz grain size would average 37.9 m in height while those over medium to coarse grained rocks would be 36.0 m. Similar stands over mylonitic rocks would average 38.3 m in height and those over nonmylonitic rocks would be 36.9 m.

The most appropriate model of the logarithm of total height on the biological

Table 3
Statistical parameters for geological variables analyzed with regression model 1.

Geologic Variable	Coefficient of Determination	Error Mean Square	Coefficient of Variation
Quartz size class	0.538	0.025	1.616
Mylonitization class	0.511	0.026	1.662
Feldspar content class	0.485	0.027	1.706
Mica content class	0.482	0.027	1.712
Rock type class	0.48 1	0.027	1.714

and geologic parameters included tree age and only one geologic variable, quartz texture class. The effect of this model on tree height over time is shown in Figure 2. This equation explains about 54 percent of the variation in total height of yellow-poplar in the Bald Mountains at a mean age of 54 years. Mylonitization class was not significant in the model apparently because it explained some of the same variation accounted for by quartz texture class. Mylonitization is associated with faults and results in fine-grained laminated rocks with mineral content similar to the original rock.

Quartz texture class probably affects tree growth by influencing the moisture retention characteristics of the soil as the rock weathers (Rohrer, 1983). As the calcareous sandstones weather, leaching of carbonate compounds leaves a porous

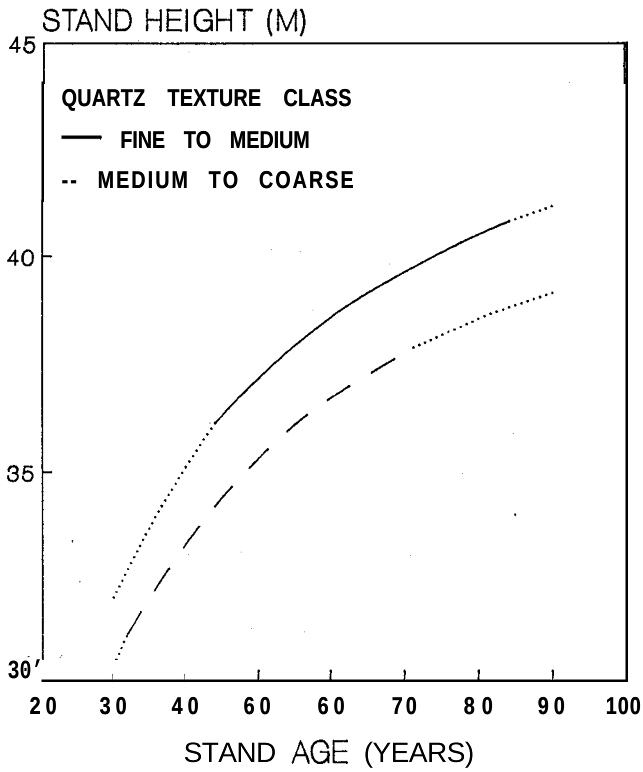

FIG. 2. Predicted yellow-poplar stand height as a function of stand age and quartz texture class. Solid lines indicate range of field data.

sandy soil. In all but highly quartzitic rocks, feldspars are gradually changed to clayey minerals resulting in a loose and porous rock.

The similar mineral composition of the rock groups may partially explain the small differences in mean total height of the tree stands. All rock types except metashale are quartzo-feldspathic in composition and differ only in the proportions of quartz and feldspar. Also adding to their mineralogic similarity is the fact that most sites had more than one rock type, one of which was quartzo-feldspathic.

In summary, results from this case study suggest that tree growth is correlated with several on-site measured geologic variables. In the absence of soil data, quartz grain size and mylonitization were significantly associated with height growth of yellow-poplar. Quartz grain size should be useful to include as an independent variable in models describing tree height growth in relation to environmental factors. More study is needed to determine if these or other variables can be obtained from detailed geologic mapping and used in predicting forest site quality.

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