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Geological substratum, herbaceous vegetation and floristic diversity of mature upland forest sites in northern New Jersey

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Summary: Data from forty stands of upland forests in northern New Jersey were used to determine the impact of geological substratum on species diversity of herbaceous plants. Ten different substrata were studied, with more than three stands available on six of the substrata. The ten geological substrata were Kittatinny Limestone (82 species per substratum), Martinsburg Shale (95), Brunswick Shale (18), Triassic Conglomerate (45), Basalt (68), Longwood Shale (25), Gneiss (Byram, Pochuk and Losee 118), High Falls Sandstone (80), Green Pond Conglomerate (19) and Shawangunk Conglomerate (37). Greatest diversity was found on Gneiss (118 species), Martinsburg Shale (95), High Falls Sandstone (80) and Kittatinny Limestone (82). Species, which are restricted to specific substrata, are discussed. These studies encompassed 171 herbaceous species.

Zusammenfassung: Es wurden Daten von über 40 Bergwald-Beständen im Norden von New Jersey verwendet, um den Einfluss von geologischen Substraten auf die Artenvielfalt von krautigen Pflanzen zu bestimmen. Zehn verschiedene Substrate wurden untersucht, dabei waren mehr als drei Bestände auf sechs Substraten verfügbar. Die 10 Substrate waren: Kittatinny Kalkstein (82 Arten pro Substrat), Martinsburg Schiefer (95), Brunswick Schiefer (18), Trias-Konglomerat (45), Basalt (68), Longwood Schiefer (25), Gneiss (Byram, Pochuk und Losee 118), High Falls Sandstein (80), Green Pond Konglomerat (19) und Shawangunk Konglomerat (37). Die höchste Vielfalt fand sich auf Gneiss (118 Arten), Martinsburg Schiefer (95), High Falls Sandstein (80) und Kittatinny Kalkstein (82). Es werden hier auch die Arten besprochen, die auf ein spezielles Substrat beschränkt sind. Diese Untersuchungen umfassen 171 unterschiedliche krautige Taxa.

Keywords: geological substrata, herbaceous vegetation, upland forest, flora of New Jersey, species diversity, distribution

When Muray F. Buell joined the Botany Department Faculty at Rutgers University, New Brunswick, in 1946, he immediately began investigations of vegetation of northern New Jersey, which was ultimately marked by the book by ROBICHAUD & BUELL (1973). However, even though DAVIDSON (1963) published the paper on continua in upland forest sites, the full impact of geological substratum on shrub and herb vegetation and floristic diversity of shrubs and herbs were never examined in full. Therefore, I felt, that even though the data are from a previous time (collected in 1959–1963), it would be fruitful to further evaluate the role of geological substratum and the herbaceous data. These studies were supported by N. S. F. Grant G-7177, and also by the Board of Regents of the University of Wisconsin System through the office of Dr. J. C. Haugland (Vice-Chancellor, U. W. S.). Support for these studies was also provided by Dr. Arthur N. Langford, Dr. Louis F. Ohmann and Dr. Helen F. Buell.

Dr. James Montgomery assisted greatly in the identification of *Carex*. Sarah Haavik, Margaret E. Nolan and Joseph Znidarsich assisted in later analysis at U. W. S. Mr. Julian Opella of the University of Minnesota computer center also assisted in data analysis. Data (important values) were computed on the basis of relative cover/dominance and relative frequency in each of the 40 stands selected.

Trees have deep roots and extend downward into the soil profiles of the forests quite deeply. The roots of herbs, however, do not extend as deeply (DAVIDSON et al. 1989), and in addition, in most of northern New Jersey areas, there is deposited a blanket of glacial debris through which tree, shrub and herbaceous plants must grow before they come into contact with the geological substrata of the ten geological formations. Therefore, extensive sampling and analysis of the under-story vegetation layers were necessary before the impact (positive or negative) of the substrata on herb growth and distribution could be ascertained.

Field methods

The field methods for the study of shrubs and herb vegetation were described in DAVIDSON (1963), and will not be elaborated here, other than to say that the stands were naturally established and free from pronounced disturbance for at least 60 years. All stands were upland and well-drained. Nomenclature follows FERNALD (1950).

