Lecture 7: Ordination of vegetation
I. Direct Gradient Analysis

- Classification vs. Ordination
- Direct gradient analysis
  - One dimensional
  - Multi dimensional approaches
  - Toposequences

Ordination

- "...an arrangement of units in a uni- or multi-dimensional order..." as opposed to "a classification in which units are arranged in discrete classes."

Goodhall 1953

Same as "Ordnung" of Ramensky (1930).

- The arrangement of plots to show floristic relationships between stands of vegetation or between species. The arrangement is in an "ordination space" in as compact a manner as possible. The distances between points on the ordination are measures of their degree of floristic similarity.
- Like numerical classification, ordination is a data reduction method that summarizes information in a simpler, more space-efficient, more visual means than a table.
- Often a major objective is to relate the ordination to environmental gradients.

Two basic types of ordination

Direct ordination examines vegetation changes along known environmental gradients (e.g. a moisture gradient or elevation gradient.

Indirect ordination examines the environmental causes of vegetation patterns by first arranging the stands or species according to their floristic similarity and then through correlation of the ordination axes with environmental variables.

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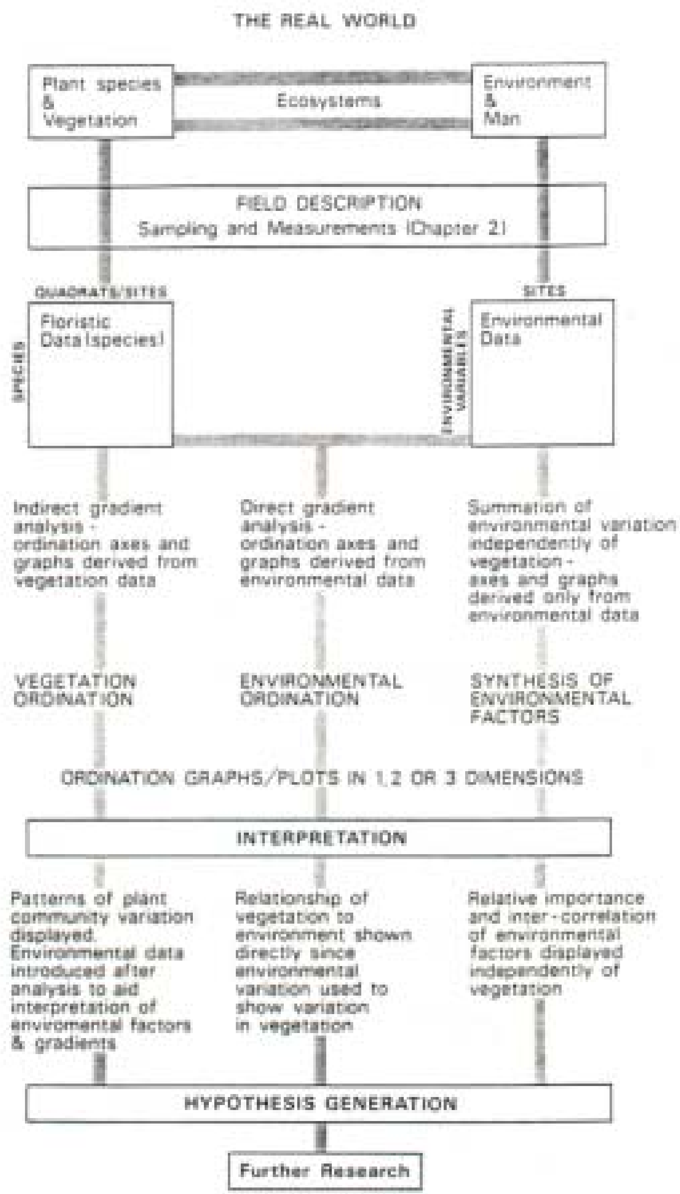
Approaches to ordination



Direct gradient analysis

- **Definition:** A highly intuitive way to portray variation along a single or multiple environmental gradients. The plots display species or community abundance in response to a known environmental gradient (often this is a complex environmental gradient).
- **Basis of approach:**
  - There are key factors in the development of soils and vegetation, including climate, parent material, topography, other organisms, and time.
  - Direct gradient analysis is an examination of the response of individual species or vegetation types to gradients of these factors.

Some basic definitions

Complex environmental gradient: An environmental gradient that is composed of multiple, often correlated factors. Almost all physical gradients are complex environmental gradients (e.g. soil moisture gradient is also usually a gradient of soil pH, soil organic matter, soil aeration, etc.).

Coenocline: A gradient in plant community composition.

Ecocline: The simultaneous gradient in species composition and environmental variation.

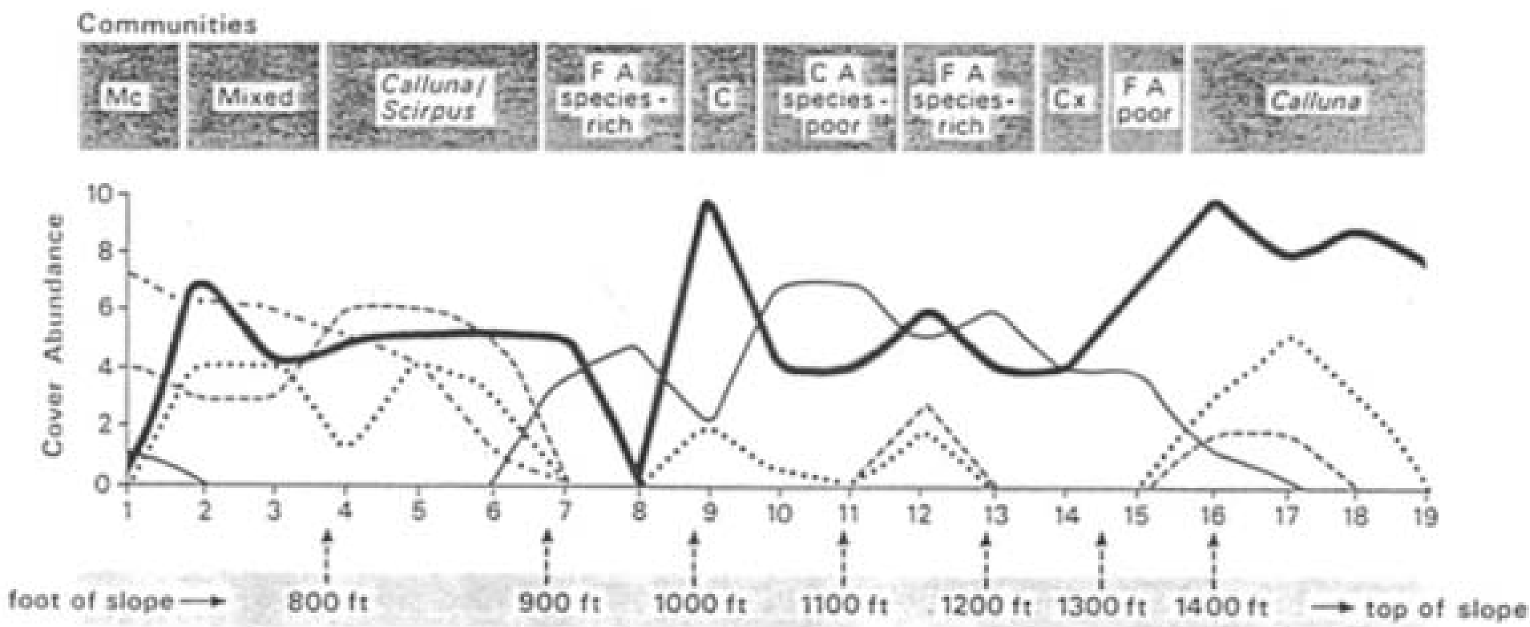
Normal distribution: (= Gaussian distribution), a mathematical distribution defined with a mean and variance. Graphically, a normal distribution looks like a bell-shaped curve. With respect to vegetation, patterns of species along environmental gradients often resemble normal distributions. Gause (1930) first described such distributions in ecology in his studies of orthoptera.

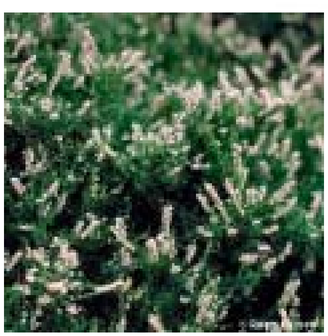
Mesotopographic gradient: An ecocline along a small to medium-sized hill slope. Coined by Billings (1973) for alpine areas to portray the variation in communities along hill-slope gradients mainly as a response to varying soil moisture and snow conditions.

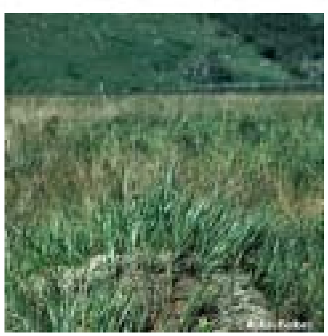
Catena: The soil science term for change along a hill slope, often with specific reference to the hill crest, shoulder, backslope, footslope, and toeslope.

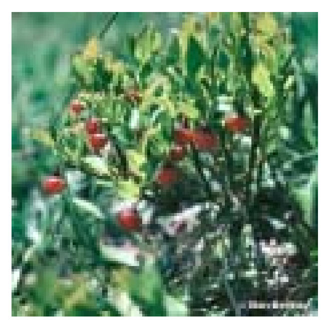
State factors: The set of variables that control another variable. With respect to vegetation they are the factors that control development of vegetation. A mathematical equation describes vegetation as a function of a set of primary state factors: ***Vegetation = f(Cl, O, R, P, T),*** where *Cl* is the climate, *O* is the organisms, *R* is the relief (topography), *P* is the parent material, and *T* is time. Jenny (1941) first wrote this equation with respect to the state factors controlling soil development. He considered the soil to be a function of same five independent factors. Major (1951) later used the same variables as controls on the vegetation. Even more broadly, the same variables determine ecosystem structure and function.

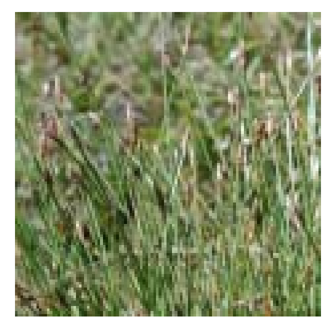
A simple one-dimensional direct ordination of species along a topographic gradient in Ireland



