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BIOPHYSICAL CLASSIFICATIONS FOR TWO ATLANTIC MARITIME REGIONS: SOUTH WALES, BRITAIN AND THE MARITIMES, CANADA.

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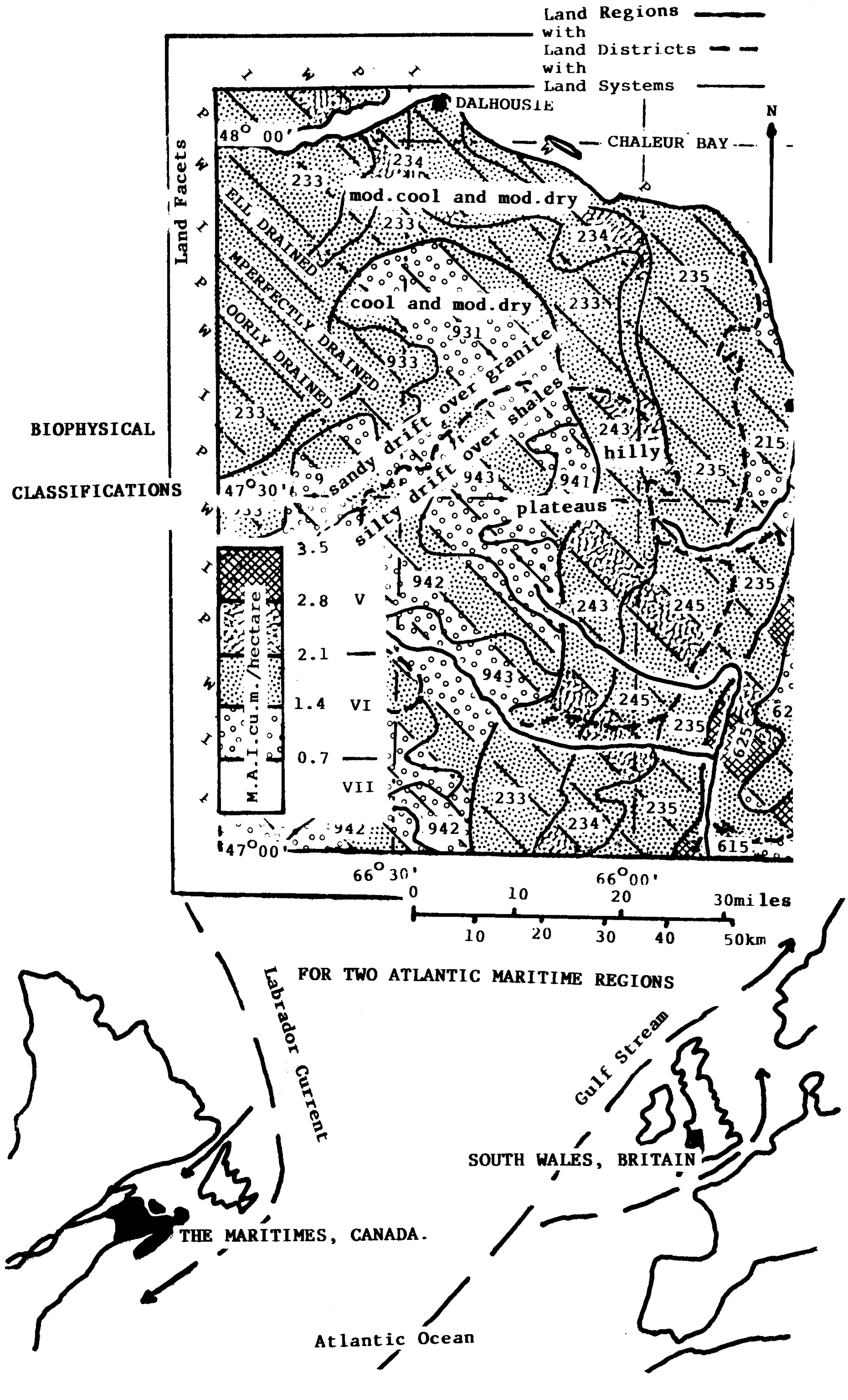

BIOPHYSICAL
CLASSIFICATIONS
FOR TWO ATLANTIC MARITIME REGIONS
Land Regions
with
Land Districts
with
Land Systems
Land Facets
DALHOUSIE
CHALEUR BAY
N
48° 00'
47°30'
47°00'
66° 30'
66°00'
mod.cool and mod.dry
cool and mod.dry
sandy drift over granite
silty drift over shales
hilly
plateaus
ELL DRAINED
MPERFECTLY DRAINED
OORLY DRAINED
233
234
235
243
245
215
931
933
941
942
943
615
625
M.A.I.cu.m./hectare
3.5
2.8
V
2.1
1.4
VI
0.7
VII
0
10
20
30miles
10
20
30
40
50km
Labrador Current
Gulf Stream
SOUTH WALES, BRITAIN
THE MARITIMES, CANADA.
Atlantic Ocean

CONTENTS

This paper is a study of some of the many interacting physical and cultural facets of two "cultural landscapes", situated either side of the Atlantic Ocean. A flexible classification is proposed for allowing the most useful appraisal of comparisons and contrasts.