Laboratory methods

Laboratory methods for the analysis of the data from the herbaceous data of the forests were described in DAVIDSON (1963). Importance values were calculated from relative cover and relative frequency of species from the field data. A total importance value (relative cover plus relative frequency) of 200 was thus obtained from every stand for herbs. Hence the figures for the herb populations are comparable from stand to stand. Relative frequency was used by DAVIDSON (1963), because relative density could not be used in the importance value computation (because of multiple stems of grasses, ferns and many of the woodland herbs), thus necessitating the need for the use of frequency. Importance values were compared for the ten substrata from 40 stands in northern New Jersey.

The species present were used to order the geological substrata from rich (Limestone) to poor (Conglomerate) by me.

Results

The 171 species of herbaceous plants identified, and shown in Table 1, were delineated on the ten substrata worked with in the study. In Table 2 the abbreviations for geological substrata from northern New Jersey are listed. Table 3 delineates the total number of forest sites for each substratum type. The average numbers of herbs per substratum are shown in Table 4. Plants restricted to specific substrates are shown in Table 5.

Because of the lack of clear-cut patterns that did not emerge from the quantitive analysis of importance values on the ten geological substrata, it was decided to examine each of the species by presence on the ten geological substrata. The total number of species per substratum is higher when based on the presence list as all species found in the quantitive survey, and those found in the presence list (found in the stand by surveying, but not in plots) gave a total of presence list and quantitive survey data of 171 species (Table 1).

Table 1: Presence of 171 herbaceous species on ten substrata in upland northern New Jersey mature forest.

Species	**Lim**	**MS**	**BS**	**TrC**	**Ba**	**LS**	**Gn**	**HF**	**GPC**	**SC**	**Total**
Actaea pachypoda Ell.	x	x		x	x		x	x			6
Adiantum pedatum L.	x				x	x	x	x			5
Agrimonia gryosepala Wallr.	x						x				2
Agrimonia striata Michx.							x				1
Agropyron repens (L.) Beauv.							x				1
Agrostis hyemalis (Walt.) BSP.		x			x		x	x			4
Amphicarpa bracteata (L.) Fern.	x	x		x	x		x	x			6
Anaphalis margaritacea C.B. Clarke								x			1
Anemone canadensis L.							x				1
Anemone quinquefolia L.	x			x			x	x			4
Anemone virginiana L.		x									1
Anemonella thalictroides (L.) Spach.	x	x			x		x	x			5
Angelica venenosa (Greenway) Fern.								x			1
Antennaria plantaginifolia (L.) Hook.	x	x			x		x	x		x	6
Apocynum cannabinum L.	x									x	2
Aquilegia canadensis L.	x							x			2
Arabis laevigata (Muhl.) Poir.							x				1
Aralia nudicaulis L.	x	x		x	x	x	x	x	x	x	9
Aralia racemosa L.	x	x			x						3
Aralia spinosa L.	x										1
Arisaema triphyllum (L.) Schott	x	x	x	x	x		x	x			7
Aristolochia serpentaria L.	x	x			x		x	x			5
Asarum canadense L.	x										1
Asclepias exaltata L.		x			x		x				3
Asplenium platyneuron (L.) Oakes.	x						x			x	3
Asplenium trichomanes L.		x									1
Aster divaricatus L.	x	x	x	x	x	x	x	x	x		9
Aster lateriflorus (L.) Britt.	x										1
Aster macrophyllus L.		x			x		x			x	4
Baptisia tinctoria (L.) R.Br.								x			1
Botrychium lanceolatum Angstr.	x										1
Botrychium virginianum (L.) Sw.	x	x			x		x				4
Brachyelytrum erectum (Schreb.) Beauv.	x	x			x		x	x			5
Bromus purgans L.	x						x				2
Camptosorus rhizophyllus (L.) Link.	x										1
Carex blanda Dev.		x			x		x				3
Carex cephalophora Muhl.	x						x				2
Carex digitalis Willd.		x	x		x		x	x			5
Carex laxiflora Lam.	x	x					x	x			4
Carex pensylvanica Lam.	x	x		x	x	x	x	x	x	x	9
Carex retroflexa Muhl.							x				1
Carex rosea Schkuhr.	x	x					x				3
Carex swanii (Fern.) MacKenz.		x		x			x				3
Carex virescens Muhl.			x				x	x			3
Chimaphila maculata (L.) Pursh.	x	x	x	x	x		x	x		x	8

Table 1: cont.