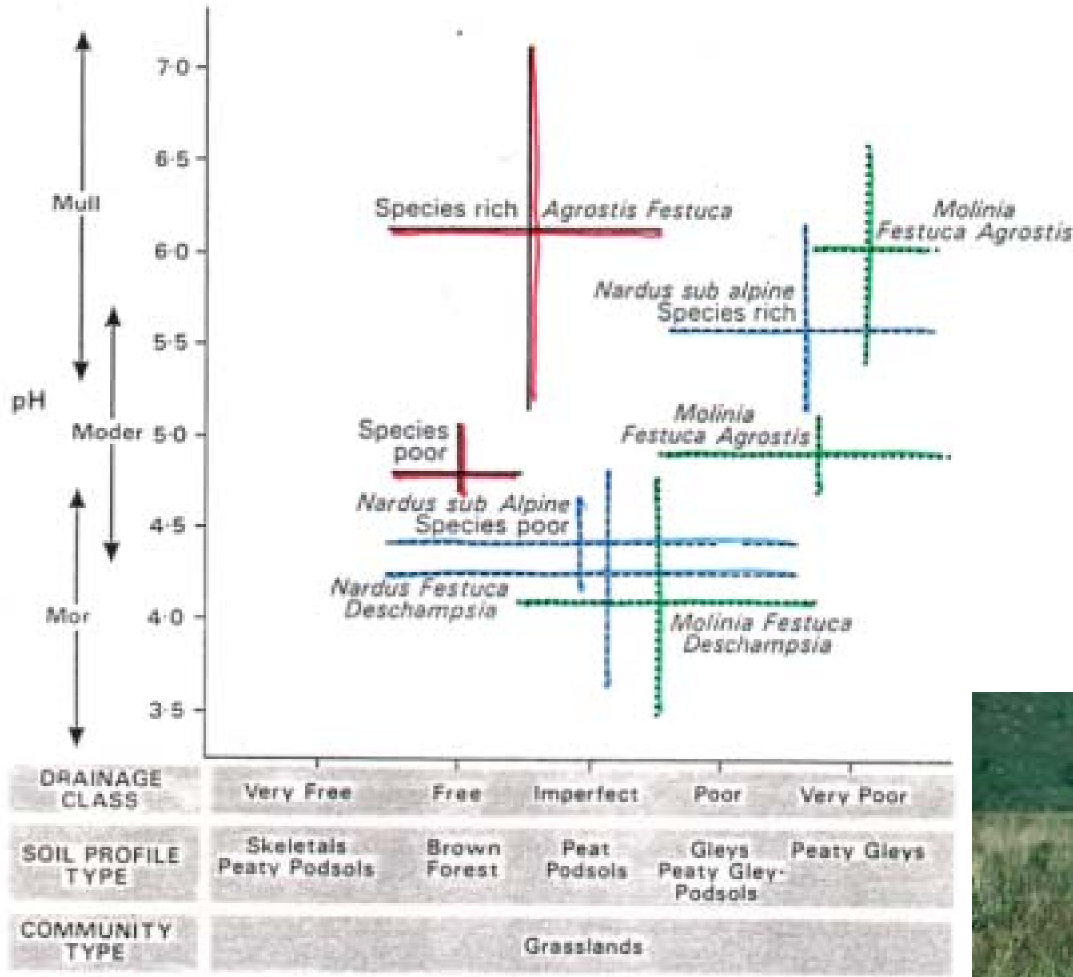

Calluna vulgaris


Molinia caerulea


Vaccinium myrtillus


Trichophorum caespitosum

2D Ordination of Irish moor grasslands



Nardus stricta

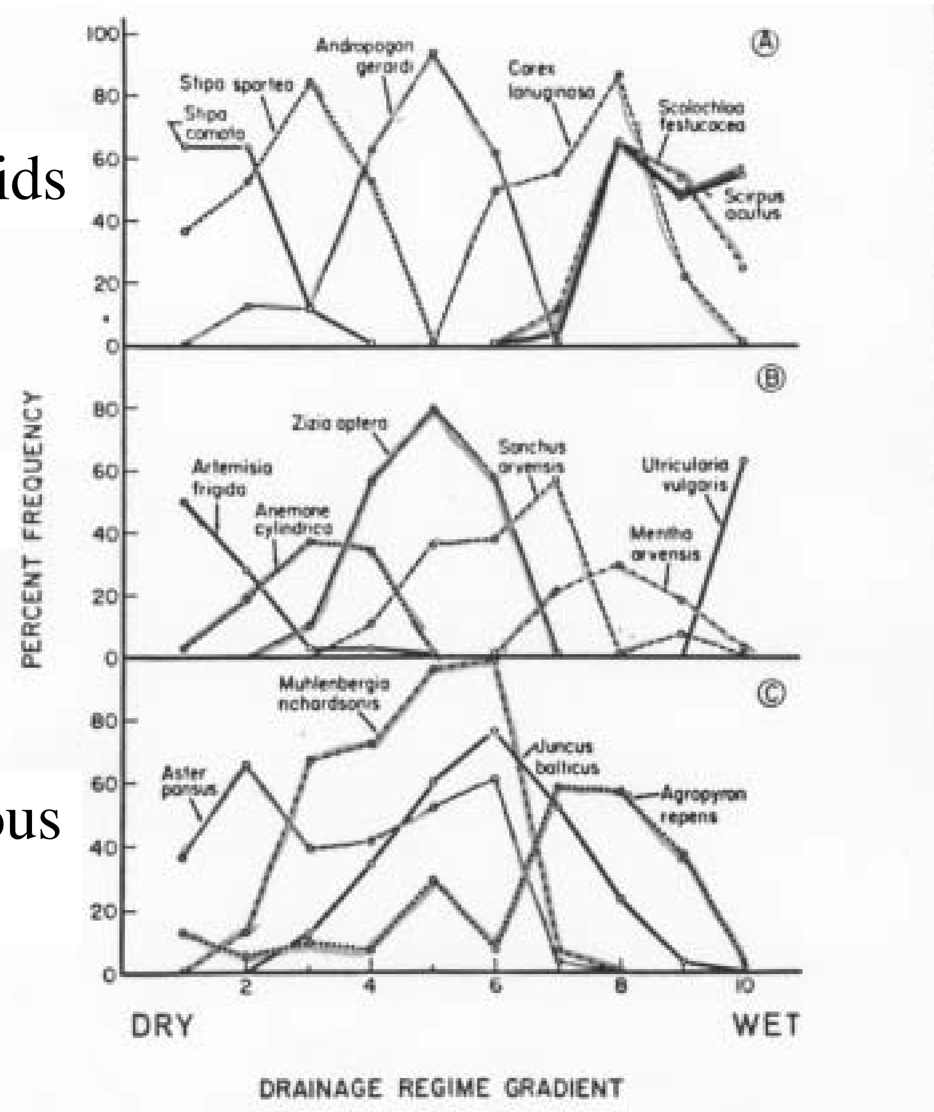
Molinia caerulea

Grassland species along a moisture gradient in Nelson County, North Dakota

Graminoids

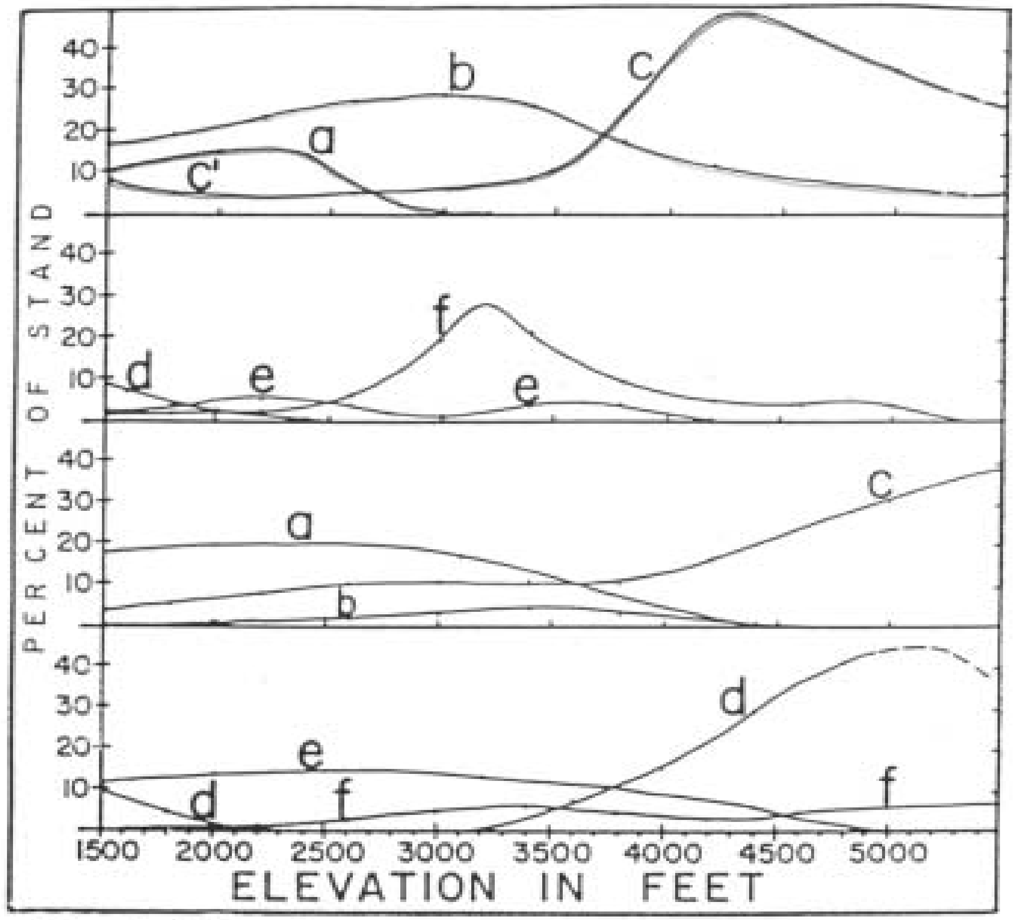
Forbs

Ubiquitous species



Dix and Simiens (1967)

Another example from Whittaker (1956)



Submesic sites

Subxeric sites

FIG. 9. Elevation transects in submesic and subxeric sites, smoothed curves for tree species. Above—submesic sites: a, *Cornus florida*; b, *Acer rubrum*; c and c', *Quercus borealis* and var. *maxima*; d, *Carya tomentosa*; e, *Carya glabra*; f, *Hamamelis virginiana*. Below—subxeric sites: a, *Quercus prinus*; b, *Sassafras albidum*; c, *Castanea dentata*; d, *Quercus alba*; e, *Oxydendrum arboreum*; f, *Robinia pseudoacacia*.

2-D ordination of stands along soil pH and calcium gradients at Prudhoe Bay, AK

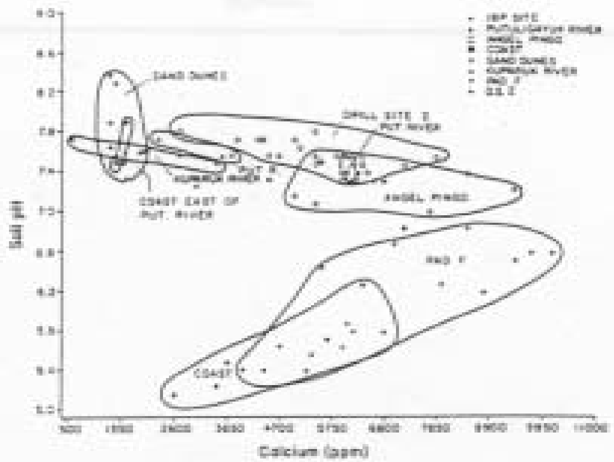


Figure 55. Soil pH vs calcium concentration. Distinct clusters represent the major study sites.