INTRODUCTION

The Land Research and Regional Survey Division, CSIRO (Commonwealth Scientific and Industrial Research Organization), mapped Land Systems in the Hunter River Valley, where each Land System was a landform or a combination of naturally associated landforms interacting with the geology, soils and vegetation. The survey was undertaken by a multi-disciplinary team (Galloway et al., 1963). Later, the Australian Federal Government financed relocation of farmers on the basis of this extensive (rather than intensive, large scale survey), moving those upon Vertisols ("cracking" soils) and Solonetzic (salty) soils originally colonized by early immigrants, to areas more suitable for farming. Clayey Vertisols are difficult to farm because of their intractable consistency and sensitivity to pedoturbation (churning), while Solonetzic soils are salty and toxic unless managed expensively.

In the Mackenzie River Valley of the Northwest Territories various extensive biophysical surveys were undertaken by the Canadian Federal Government (eg. Heginbottom, 1973; Kurfurst, 1973; Crampton, 1973, summarized with the results of social impact studies by Hunt et al., 1974), and by consortiums such as Arctic Gas and Foothills Pipelines under the auspices of the Berger Commission Inquiry. Mapped distributions of permafrost environments aided later construction of the Norman Wells Oil Pipeline from Norman Wells in the lower Mackenzie River Valley into Alberta such that the minimum environmental damage was caused. Construction of the Trans-Alaskan Oil Pipeline from Prudhoe Bay on the Arctic coast to Valdez on the south coast of Alaska was based upon a biophysical survey which indicated where the pipeline should be carried above ground, or trenched where the ground was less sensitive to disturbance. In these surveys the Land System (as defined above) was used as the mapping unit.

To allow rapid mapping of large areas, the Land Systems must be identifiable in air photographs so that extrapolation can be undertaken from sites selected for detailed examination. These site investigations allow determination of the catenary sequence of soils and associated vegetation across each landform in a Land System, each unit within a catena being a Land Facet which, together, become subdivisions of that Land System. Land Systems can be grouped within a smaller number of Land Districts, each representing a particular geological or surficial deposit, which can be grouped within a few Land Regions, each an eco-climatic region or ecoregion. Since meteorological data is rarely sufficiently dense to allow a continuous climatic subdivision of the land necessary for a biophysical classification, the vegetation is often used to extrapolate the available data over larger areas into Land Regions.

Thus, the smallest land divisions, the Land Facets can be shown as parts of a catena, or they may be discussed as members of Land Systems shown on maps. Land Systems are often shown on maps combined within Land Districts which, depending upon the scale, can be mapped as units of Land Regions. This stratified land classification procedure has to be flexible if it is to be useful. The detail which is useful varies from study-area to study-area.

Too often the value of a particular biophysical classification to the user of the classification is diluted by the desire of the field worker for the greatest possible precision, not justified by the available field evidence, and which is beyond the comprehension of the user who has a very different specialization. Consequently, much useful land classification work has been ignored by potential users. Of course the user must be expected to make an effort to understand, but so must the land classifier who has the most field experience necessary to make practical generalizations. It is sad to remember those many biophysical classifications that have filled the potential users with awe because of their perceived technological skill, but which have not been used.

Many specialists worked prior to the Northeast Coal Project, each producing detailed maps and reports but, at no time was all of this essential information brought together within one composite map readily understandable by engineers involved in the development. A considerable investment in skills lacked final clout. A biophysical survey in the lower and central Mackenzie River Valley identified areas sensitive to disturbance by pipeline construction activity. The most sensitive areas were clearly, starkly delineated on maps by colour or shading to have the maximum impact (e.g. Crampton, 1975). Engineers were obliged to take notice and, yet, each map presented was a composite of many interactions, knowingly simplified to draw attention. A good classification helps potential users to inter-relate several different disciplines such as geology, geomorphology and biology in a way that would not otherwise be possible.

In this study biophysical land classifications have been illustrated for two maritime areas, one to the east of the Atlantic Ocean, South Wales, Britain, warmed by the Gulf Stream and very different from the other area washed by the cool Labrador Current of the western Atlantic, the Maritime Provinces of Canada (front diagram). These classifications have been used as a reference framework within which to discuss such diverse subjects as agriculture, forestry, geomorphology and archaeology.