Species	**Lim**	**MS**	**BS**	**TrC**	**Ba**	**LS**	**Gn**	**HF**	**GPC**	**SC**	**Total**
Chimaphila umbellata (L.) Bart.					x		x	x		x	4
Cimicifuga racemosa (L.) Nutt.							x				1
Circaea quadrisulcata Maxim.		x		x	x		x				4
Claytonia virginica L.				x							1
Collinsonia canadensis L.	x	x		x	x		x	x			6
Comandra umbellata (L.) Nutt.								x		x	2
Corallorhiza maculata Raf.	x	x						x			3
Cryptotaenia canadensis (L.) DC.				x	x						2
Cunila origanoides (L.) Britt.					x		x	x			3
Cypripedium parviflorum Salisb.							x				1
Cystopteris fragilis (L.) Bernh.		x					x				2
Danthonia spicata (L.) Beauv.		x					x	x	x	x	5
Dennstaedtia punctilobula Michx.		x		x	x	x	x	x	x		7
Deschampsia flexuosa (L.) Trin.							x	x		x	3
Desmodium glutinosum (Muhl.) Wood.	x	x					x			x	4
Desmodium nudiflorum (L.) DC.	x	x		x	x	x	x	x			7
Desmodium paniculatum (L.) DC.		x						x			2
Dryopteris cristata (L.) Gray.	x										1
Dryopteris hexagonoptera Michx.					x						1
Dryopteris noveboracensis (L.) Gray.	x	x			x	x	x	x			6
Dryopteris marginalis (L.) Gray.	x	x				x	x	x	x	x	7
Dryopteris spinulosa (O.F. Muell) Watt.	x				x		x	x			4
Epigaea repens L.							x	x		x	3
Erechtites hieracifolia (L.) Raf.								x			1
Erigeron philadelphicus L.					x						1
Eupatorium dubium Willd.					x						1
Eupatorium rugosum Houtt.	x	x		x	x		x	x			6
Fragaria virginiana Duchesne	x	x		x	x		x				5
Galium asprellum Michx.		x			x		x				3
Galium circaezans Michx.	x	x			x		x	x			5
Galium lanceolatum Torr.	x	x		x	x		x	x		x	7
Galium triflorum Michx.		x		x	x		x	x			5
Gaultheria procumbens L.		x					x	x	x	x	5
Geranium maculatum L.	x	x		x	x		x	x			6
Gerardia flava L.	x						x			x	3
Gerardia virginica (L.) BSP.										x	1
Geum canadense Jacq.		x					x				2
Goodyera pubescens (Willd.) R.Br.	x	x					x				3
Hedeoma pulegioides (L.) Pers.							x	x			2
Helianthus divaricatus L.										x	1
Hepatica americana (DC.) Ker.	x	x			x		x	x			5
Heuchera americana L.		x									1
Hieracium paniculatum L.		x		x			x				3
Hieracium venosum L.		x					x	x			3
Hypericum punctatum Lam.							x				1

Table 1: cont.