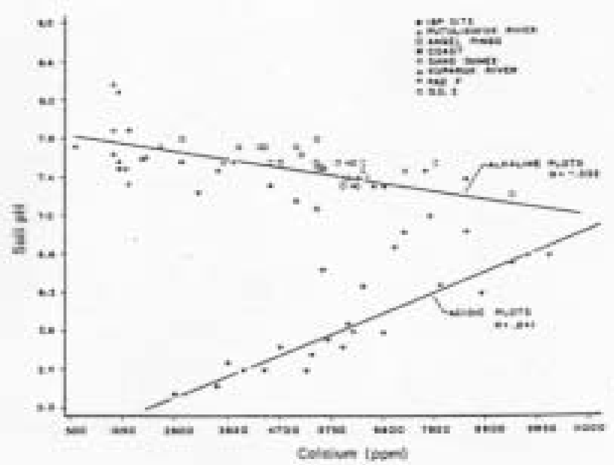
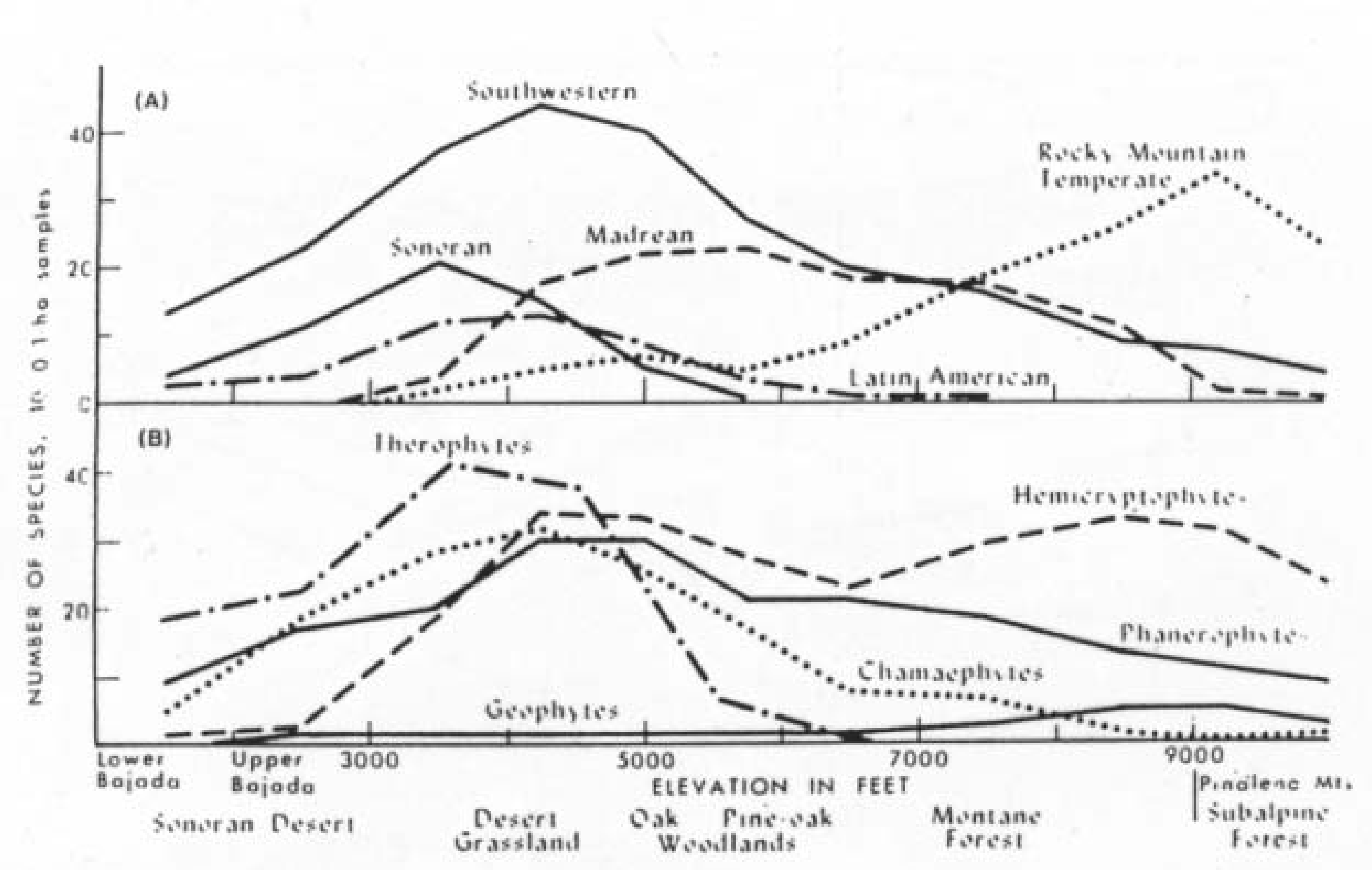


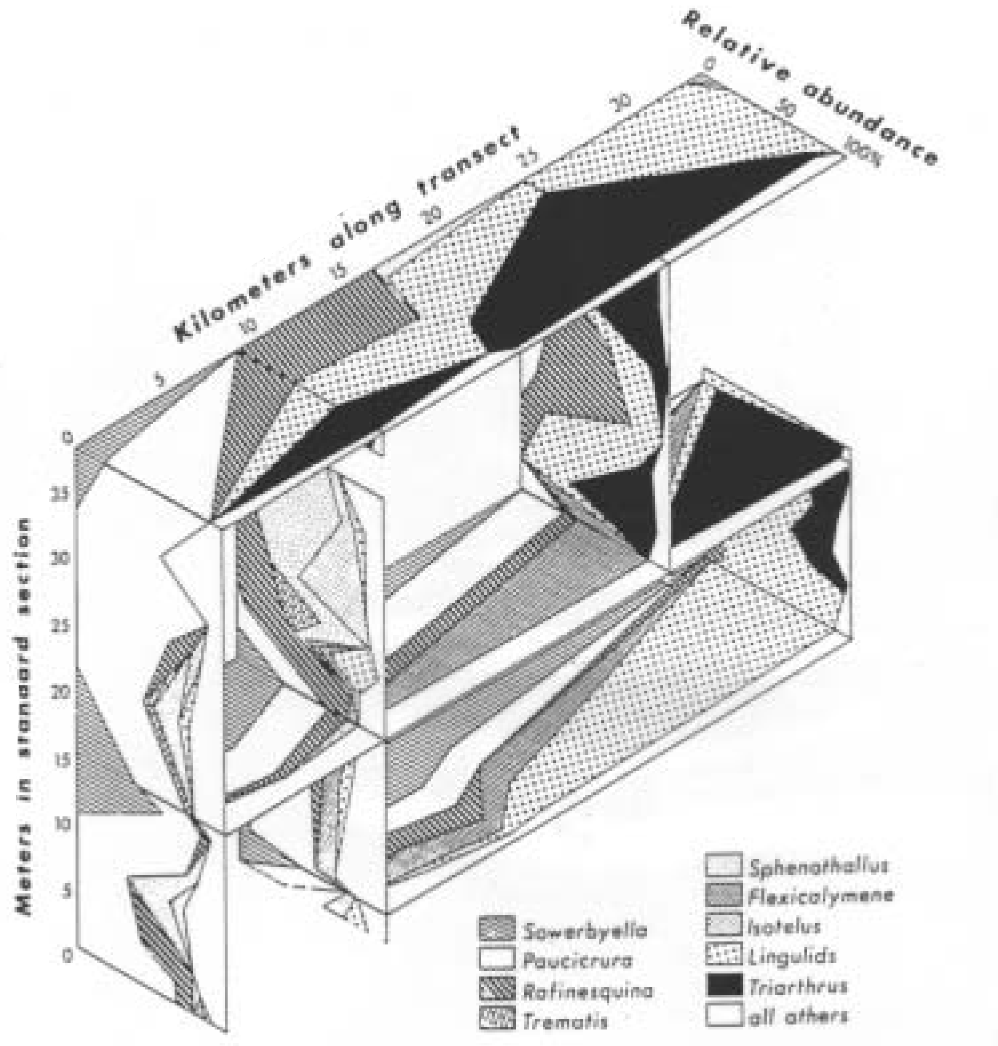
Figure 56. Regressions of calcium concentration vs soil pH for the acidic and alkaline tundra areas. The highest calcium levels are in soils with pHs near 7.

From Walker 1980

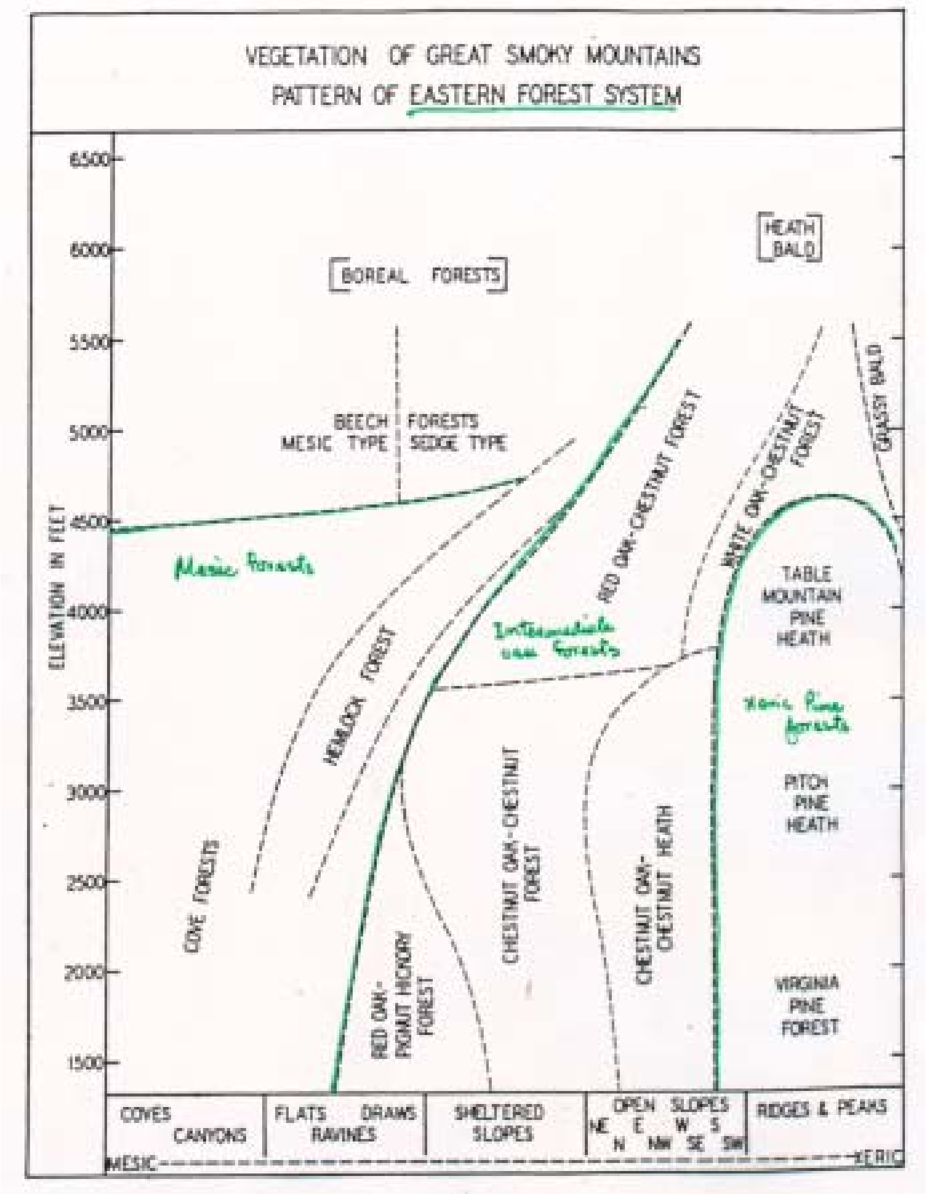
Ordination of flora elements and life forms along an elevation gradient in Arizona



3-D distribution of salt-water organisms



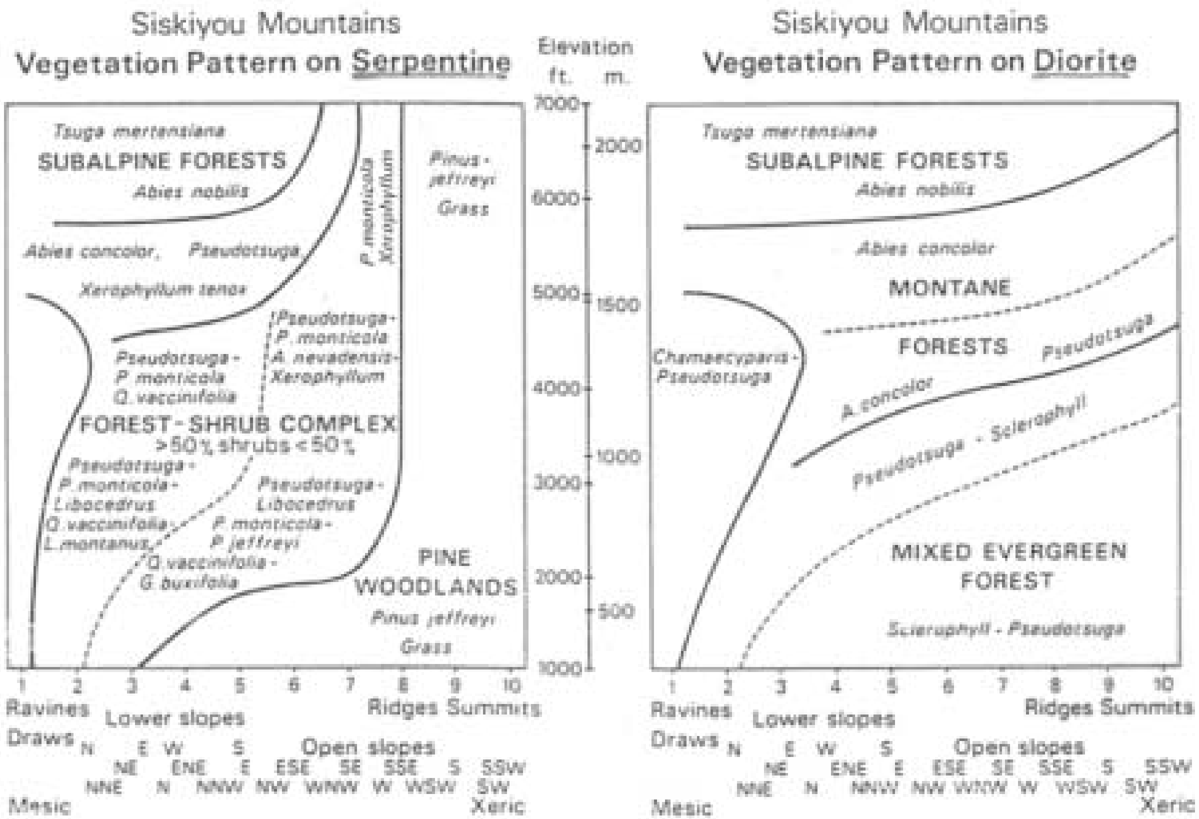
Whittaker diagram: 2-D ordination showing location of major plant communities along moisture and elevation gradients in the Smokey Mountains



- x-axis: moisture/topography gradient
- y-axis: major elevation gradient
- Isolines show positions of broad plant formations.