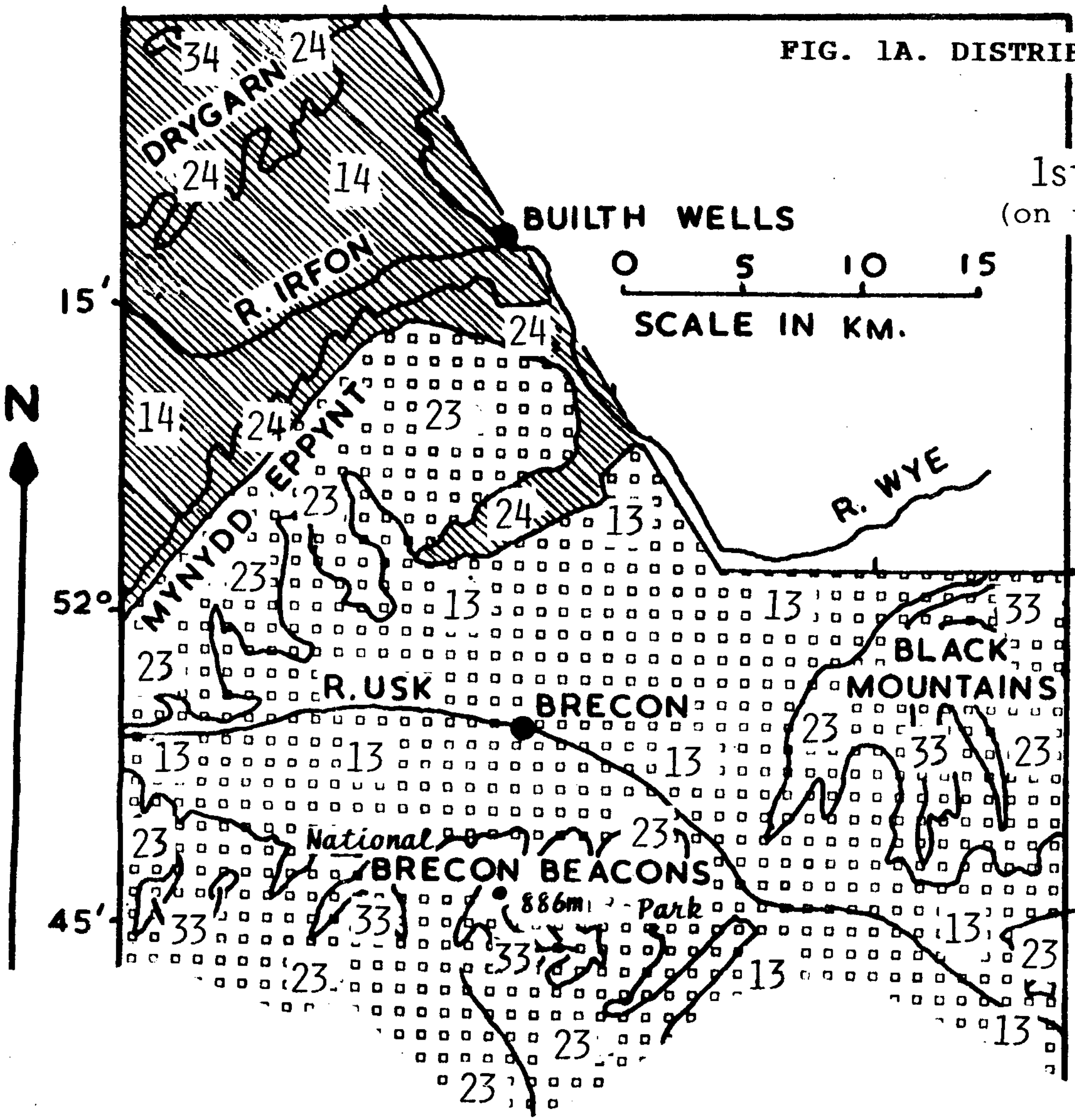
SOUTH WALES, BRITAIN.

LAND CLASSIFICATION

After about four thousand years of human activity in the area, South Wales is predominantly a cultural landscape. However, steep-sided river valleys, disturbed but retaining some elements of their original character, and pollen analyses of peat-bog basin soils (Crampton, 1968) suggest that mixedwoods with oak were once extensive in the region. There extent in lowlands and middlelands is now severely limited by farming. In the transition from relatively warm, lower lands into relatively cooler uplands these oakwoods become increasingly more stunted within isolated pockets. They merge into surrounding heathland and moorland, sharing many ground flora species. Only on the most exposed ridges at the highest elevations do they give way completely to heathland (dominated by ericaceous species) and moorland (dominated by grasses). Therefore, the ground flora associated with scattered remnants of these somewhat open, oak-dominated woodlands was assumed to be the most natural vegetation reflecting climatic differences between Land Regions in the study-area.

For the biophysical land evaluation of South Wales the area was divided into three Land Regions, each defined in terms of a specific range in elevation, an approximate mean annual precipitation, and characteristic graminoid species associated with oak woodland remnants on, first, well drained soils and,

FIG. 1A. DISTRIBUTION OF LAND REGIONS AND LAND DISTRICTS.