Species	**Lim**	**MS**	**BS**	**TrC**	**Ba**	**LS**	**Gn**	**HF**	**GPC**	**SC**	**Total**
Hypoxis hirsuta (L.) Coville	x	x			x		x	x		x	6
Hystrix patula Moench								x			1
Lactuca biennis (Moench) Fern.		x									1
Lactuca canadensis L.		x									1
Lespedeza intermedia (S. Wats.) Britt.							x				1
Luzula campestris (L.) DC.	x	x			x		x	x			5
Lycopodium complanatum L.				x							1
Lycopodium lucidulum Michx.	x	x	x	x			x	x			6
Lycopodiumobscurum L. var. *dendroideum* (Michx.) D.C. Eaton	x			x		x	x	x			5
Lycopodium tristachyum Pursh.				x							1
Lysimachia ciliata L.	x	x			x						3
Lysimachia quadrifolia Sims.	x	x	x	x	x	x	x	x	x	x	10
Maianthemum canadensis Desf.	x	x		x	x	x	x	x	x	x	9
Medeola virginiana L.	x	x		x	x	x	x	x			7
Melampyrum lineare Desf.		x					x	x	x	x	5
Melanthium hybridum Walt.	x	x					x				3
Menispermum canadense L.	x										1
Mitchella repens L.	x	x	x	x	x		x	x			7
Monotropa hypopithys L.	x	x	x		x			x			5
Monotropa uniflora L.	x	x	x	x	x	x	x	x	x	x	10
Muehlenbergia sobolifera (Muhl.) Trin.		x					x				2
Muehlenbergia tenuiflora (Willd.) BSP.		x									1
Onoclea sensibilis L.	x	x			x			x			4
Ophioglossum vulgatum L.								x			1
Orchis spectabilis L.		x									1
Osmorhiza claytoni C.B. Clarke	x	x		x	x						4
Osmorhiza longistylis (Torr.) DC.		x									1
Osmunda cinnamomea L.		x					x				2
Osmunda claytoniana L.	x	x			x	x		x			5
Osmunda regalis L.							x				1
Oxalis europaea Jord.		x									1
Oxalis florida Salisb.		x			x						2
Oxalis stricta L.		x									1
Panicum boscii Poir.	x						x	x			3
Panicum clandestinum L.						x	x				2
Panicum dichotomiflorum Michx.	x	x					x	x		x	5
Panicum lanuginosum Ell.							x				1
Panicum linearifolium Scribn.							x			x	2
Parthenocissus quinquefolia (L.) Planch.	x	x	x	x	x	x	x	x	x	x	10
Phryma leptostachya L.	x										1
Physalis heterophylla Nees							x				1
Podophyllum peltatum L.	x	x			x		x				4
Polygala paucifolia Willd.						x					1
Polygonatum biflorum (Walt.) Ell.	x	x	x	x	x		x	x	x	x	9

Table 1: cont.

Species	**Lim**	**MS**	**BS**	**TrC**	**Ba**	**LS**	**Gn**	**HF**	**GPC**	**SC**	**Total**
Polygonatum pubescens (Willd.) Pursh.	x	x	x	x	x	x	x	x	x		9
Polygonum orientale L.							x				1
Polypodium virginianum L.	x						x	x	x	x	5
Polystichum acrostichoides Schott	x	x	x		x	x	x	x		x	8
Potentilla canadensis L.	x	x			x		x	x	x	x	7
Potentilla simplex Michx.		x		x	x			x		x	5
Prenanthes trifoliolata (Cass.) Fern.	x	x	x		x	x	x				6
Pteridium aquilinum (L.) Kuhn				x		x	x	x			4
Pyrola secunda L.							x				1
Ranunculus abortivus L.		x		x							2
Sanguinaria canadensis L.							x				1
Sanicula canadensis L.		x		x	x		x				4
Sanicula gregaria Bickn.							x				1
Sanicula marilandica L.	x						x				2
Scirpus verecundus Fern.	x										1
Scutellaria epilobiifolia A. Hamilton							x				1
Senecio obovatus Muhl.	x						x				2
Smilacina racemosa (L.) Desf.	x	x	x	x	x	x	x	x	x	x	10
Smilacina trifolia (L.) Desf.		x					x				2
Solidago caesia L.	x	x	x	x	x	x	x	x	x	x	10
Solidago flexicaulis L.	x				x						2
Solidago graminifolia (L.) Salisb.		x						x			2
Solidago juncea Ait.	x			x			x			x	4
Solidago nemoralis Ait.	x						x				2
Solidago rugosa Ait.			x				x	x			3
Solidago ulmifolia Muhl.							x				1
Trientalis borealis Raf.							x	x			2
Uvularia perfoliata L.	x	x		x	x	x	x	x		x	8
Uvularia sessilifolia L.		x		x	x	x	x	x	x	x	8
Verbena urticifolia L.							x				1
Veronica officinalis L.		x						x			2
Viola blanda Willd.		x		x	x		x				4
Viola palmata L.	x	x					x	x			4
Viola pensylvanica Michx.		x					x				2
Viola pubescens Ait.	x	x		x	x		x				5
Viola rotundifolia Michx.							x				1
Waldsteinia fragarioides (Michx.) Trott.								x			1
Total	82	95	68	45	68	25	118	80	19	37	
Total stands	3	5	1	1	5	2	11	8	3	1	40

Table 2: Abbreviations for geological substrata from northern New Jersey.