From: Whittaker, R.H. 1956. Vegetation of the Great Smoky Montains. *Ecological Monographs* 26: 1-80.

Whittaker diagrams for two different substrates:

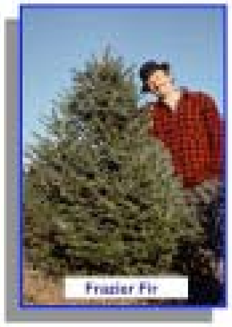


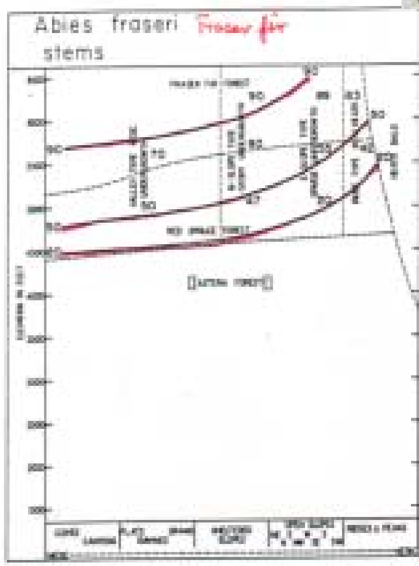
- x-axis: moisture/topography gradient.
- y-axis: major elevation gradient.
- Separate ordinations for serpentine and diorite soils.
- Isolines show positions of broad plant formation. Dashed lines are plant associations.

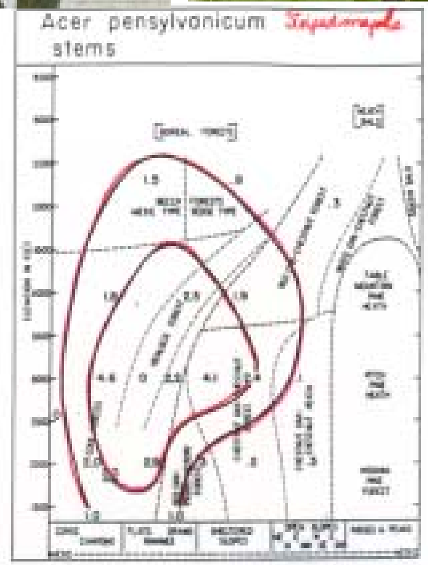
From Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs* 30: 279-338.

Species distribution plotted on background ordination space


- 4 species from Whittaker's Smokey Mountain study.
- Background shows the distribution of plant communities in the ordination space.
- Small numbers show cover values for the given species in stands.
- Red lines are isolines of showing areas of equal cover classes for each species.

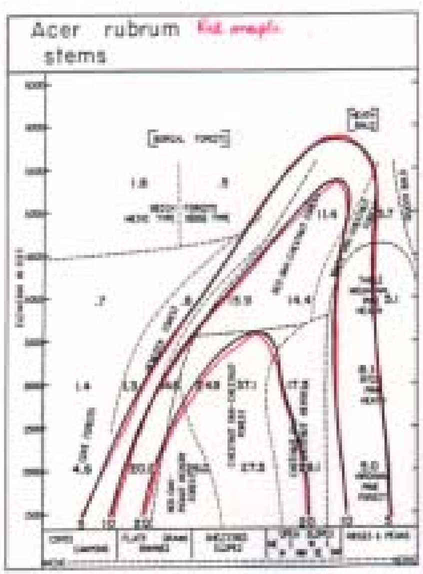


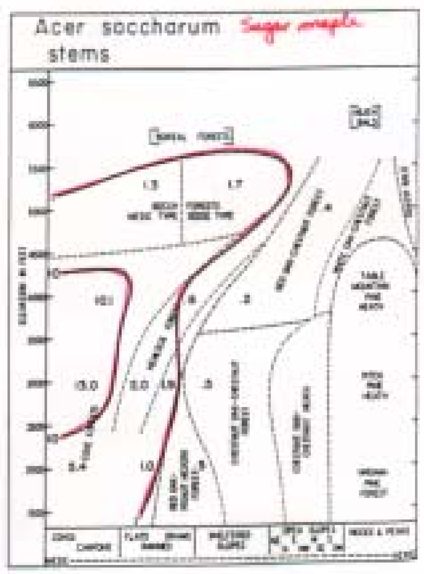


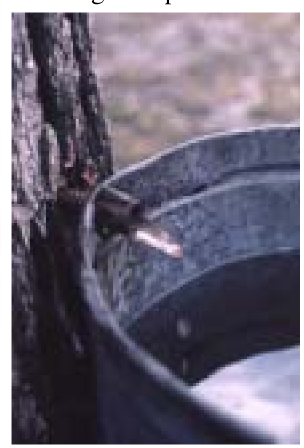


Species distributions:

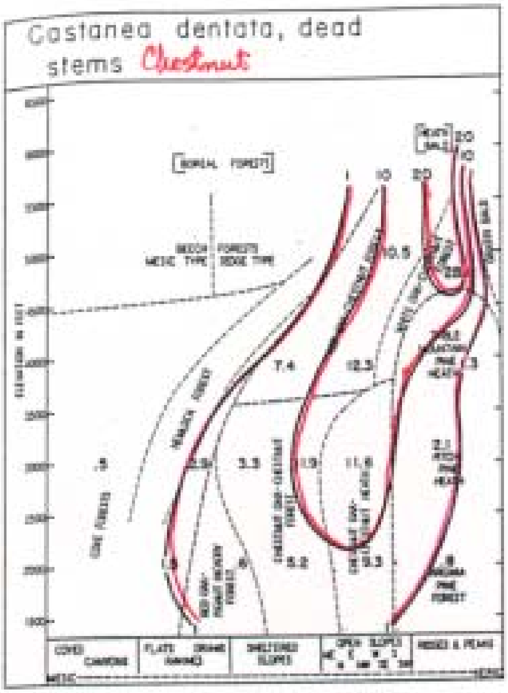
- Fraser fir: Limited to high-elevation, fraser-fir forests.
- Striped maple: coves, ravines, sheltered slopes at all elevations.
- Red maple: broad range of slope positions and elevations, but focused at lower elevations.
- Sugar maples: sheltered coves and ravines at most elevations.

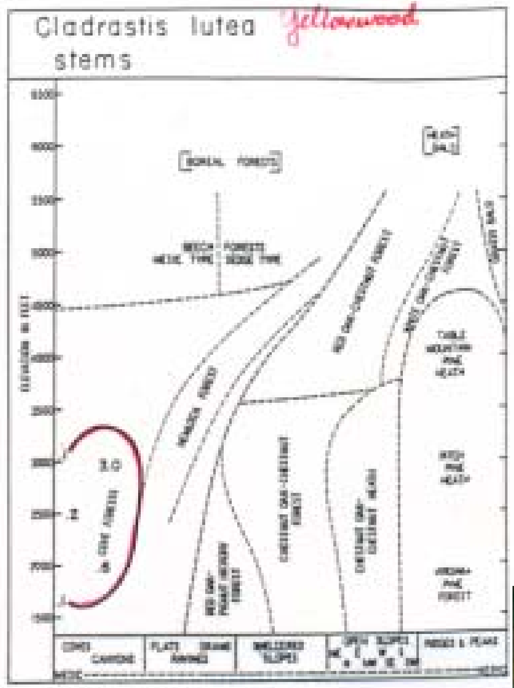


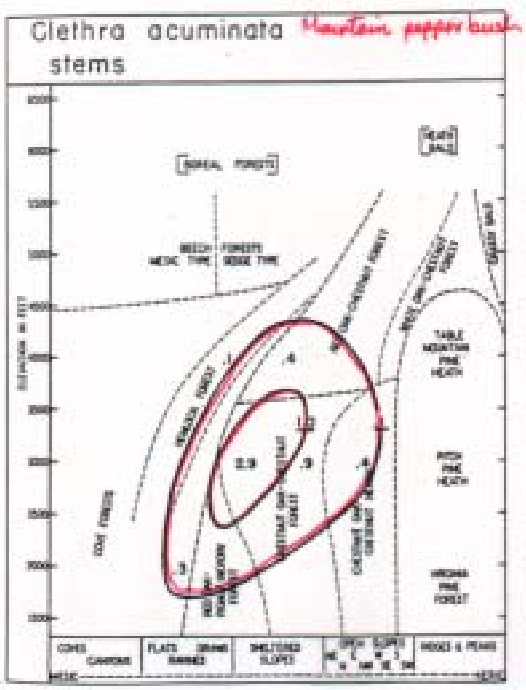


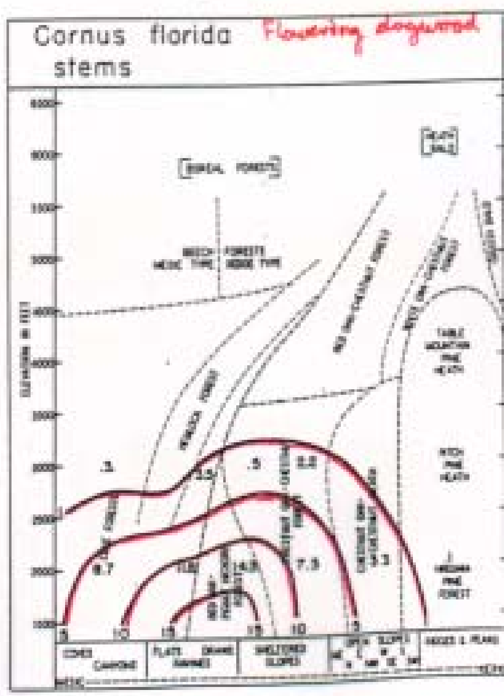


Whittaker 1956





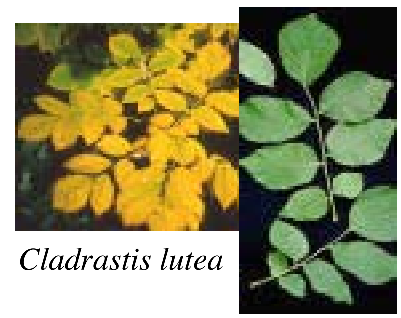




4 more species

- Chestnut dead stems: mid- to higher elevation, oak forests.
- Yellow wood: lower elevation, cove forests.
- Mountain paperbush: mid-elevation oak forests.
- Flowering dogwood: lower elevation cove and and oak forests.