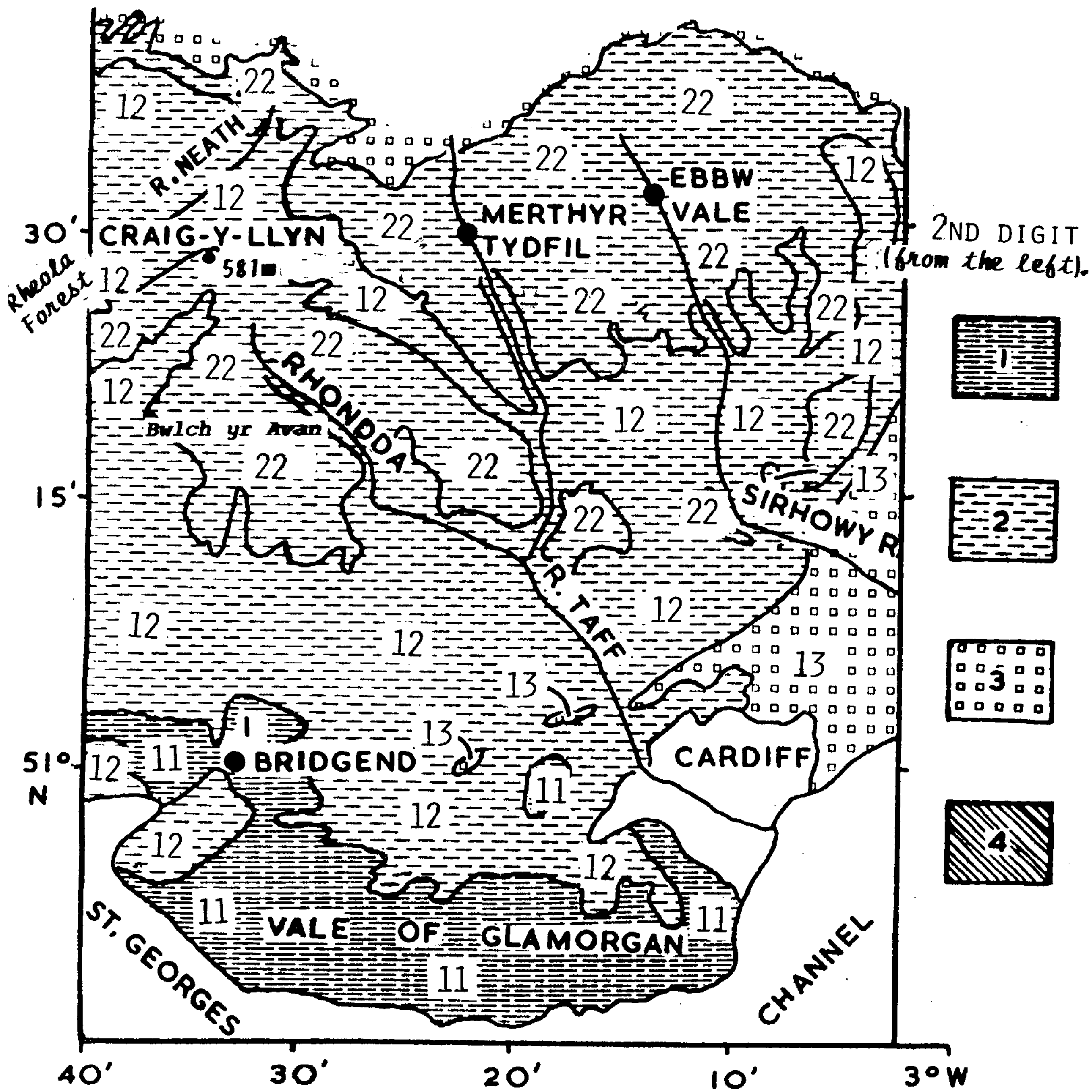
1ST DIGIT
(on the left)

LAND REGIONS IN SOUTH WALES BASED PRIMARILY ON DOMINANT SPECIES IN OAKWOOD REMNANTS, TRANSITIONAL TO OPEN HEATHLAND AND MOORLAND, AT DIFFERENT ELEVATION INTERVALS ASSOCIATED WITH DIFFERENT CLIMATIC ENVIRONMENTS.

1 LOWLANDS AND MIDDLELANDS: RELATIVELY MARITIME CLIMATE: MEAN ANNUAL PRECIPITATION ABOUT 800 mm. CHARACTERISTIC GROUND FLORA SPECIES: FALSE BROME-GRASS & TUFTED HAIR-GRASS. 0 - 300 m.

2 UPLAND RIDGES AND VALLEYS: RELATIVELY COOL CLIMATE: MEAN ANNUAL PRECIPITATION ABOUT 1,700 mm. CHARACTERISTIC GROUND FLORA SPECIES: MAT-GRASS & PURPLE MOOR-GRASS. 301 - 600 m.

3 MOUNTAINS WITH EXPOSED RIDGES: ALPINE CLIMATE: MEAN ANNUAL PRECIPITATION ABOUT 2,500 mm. PURPLE MOOR-GRASS & DEER-SEDGE. 601 m. +



LAND DISTRICTS IN SOUTH WALES BASED ON GEOLOGICAL STRATA.