Lim	Kittatinny Limestone
MS	Martinsburg Shale
BS	Brunswick Shale
TrC	Triassic Conglomerate
Ba	Basalt
LS	Longwood Shale
Gn	Gneiss (Byram, Pochuck and Losee)
HF	High Falls Sandstone
GPC	Green Pond Conglomerate
SC	Shawangunk Conglomerate

Table 3: Total number of forest sites for each substratum type.

Kittatinny Limestone	3
Martinsburg Shale	5
Brunswick Sormation	1
Triassic Conglomerate	1
Basalt	5
Longwood Shale	2
Gneiss	11
High Falls Sandstone	8
Green Pond Conglomerate	3
Shawangunk Conglomerate	1
	40

Table 4: Average number of herbs per substratum.

Kittatinny Limestone	82
Martinsburg Shale	95
Brunswick Shale	18
Triassic Conglomerate	45
Basalt	68
Longwood Shale	25
Gneiss	118
High Falls Sandstone	80
Green Pond Conglomerate	19
Shawangunk Conglomerate	37

Table 5: Taxa restricted to specific substrata or substrata not having restricted species

Kittatinny Limestone	*Aralia spinosa* L. *Asarum canadense* L *Botrychium lanceolatum* (Gmel.) Angstr. *Camptosorus rhizophyllus* (L.) Link. *Menispermum canadense* L. *Phryma leptostachya* L.
Basalt	*Eupatorium dubium* Willd.
Longwood Shale	*Polygala paucifolia* Willd.
Gneiss	*Agrimonia striata* Michx. *Arabis laevigata* (Muhl.) Poir. *Carex retroflexa* Muhl. *Cimicifuga racemosa* (L.) Nutt. *Cypripedium parviflorum* Salisb. *Lespedeza intermedia* (S. Wats.) Britt. *Osmunda regalis* L. *Panicum lanuginosum* Ell. *Physalis heterophylla* Nees *Pyrola secunda* L. *Sanguinaria canadensis* *Sanicula gregaria* Bickn. *Scutellaria epilobifolia* A. Hamilton *Solidago ulmifolia* Muhl. *Viola rotundifolia* Michx.
High Falls Sandstone	*Anaphalis margaritacea* (L.) C. B. Clarke *Angelica venenosa* (Greenway) Fern. *Baptisia tinctoria* (L.) R. Br. *Erechtites hieracifolia* (L.) Raf. *Hystrix patula* Moench *Ophioglossum vulgatum* L. *Waldsteinia fragarioides* (Michx.) Trott.
Green Pond Conglomerate	None
Shawangunk Conglomerate	*Gerardia virginica* (L.) BSP. *Helianthus divaricatus* L.
Martinsburg Shale	*Anemone virginiana* L. *Asplenium trichomanes* L. *Lactuca biennis* (Moench) Fern. *Muehlenbergia tenuiflora* (Willd.) BSP. *Oxalis europaea* Jord. *Oxalis stricta* L.
Brunswick Formation	None
Triassic Conglomerate	*Claytonia virginica* L. *Lycopodium tristachyum* Pursh.

Table 6: Wide-ranging species on substrata. The number of substrata on which the plants are found.

Aralia nudicaulis L.	9
Arisaema triphyllum (L.) Schott	7
Aster divaricatus L.	9
Carex pensylvanica Lam.	9
Chimaphila maculata (L) Pursh.	8
Dennstaedtia punctilobula (Michx.).	7
Desmodium nudiflorum (L.) DC.	7
Dryopteris marginalis (L.) Gray	7
Lysimachia quadrifolia Sims.	10
Maianthemum canadensis Desf.	9
Medeola virginiana L.	7
Mitchella repens L.	7
Monotropa uniflora L.	10
Parthenocissus quinquefolia (L.) Planch.	10
Polygonatum biflorum (Walt.) Ell.	9
Polystichum acrostichoides (Michx.) Schott	8
Potentilla canadensis L.	7
Smilacina racemosa (L.) Desf.	10
Solidago caesia L.	10
Uvularia perfoliata L.	8
Uvularia sessilifolia L.	8