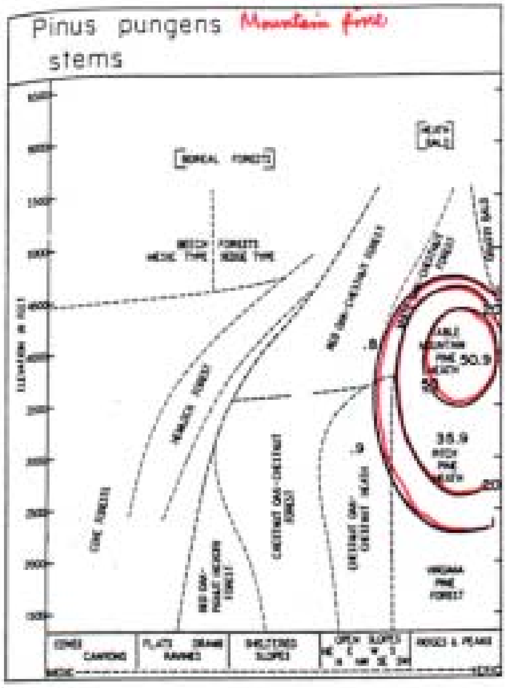
Castanea dentata

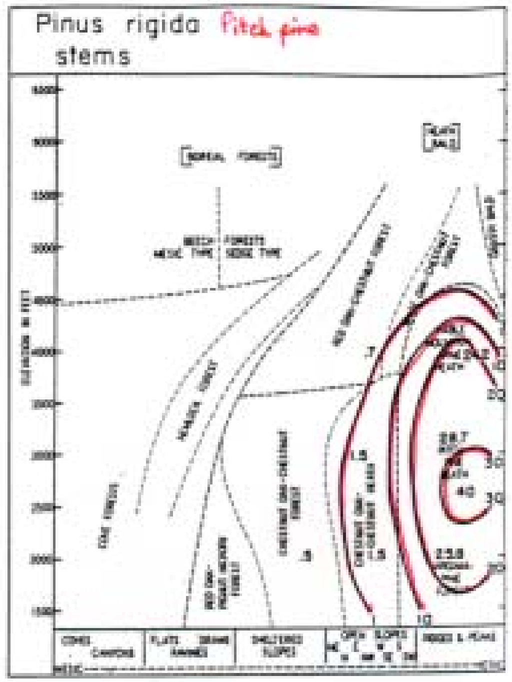


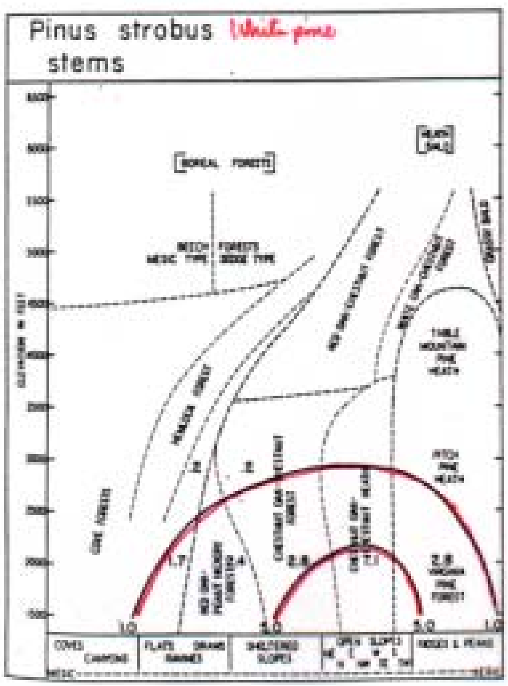
Cladrastis lutea

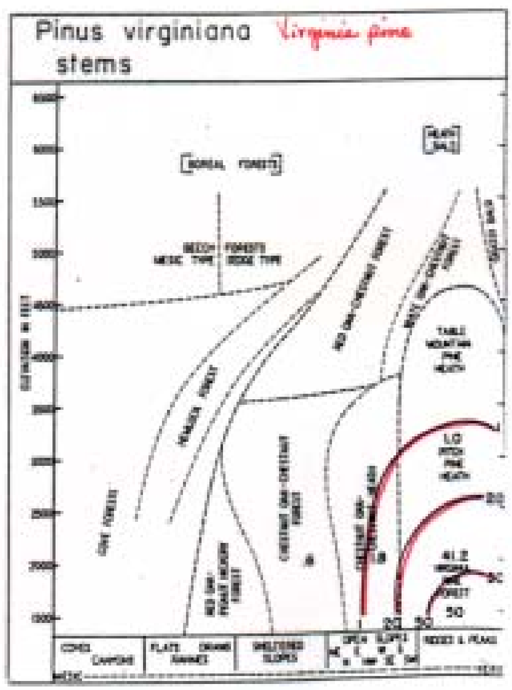
Clethera acuminata

Cornus florida





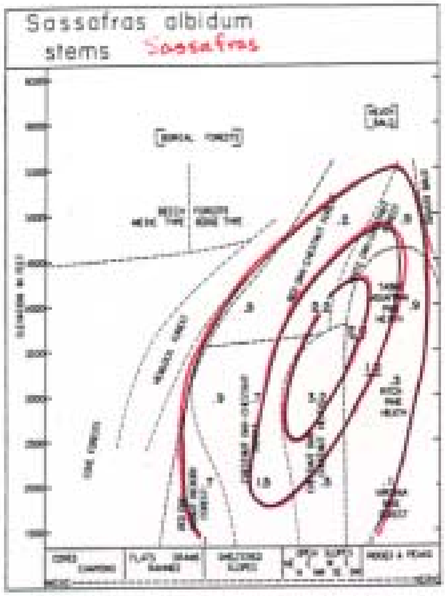


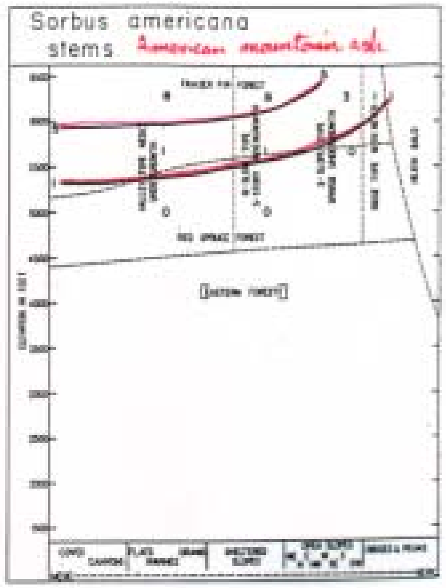


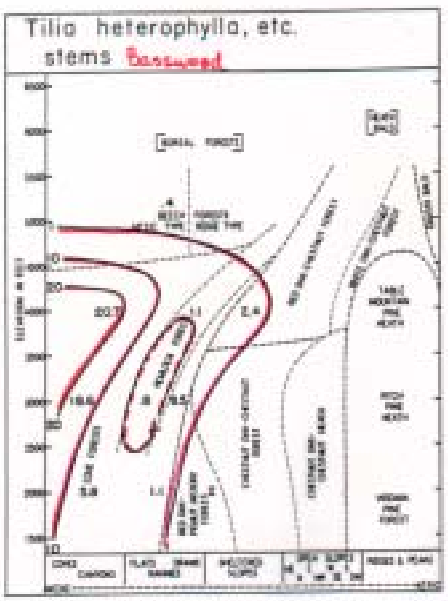
Pine species

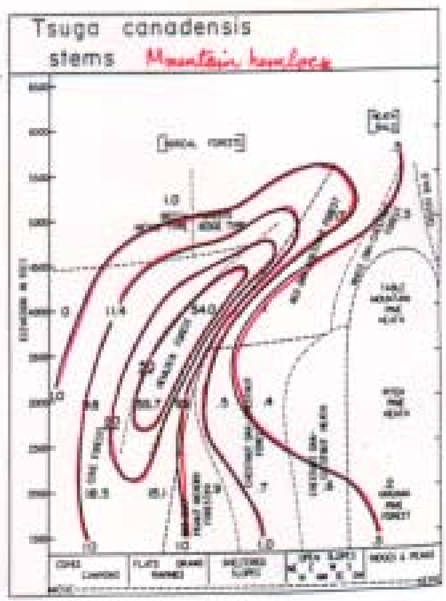
- Focused in the drier rocks and ridges and open slopes.

What are the habitats of these four species?



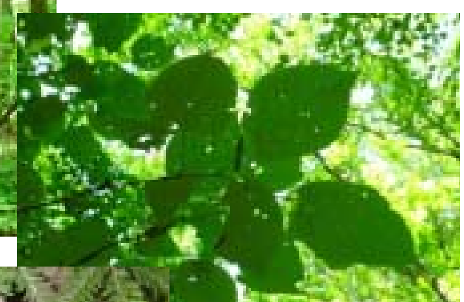






Sassfras albidum

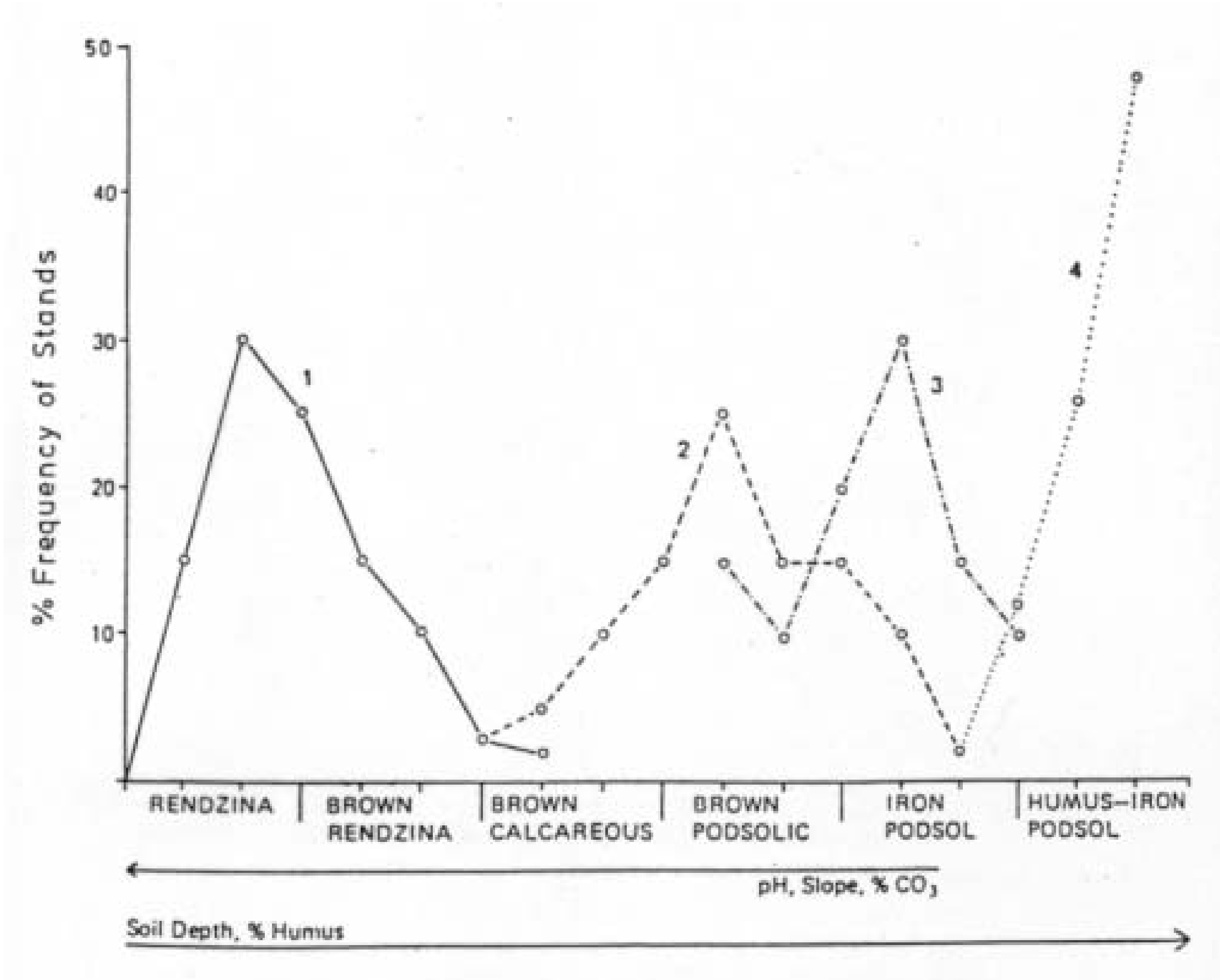
Sorbus americana



Tilia heterophylla

Tsuga canadensis

Complex environmental gradients: complex soil moisture gradient



Toposequences or catenas

One of the most common direct gradient analyses is the portrayal of vegetation and soils along moderate-sized hill slope gradients that do not involve major elevation transitions. In soils, such gradients are often called *catenas* (L. chain; referring to series or closely connected series, especially a series of excerpts from the works of the Fathers of the Church). These are especially instructional because they portray the variation in species in response to complex soil and moisture gradients typical of most landscapes.