1 MESOZOIC SHALES AND LIMESTONES WITH LOCAL DOLOMITIC CONGLOMERATES.

2 CARBONIFEROUS SANDSTONES AND SHALES IN CENTRAL CROP: WITH LIMESTONES AND GRITS IN NORTH AND SOUTH CROPS.

3 DEVONIAN CALCAREOUS MUDSTONES AND SANDSTONES, WITH LOCAL GRITS AND CONGLOMERATES IN SOUTH CROP.

4 SILURIAN AND ORDOVICIAN SHALES, WITH LOCAL GRITS AND CONGLOMERATES.

THE TILL MANTLE IS CLOSELY RELATED TO THE UNDERLYING ROCKS.

LAND REGIONS (First digit - to left)

1 Lowlands and middlelands: relatively maritime climate: mean annual precipitation about 800 mm: characteristic ground flora species, false brome-grass and tufted hair-grass: elevation 0 - 300 m.

2 Upland ridges and valleys: relatively cool climate: mean annual precipitation about 1,700 mm: characteristic ground flora species, mat-grass and purples moor-grass: elevation 301 - 600 m.

3 Mountains with exposed ridges: alpine climate: mean annual precipitation about 2,500 mm: characteristic ground flora species, purple-moor grass and deer-sedge: elevation 601 m plus.

LAND DISTRICTS (Second digit)

0 1 Mesozoic shales and limestones with local dolomitic conglomerates.

0 2 Carboniferous sandstones and shales in central crop, with limestones and grits in northern and southern crops.

0 3 Devonian calcareous mudstones and sandstones, with local grits and conglomerates in southern crop.

0 4 Silurian and Ordovician shales, with local grits and conglomerates.

Land Districts in South Wales based on the Geological strata.

Land Regions in South Wales based primarily on dominant graminoid species in oakwood remnants, transitional to open heathland and moorland, at different elevation intervals and associated with different climatic environments.

LAND SYSTEMS (Third digit)

001 Coastal plains.

002 Undulating foothills.

003 Steep slopes.

004 Ridge plateaus.

005 Upland plains and gentle slopes

006 Mountain crests.

Land Systems based primarily upon the characteristic landforms, each associated with a characteristic soil and vegetation.

The distribution of Land Systems and Land Facets is illustrated within maps for selected study areas.

LAND FACETS (Fourth digit from left)

0001 Eutric Brunisols
over calcareous rocks and shales
0002 Gleyed Brunisols

0003 Dystric Brunisols over sandstones.

0004 Dystric Brunisols on moraines.

0005 Rego and Fera Gleysols on moraines.

0006 Humic Gleysols over sandstones.

0007 Humic Gleysols on moraine.

0008 "Podzols with gleying" over sandstones

0009 Placic Podzols.

0010 Rock outcrops.

Land Facets based primarily upon the soil type, associated with a certain drainage.

FIG.1B.

TABULATED LISTS OF LAND REGIONS, DISTRICTS, SYSTEMS AND FACETS.

Relief		Dominant soil	Oakwoods, mostly sessile oak* on freely drained soils, and pedunculate oak* on poorly drained soils	Heathlands and moorlands	*reference *Quercus petraea* (Matt.) Liebl. *Quercus robur* L.
Lowlands and Middlelands	over calcareous rocks	Eutric Brunisols	false brome-grass* dog rose*	ribwort plantain* dog's mercury* cuckoo pint*	*Brachypodium sylvaticum* (Huds.) Beauv. *Rosa canina* L. *Plantago lanceolata* L. *Mercurialis perennis* L. *Arum maculatum* L.
Lowlands and Middlelands	over calcareous rocks	Gleyed Brunisols	false brome-grass tufted hair-grass* dog rose ivy* wood loose-strife*	wood brome* wood-spurge* hairy St. John's wort* wild strawberry* primrose*	*Bromus ramosus* Huds. *Deschampsia caespitosa* (L.) Beauv. *Euphorbia amygdaloides* L. *Hedera helix* L. *Lysimachia nemorum* L. *Hypericum hirsitum* L.
Lowlands and Middlelands		Dystric Brunisols	tufted hair-grass wood meadow-grass* wood sorrel* bluebell* bracken*	common bent-grass* bracken*	*Agrostis tenuis* Sibth. *Poa nemoralis* L. *Oxalis acetosella* L. *Scilla nonscripta* L. Hoffm. & Link *Pteridium aquilinum* (L.) Kuhn
Lowlands and Middlelands		Rego/Fera Gleysols	ivy wood loose-strife	purple moor-grass* cross-leaved heath*	*Molinia caerulea* (L.) Moench *Erica tetralix* L.
Upland Ridges and Valleys	over some calcareous rocks	Upland Eutric Brunisols	common bent-grass sheep's fescue grass* ribwort plantain wild white clover* thyme* birds foot trefoil* mouse-ear hawkweed* yarrow* bulbous buttercup*		*Festuca ovina* L. *Trifolium repens* L. *Thymus serpyllum* agg. *Lotus corniculatus* L. *Hieracium pilosella* L. *Achillia millefolium* L. *Ranunculus bulbosus* L.
Upland Ridges and Valleys		Slope Dystric Brunisols	bracken tufted hair-grass creeping soft-grass* cock's-foot grass* wood sorrel dog violet* wild strawberry bentony* self-heal*	bracken wavy hair-grass* common bent-grass sheep's sorrel* heath bedstraw*	*Deschampsia flexuosa* (L.) Trin. *Holcus mollis* L. *Dactylis glomerata* L. *Rumex acetosella* (L.) Trin. *Viola canina* L. *Galium hercynicum* Weig. *Betonica officinalis* L. *Prunella vulgaris* L.
Upland Ridges and Valleys	Mountains with Exposed Ridges	Podzols with Gleying	bilberry* mat-grass* wavy hair-grass common bent-grass		*Vaccinium myrtillus* L. *Nardus stricta* L.
Upland Ridges and Valleys	Mountains with Exposed Ridges	Humic Gleysols on rock	purple moor-grass mat-grass bilberry heather* moor-rush* common hair-moss*		*Calluna vulgaris* (L.) Hull. *Juncus squarrosus* L. *Polytrichum commune* Hedw.
Upland Ridges and Valleys	Mountains with Exposed Ridges	Placic Podzols	heather dominant		
Upland Ridges and Valleys	Mountains with Exposed Ridges	Humic Gleysols in moraine	purple moor-grass deer-sedge cotton-grass* bog asphodel* bog mosses*		*Trichophorum caespitosum* (L.) Hartm. *Eriophorum angustifolium* Honck. *Narthecium ossifragum* (L.) Huds. *Sphagnum spp.*
	Mountains with Exposed Ridges	Alpine Regosols		deer-sedge* dominant	