Discussion

ROBICHAUD & BUELL (1973) wrote on the vegetation of northern New Jersey, but the analysis reported in this paper was not available to them, and so clear-cut patterns of species endemism as shown in PLATT (1951) on the shale barrens of Pennsylvania was not available in the mentioned work by ROBICHAUD & BUELL. TEDROW (1986) reviewed the relationship of soils and vegetation with particular detail paid to the work of BUELL and his students, but again, as mentioned for ROBICHAUD & BUELL (1973), the various plant taxa in northern New Jersey were not available to him as delineated in the present work.

The restriction of some species (Table 5) to certain of the substrata, as shown here is possibly of considerable significance. The fact, that the disturbance factor had been kept to a minimum (at least 60 years since disturbance), makes it possible to conclude that the restricted species may have evolved in their present location following the recession of the last Wisconsin Ice Age Stage. Further work would help to more precisely document this.

Diversity of canopy species is relatively low in stands on Conglomerate, Longwood Shale and the Brunswick Formation, intermediate in stands on High Falls Sandstone, and relatively high in stands on Gneiss, Basalt, Martinsburg Shale and Kittatinny Limestone. The increase in species represented with increased sampling suggests, that, of all substrata studied, Limestone may support the greatest diversity of tree species. PEARSON (1960) showed 32 species occurring in 17 stands on Kittatinny Limestone. Herb diversity is not as great on Limestone and above the richness found with the trees is not as significant with Limestone herb flora.

PEARSON (1960) worked with 12 stands on Kittatinny Limestone and Franklin Marble and found a total of 78 species of herbs (at species level), compared with the 82 species which I found on the Kittatinny Limestone as reported in this paper. These data are comparable to the point of concluding that the PEARSON Limestone data (12 stands) are equivalent to my number of Limestone species in 5 stands.

PEARSON (1960) also dealt with the fact that the chi-square test of homogeneity was not applicable to his 12 stands (herb data) or 17 stands (tree data). Also, his stands had a total of points ranging from 25 to 100 points.

PEARSON (1960) also did not deal with the problem of endemic species of herbs on Limestone and therefore, the species which I found to be only on Limestone (six) could not be directly comparable to PEARSON's results. Of these six, however, PEARSON found four of them on Limestone and Marble.

Nomenclature follows FERNALD (1950), because all of the studies of the department of Botany at Rutgers University over the years did follow him, and thus the data are directly comparable.

Northern New Jersey, with the more than 10 different geological substrata, has the same type of setting as the Nevada and California sites of BILLINGS (1950), as these are juxtaposed on quite different geological substrata each with a different complement of soil series (as shown by TEDROW 1986). These substrata, as did those of BILLINGS with the altered and unaltered andesite, provided the opportunity to compare endemic species on these soils and substrata.

Comparison of floristics and vegetation from the present to other works are difficult because the 40 stands of shrubs and herbs were very strongly homogeneous. All the boundaries for the 40 stands were selected by the investigators, before the vegetation and flora were sampled. In case of PEARSON (1960, 1962; Kittatinny Limestone and Franklin Marble), the homogeneity of his stands were not as rigorously selected, in part because the Limestone and Marble vegetation remnants were so hard to locate (as was also the case for this paper).

In addition to the cited PEARSON studies, the studies of PLATT (1951) were not directly based on uniform homogeneity and therefore is difficult to compare the Martinsburg Shale of the New Jersey North, to the Shale Barrens of PLATT (1951). PLATT dealt with the normally endemic plants of the mid-Appalachian Shale Barrens. However, FERNALD (1950) did not follow the finds which PLATT reported for endemics in the mid-Appalachian Shale Barrens. None of his 8 endemic species are found in the study areas of northern New Jersey. Martinsburg Shale is also found in some of the Shale Barrens of PLATT (in Virginia).

The striking features of the western Serpentine vegetation (WHITTAKER 1954; KRUCKEBERG 1954; WALKER 1954) were not found in the stands and species here studied. Nor were the striking results of BILLINGS (1950) shown by the herbaceous flora of the upland forests of northern New Jersey.

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