Example

Graphs of species, soil, and diversity information along a toposequence at Imnavait Creek, Alaska.

a. Schematic of the toposequence showing transitions in vegetation and soils.

b. Soil physical and chemical properties along the toposequence.

c. Distributions of common growth forms and species.

d. Diversity along the gradient.

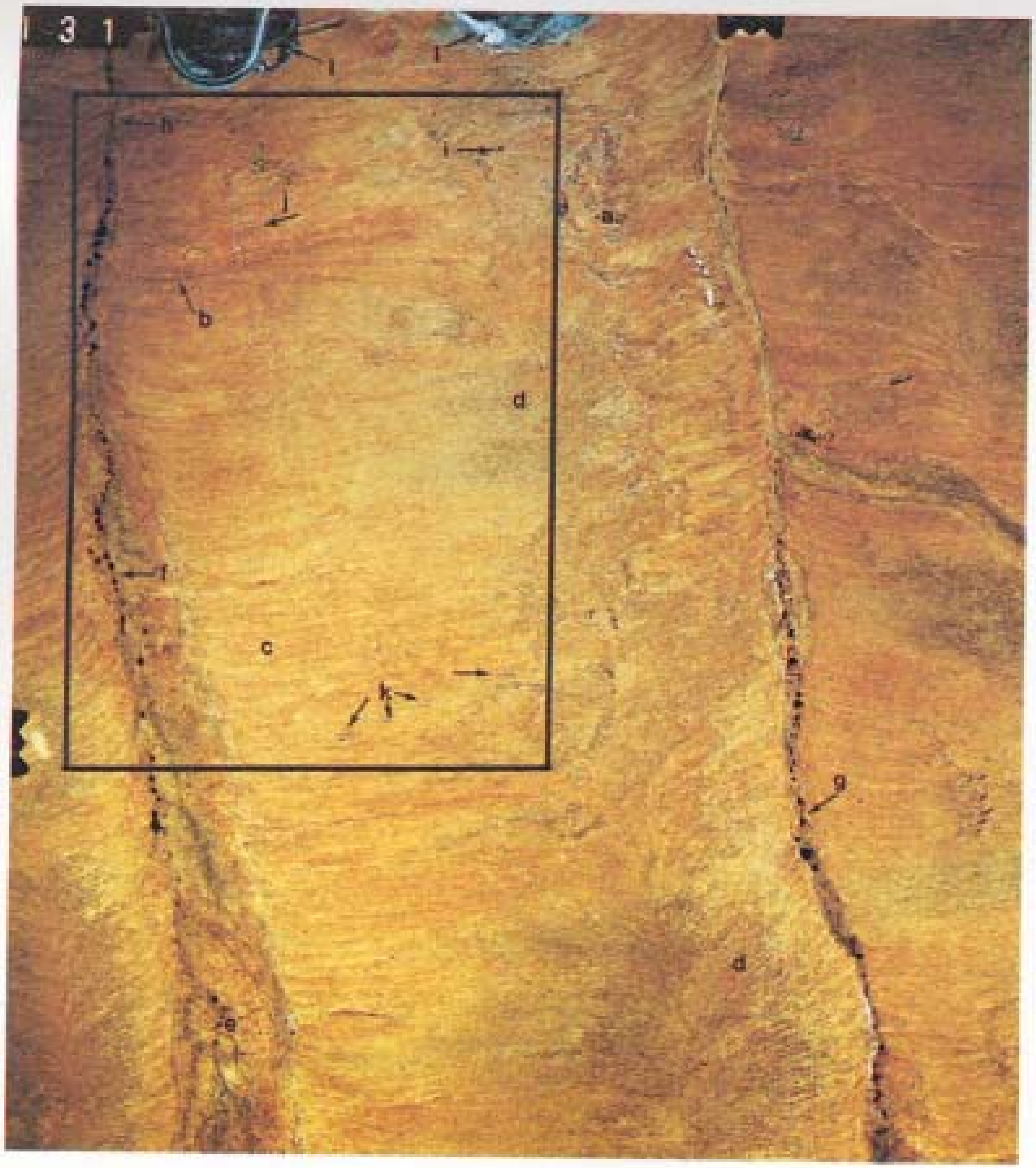
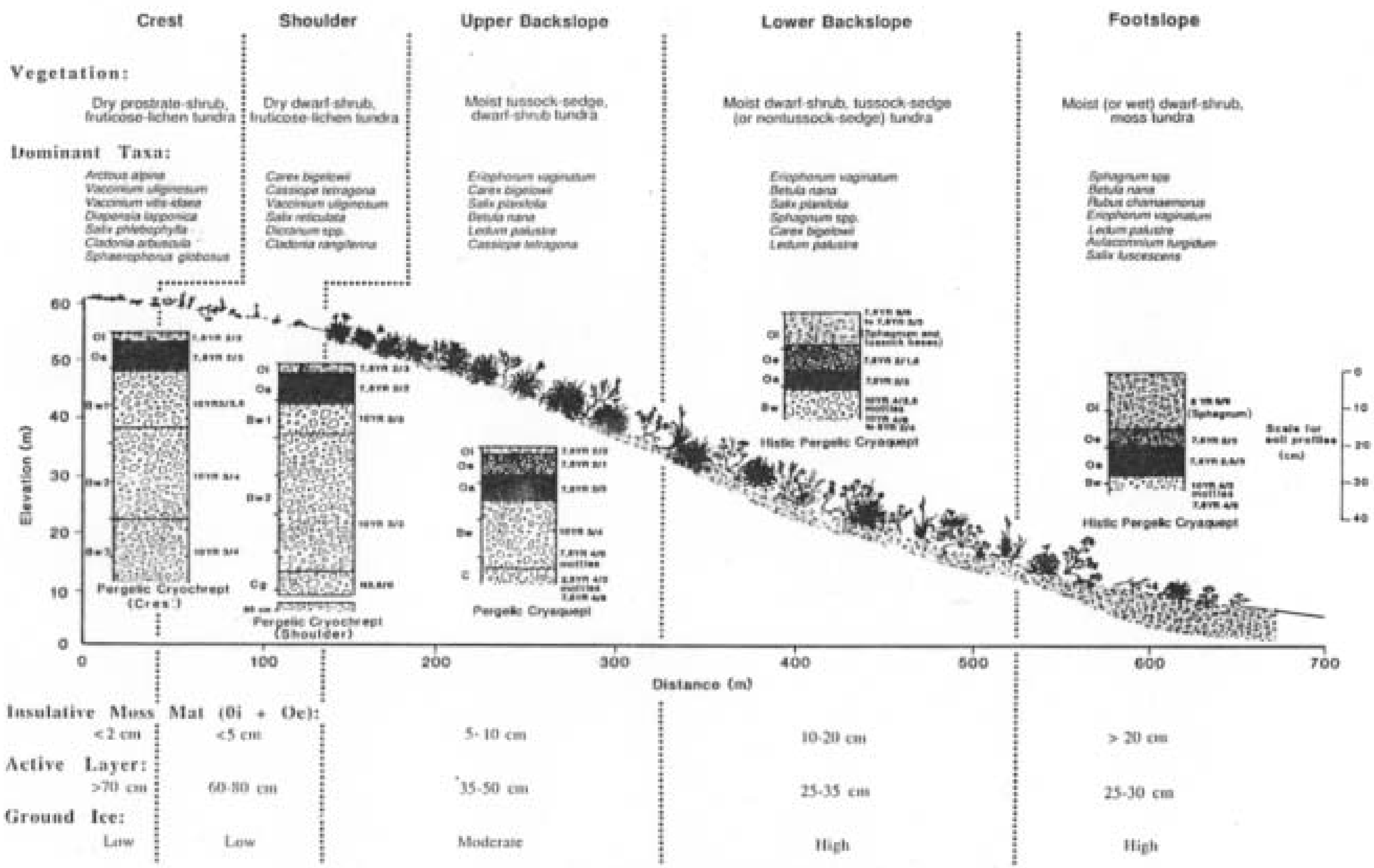
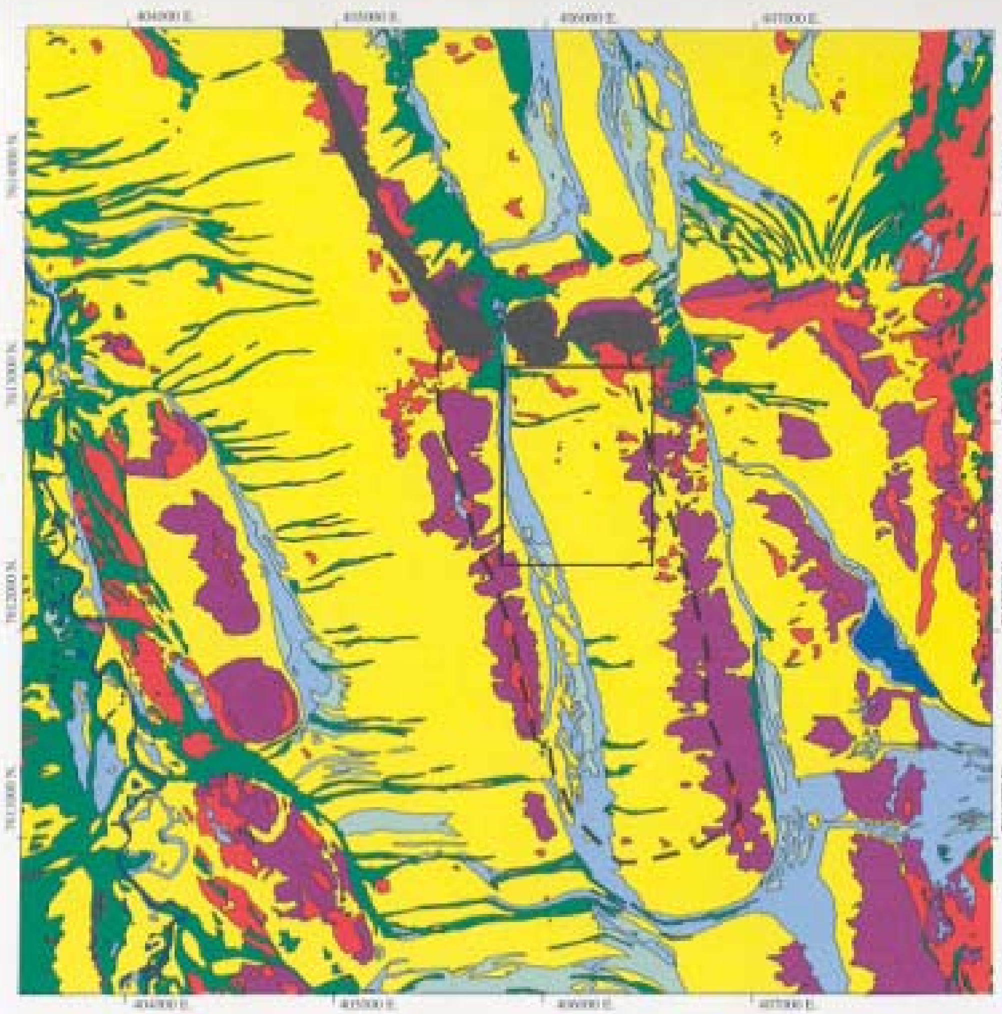


Fig. 4.4. Aerial color-infrared photograph of the Imnavait Creek research site. The *black rectangle* delineates the boundary of the geobotanical map (Fig. 4.6). ***a*** Exposed Sagavanirktok-age glacial drift; ***b*** well-defined hill-slope water tracks; ***c*** weakly defined water tracks; ***d*** nonsorted stripes; ***e*** colluvial basin; ***f*** beaded channel of Imnavait Creek; ***g*** Toolik river; ***h*** weir; ***i*** Wyoming snow gage; ***j*** pipeline for tundra watering experiment; ***k*** runoff plots; ***l*** gravel pad