Based on work with R.Garrett-Jones.

Fig. 2. Floral lists for oakwood remnants and heathlands across South Wales.

second, on imperfectly or poorly drained soils (Fig.1A). It was possible to find at least a few oakwood remnants in all three Land Regions. On the lowlands and middlelands of Land Region 1, mostly Orthic Eutric Brunisols occur on limestone low ridges nnd plains, and mostly Gleyed Eutric Brunisols in valleylands, in oakwood remnants associated with false brome-grass and tufted hair-grass on both better and less well drained sites, plus wood loose-strife on less well drained sites. (For simplicity, in this paper soil classification will be as in C.D.A., 1978, regardless of country). Over sandstones or in sandy till Orthic Dystric Brunisols are widespread where the drainage is good, grading through Gleyed Dystric Brunisols into Rego and Fera Gleysols where the drainage is poor, in oakwood remnants associated with tufted hair-grass and common bent-grass, wood sorrel and bracken on the better drained sites, plus wood loose-strife on the less well drained sites (e.g. Fig.2).

On middlelands in Land Region 1, grading into upland ridges of Land Region 2, mostly well drained, sometimes Eluviated (leached) Dystric Brunisols occur on steeper, lower slopes, and surficially imperfectly drained "Podzols with gleying" (Crampton, 1963) on less steeply inclined upper slopes, in oakwood remnants associated with bracken and tufted hair-grass on lower slopes, and mat-grass, bilberry (blueberry) and common bent-grass on upper slopes, respectively. Poorly drained, peaty Humic Gleysols, deep where there is till, become shallow over sandstones on ridge plateaus in Land Region 2, in oakwood remnants associated with purple moor-grass. Where limestones crop out, Orthic Eutric Brunisols are typical, in oakwood remnants associated with thyme and wild white clover in the ground cover. These edaphically and floristically richer swards can be seen from a distance as distinctly different from surrounding areas. They are preferentially cropped (and dunged) by mountain sheep, enhancing their fertility. In the mountains of Land Region 3 mostly peaty Rego Gleysols give way to Regosols on the most exposed sites, where there are oakwood remnants associated with purple moor-grass, giving way to deer-sedge across the most exposed sites. Along the transition between steep lower slopes and ridge plateaus there occur Orthic Placic (iron pan) Podzols, associated mostly with heather (Fig.2).

Land Region 1 incorporates the Vale of Glamorgan in the south, and adjoining, hilly parts of the South Wales Coalfield arcing around the eastern periphery of the study-area into the vales of the Rivers Usk and Irfon. Land Region 2 incorporates the higher Coalfield land around Ebbw Vale, Merthyr Tydfil and the Rhondda Valley, achieving its highest point at Craig-y-Llyn, and the adjoining Brecon Beacons - Black Mountains range on either side of the River Usk, with Mynydd Eppynt occurring on the north side of the River Usk and Drygarn on the north side of the River Irfon. Land Region 3 incorporates mountainous parts of the Brecon Beacons and Black Mountains in the centre, and of Drygarn in the north of the study-area.