West-facing slope at Imnavait Creek, AK

Idealized toposequence: Imnavait Creek Alaska





Vegetation Physiognomy

	Imnavait Creek Watershed %	Imnavait Creek Watershed Ha	R4D Region %	R4D Region Ha
Exposed Sites				
Dry prostrate-shrub, fruticose -lichen tundra	4.00	8.88	7.72	164.45
Snowbeds				
Dry or moist dwarf-shrub, fruticose -lichen tundra	15.33	34.04	11.06	235.60
Mesic Uplands				
Moist graminoid, dwarf-shrub tundra	62.09	137.86	54.56	1,161.74
Riparian Areas				
Moist or wet low-shrub tundra	2.84	6.31	12.01	256.02
Mires and Marshes				
Moist dwarf-shrub tundra	2.88	6.39	3.79	80.64
Wet graminoid tundra and wet graminoid, dwarf-shrub tundra	9.97	22.15	8.16	173.65
Water	0.00	0.00	0.70	14.83
Barren and Disturbed				
Rock, revegetated areas, and barren	2.89	6.40	2.00	42.57
	100.00	222.03	100.00	2,129.50

— - Watershed boundary

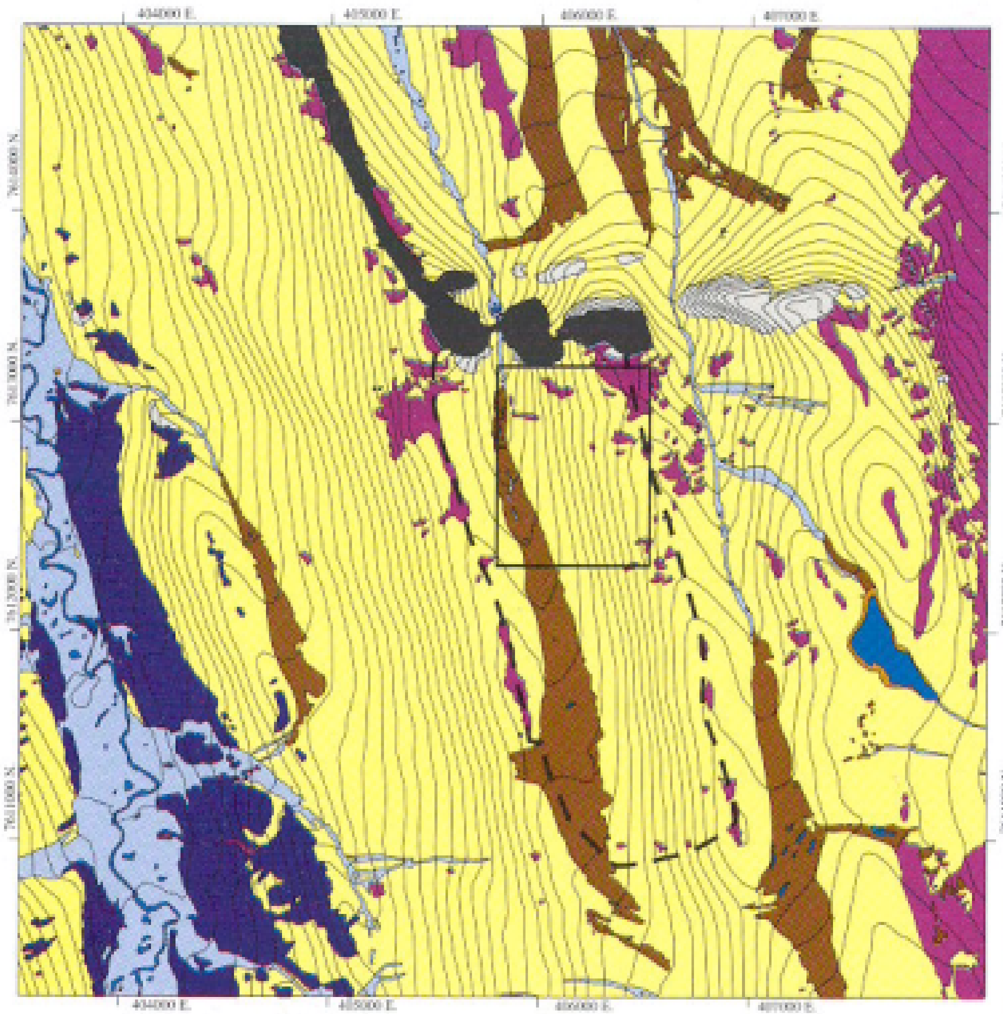
—— Imnavait Creek Intensive Research Site

0 250 500 750 1000

Meters

N

Fig. 4.5. Vegetation of the R4D region. *Dashed* and *solid lines* indicate watershed boundary and intensive research site, respectively



Surficial Geology

	Imnavait Creek Watershed %	Imnavait Creek Watershed Ha	R4D Region %	R4D Region Ha
Bedrock				
Sandstone and shale	0.70	1.56	1.09	23.24
Glacial Deposits				
Till	4.45	9.87	8.55	182.16
Fluvial Deposits				
Glaciofluvial outwash	0.00	0.00	4.40	93.69
Floodplains	0.33	0.74	6.52	138.92
Colluvial Deposits				
Basin colluvium	16.11	35.77	6.47	137.74
Hillslope deposits	75.48	167.60	70.33	1,497.58
Lacustrine Deposits				
Drained lake deposit	0.00	0.00	0.11	2.40
Other				
Lakes, ponds, streams	0.10	0.21	0.82	17.40
Disturbed	2.83	6.28	1.71	36.37
	100.00	222.03	100.00	2,129.50

Watershed boundary

Imnavait Creek Intensive Research Site

Contour Interval 5 Meters

0 250 500 750 1000

Meters

N

Fig. 4.2. Surficial geology of the R4D region. *Dashed line* indicates Imnavait Creek watershed boundary. *Solid line* indicates intensive research site of Fig. 4.1

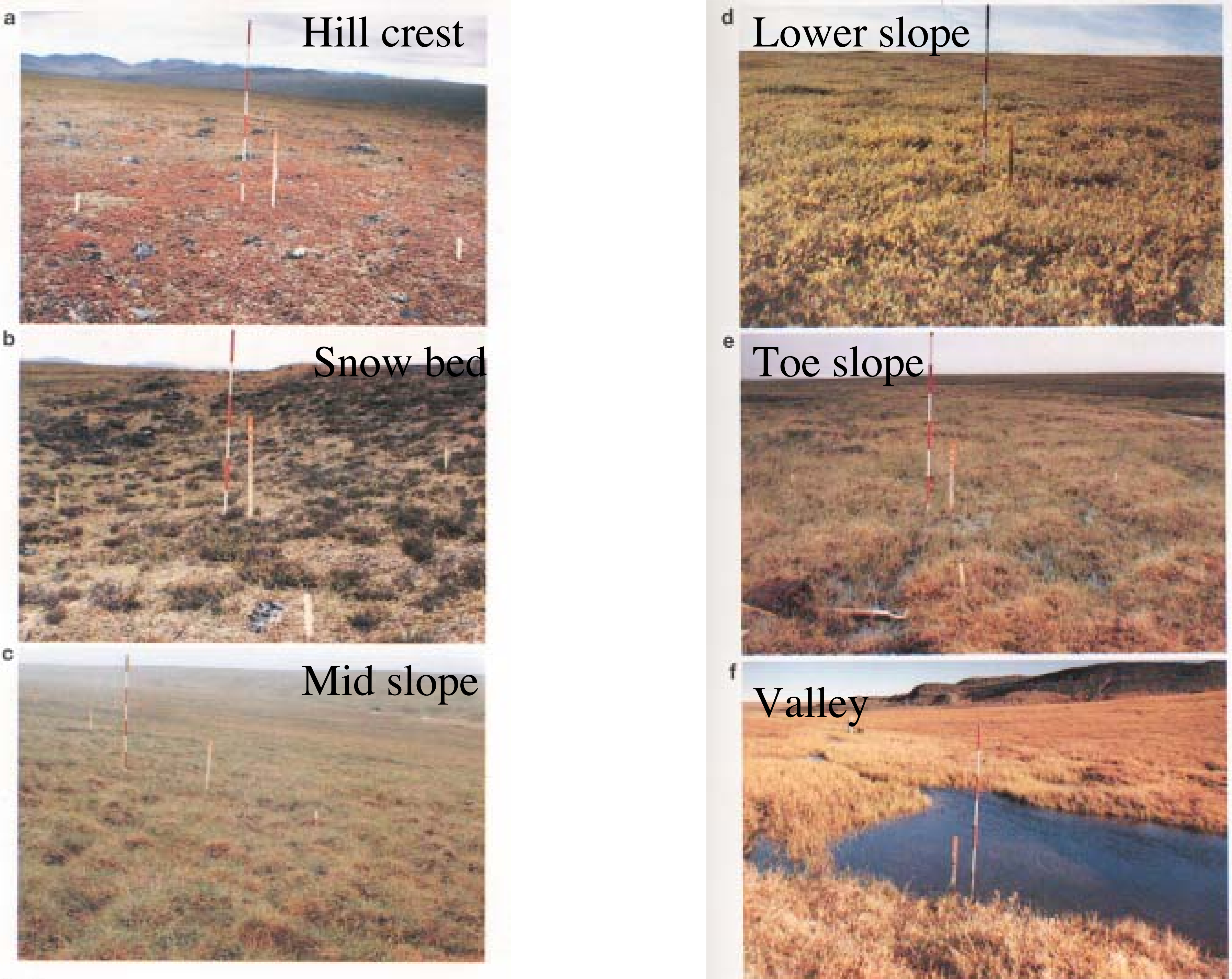

a
Hill crest
b
Snow bed
c
Mid slope
d
Lower slope
e
Toe slope
f
Valley

Fig. 4.7

Fig. 4.6. Vegetation of the Imnavait Creek intensive research site

Vegetation, Imnavait Creek Intensive Study Area

Community Type (GIS codes)	Ha	% of Map
Cetraria nigricans-Rhizocarpon geographicum (07)	0. 15	0. 22
Hierochloe alpina-Arctous alpina, subtype *Arctous alpina* (01)	0. 89	1. 29
Hierochloe alpina-Arctous alpina, subtype *Salix phlebophylla* (02)	0. 06	0. 09
Hierochloe alpina-Arctous alpina, subtype *Vaccinium vitis-idaea* (03, 04)	0. 82	1. 18
Hierochloe alpina-Betula nana (06)	1. 52	2. 21
Diapensia lapponica-Cassiope tetragona, subtype *Calamagrostis inexpansa* (05)	3. 34	4. 85
Diapensia lapponica-Cassiope tetragona, subtype *Nephroma arcticum* (09)	0. 17	0. 25
Sphagnum rubellum-Eriophorum vaginatum, subtype *Eriophorum vaginatum* (10)	20. 50	29. 74
Sphagnum rubellum-Eriophorum vaginatum, subtype *Carex bigelowii* (11)	1. 04	1. 51
Sphagnum rubellum-Eriophorum vaginatum, subtype *Cassiope tetragona* (14)	3. 09	4. 48
Sphagnum rubellum-Eriophorum vaginatum, subtype *Betula nana* (tussock tundra facies) (12)	15. 17	22. 01
Sphagnum rubellum-Eriophorum vaginatum, subtype *Salix planifolia ssp. pulchra* (tussock tundra facies) (13)	6. 16	8. 94
Sphagnum rubellum-Eriophorum vaginatum, subtype *Betula nana* (shrubland facies) (15)	6. 21	9. 01
Sphagnum rubellum-Eriophorum vaginatum, subtype *Salix planifolia ssp. pulchra* (shrubland facies) (16, 17)	4. 96	7. 20
Eriophorum angustifolium-Salix planifolia ssp. pulchra (26)	0. 33	0. 48
Salix chamissonis-Carex aquatilis (25, 19)	0. 23	0. 34
Eriophorum angustifolium-Carex aquatilis (21, 22,)	0. 08	0. 12
Sphagnum lenense-Salix fuscescens (23, 24)	3. 04	4. 41
Sphagnum orientale-Eriophorum scheuchzeri (20, 28)	0. 85	1. 22
Hippuris vulgaris-Sparganium hyperboreum (29)	0. 05	0. 08
Barren and miscellaneous vegetation types (08, 18, 30, 33, 34)	0. 23	0. 34
Water (31)	0. 03	0. 03
Totals	68. 92	100. 00