Mesozoic shales and limestones of Land District 1 crop out in the Vale of Glamorgan, making this area unique in the study. Carboniferous sandstones and shales of Land District 2 crop out within the South Wales Coalfield, with peripheral outcrops of limestone and grits. Devonian mudstones and sandstones of Land District 3 crop out in the vale of the River Usk, with grits and conglomerates capping the highest parts of the Brecon Beacons - Black Mountains range. Silurian and Ordovician shales of Land District 4 crop out in the vale of the River Irfon, with local grits and conglomerates giving rise to higher land in the Drygarn mountains. Thin limestone outcrops in high Devonian, Silurian and Ordovician land give rise to the richer pastures of "alpine meadows", which can occur in Land Regions 2 and 3.

The tabulating of Land Facets and Systems, as well as Land Districts and Regions is shown in Fig.1B. The distribution of Land Facets and Systems, and their inter-relationships are illustrated for selected, local studies.

THE VALE OF GLAMORGAN

Shallow, silty clay and silty clay loam, near-neutral, well drained Orthic Eutric Brunisols and deeper, similarly textured, imperfectly drained Gleyed Eutric Brunisols over Mesozoic (and some Carboniferous) limestones occur extensively across the coastal plain of the Vale of Glamorgan (Fig.3). Petrographic studies of the underlying limestones (Crampton, 1960), and of the overlying soils (Crampton, 1961),

Fig.3. The coastal plain of the Vale of Glamorgan, formed over Mesozoic alternating limestones and shales cropping out along the coast. Remnants of the once extensive oakwoods have survived in steep-sided valleys cutting into the plain and back from the coastline. The silty, moderately well drained soils have been farmed since Roman times.

suggest that the character of these soils has been primarily influenced by the limestones, although secondarily by morainal and aeolian additions. North of the coastal plain, somewhat acid, shallow Orthic Dystric Brunisols and, especially, deeper pooly drained Rego and Fera Gleysols have been more strongly influenced by morainal additions brought by ice off northern uplands in the study-area (Fig.1) during the last glaciation. Locally, the poorly drained soils are peaty and Humic Gleysols.

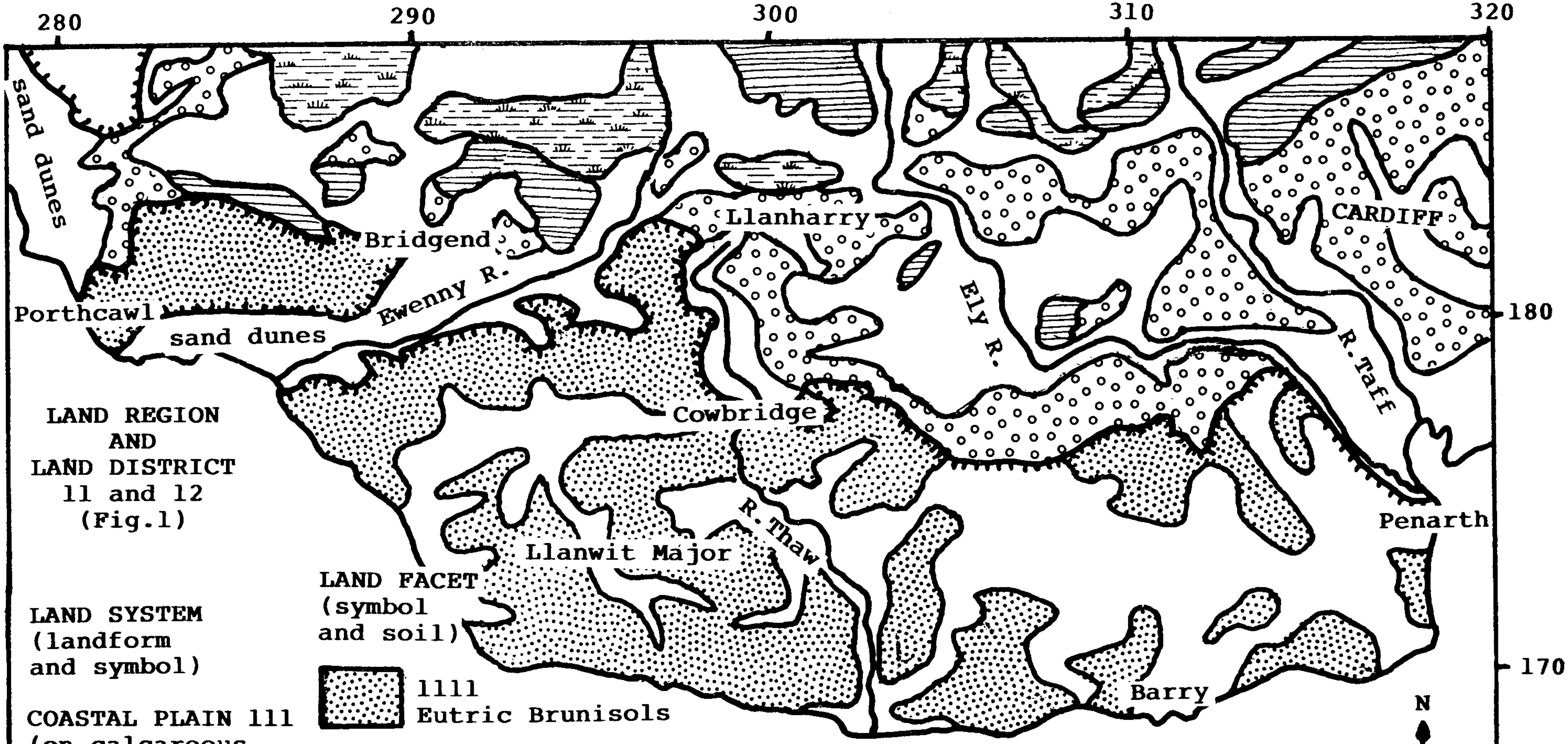
The land classification has been kept reasonably simple. Although there is a greater homogeneity in this part compared with elsewhere in the study-area, the differences classified have important implications. Land System 1 (coastal plains) (Fig.4) is coincident with Land District 1 (Mesozoic shales and limestones), and Land System 2 (undulating foothills) is coincident with Land District 2 (Carboniferous sandstones and shales, with limestones and grits of the southern crop in this case), both within Land Region 1 (relatively maritime lowlands and middlelands, with a mean annual precipitation of about 800mm). Oakwood remnants in less easily cultivated sites (Fig.3) have in the ground flora of both well and less well drained soils, false brome-grass and tufted hair-grass which, compared with other graminoids, better characterize the maritime climate associated with this Region.