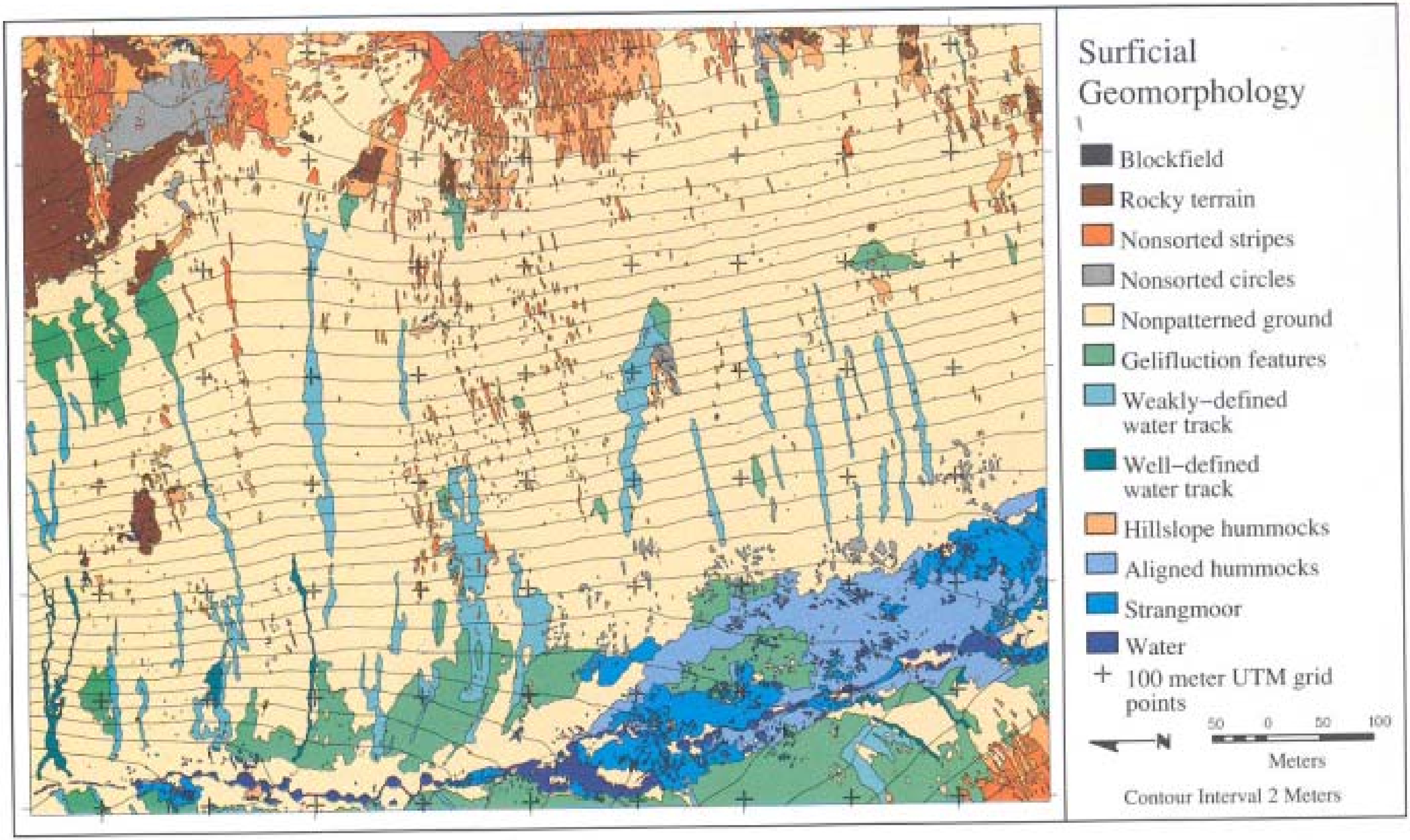
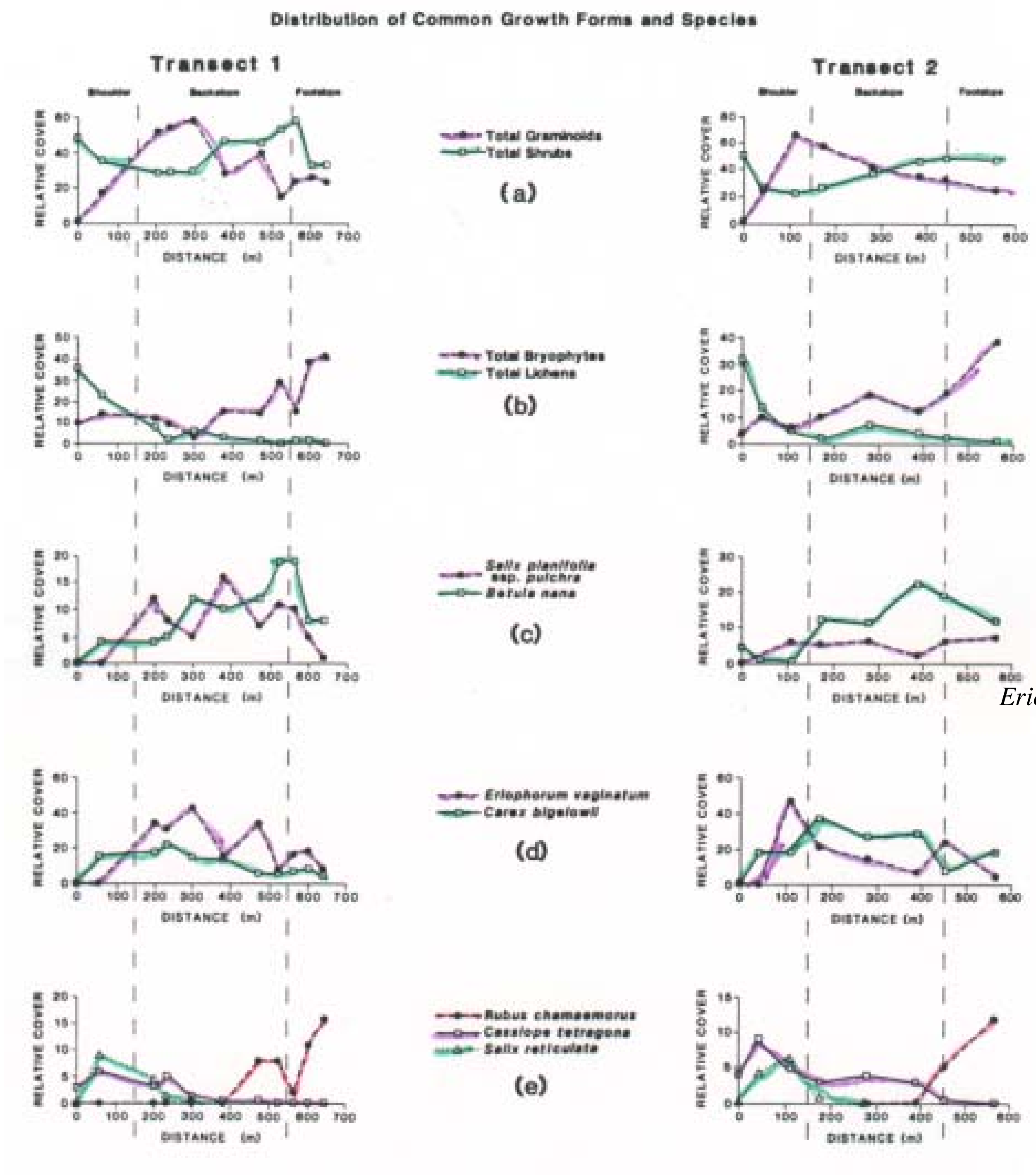


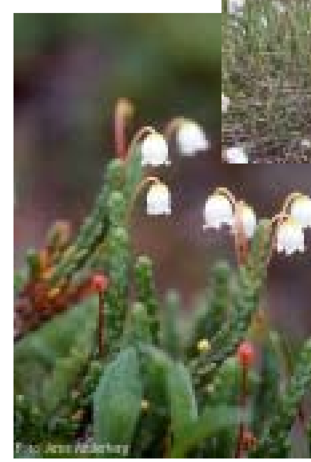
Fig. 4.3. Surficial geomorphology of the R4D intensive research site shown in Fig. 4.1

Trends in major growth forms and species along two toposequences

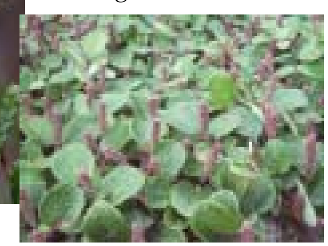


Rubus chamaemorus

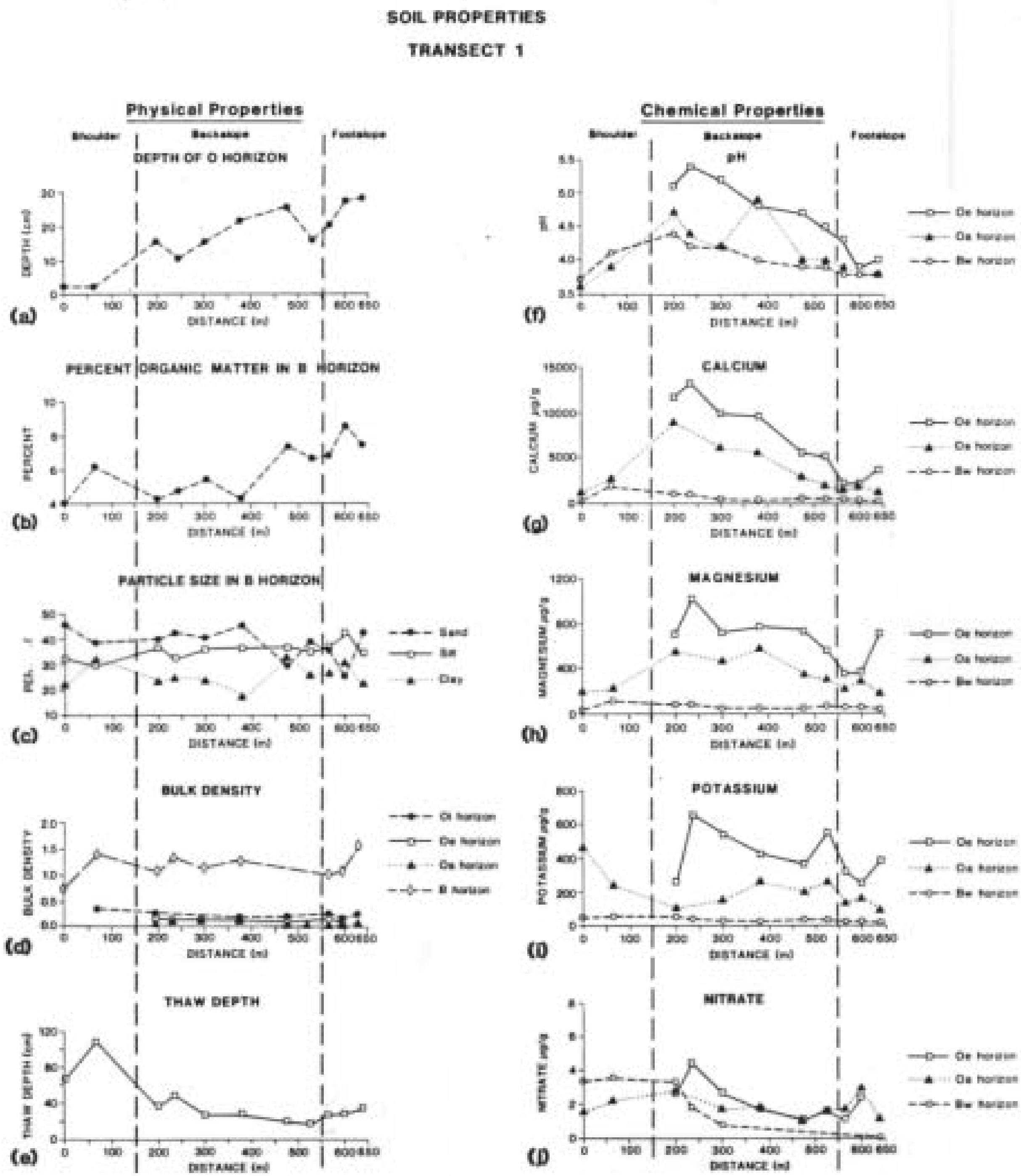
Eriophorum vaginatum



Cassiope tetragona



Salix reticulata



Trends in soil physical and chemical properties