Wireworm Infestation. Large populations of the click beetle and its larvae, wireworms, can build up in old grassland. The wireworms spend four to five years feeding and developing in the root mat before pupating. The adults emerge from the puparia, mate and lay eggs, continuing the cycle. During long, dry summers the wireworms move down into the most moist subsoil. On ploughing, this infestation feeds on the rotting turf during the first year, but during the second year they attack the near-surface root systems of crops, preferably the more nutritious cereal seedlings during spring, and also these and other maturing crops during late summer.

Standard volume soil samples are routinely collected by the National Agricultural Advisory Service, washed and sieved, and the number of wireworms present counted, the results being expressed per unit area (Fig.5). Populations under 375,000 per hectare are considered safe for all crops. Populations of 375,- to 750,000 may damage potatoe crops during late summer. Populations between 750,- and 1250,000 may damage cereal crops, particularly during spring, but can be controlled with seed dressings. Control of damage with seed dressings becomes progressively more difficult as the population increases, and with numbers greater than 1250,000 per hectare, treatment with insecticides is needed. National Surveys, particularly when old pastures were widely ploughed during the 1939-45 war years, have revealed that the greatest populations tend to develop in relatively finer-textured (silty clays), less acid, but not necessarily poorly drained soils. Infestation was found especially pronounced along the coastal plain of the Vale of Glamorgan (Fig.5).

In Land District 1 defining the coastal plain, the greatest infestation is more or less contained within two east-west belts, one on the coastal side and the other on the landward side of the District, each belt containing Orthic Eutric Brunisols of Land System 1111, shallow, near-neutral soils which are reasonably well drained despite their silty, clayey texture. Between these two belts there is Land System 1112 enclosing areas with deeper Gleyed Eutric Brunisols in which imperfect drainage occurs with the addition of more morainal material, where infestation is less. National Surveys revealed results which many found difficult to understand in that greater infestation tended to be associated with finer textures, but which textures did not produce imperfections of drainage. Such a texture-drainage relationship is unusual.

Infestation was greater with the fine textures of Land System 1111 associated with good drainage, the unexpected relationship, and less in the equally fine textures of Land System 1112 associated with imperfect drainage, the expected relationship. Presumably, during dry summer periods when the wireworms need to penetrate deeper into the soil profile in order to survive, they find suitable conditions in shallow Eutric Brunisols where the fine subsoil textures hold the moisture, but where the underlying limestones permit good drainage.



LAND REGION AND LAND DISTRICT 11 and 12 (Fig.1)

LAND SYSTEM (landform and symbol)	LAND FACET (symbol and soil)
COASTAL PLAIN 111 (on calcareous Mesozoic strata)	1111 Eutric Brunisols
	1112 Gleyed Eutric Brunisols
UNDULATING FOOTHILLS 122 (kame and kettle - mound and depression - moraine)	1223 Dystric Brunisols over sandstones
	1224 Dystric Brunisols in moraine
	1225 Rego and Fera Gleysols in moraine
	1227 Humic Gleysols (peaty, in moraine)

FIG.4.

DISTRIBUTION OF LAND FACETS (SOIL DRAINAGE) WITHIN LAND SYSTEMS (LANDFORMS) IN THE VALE OF GLAMORGAN.

Transverse Mercataor Grid

Scale

0 5 10Km

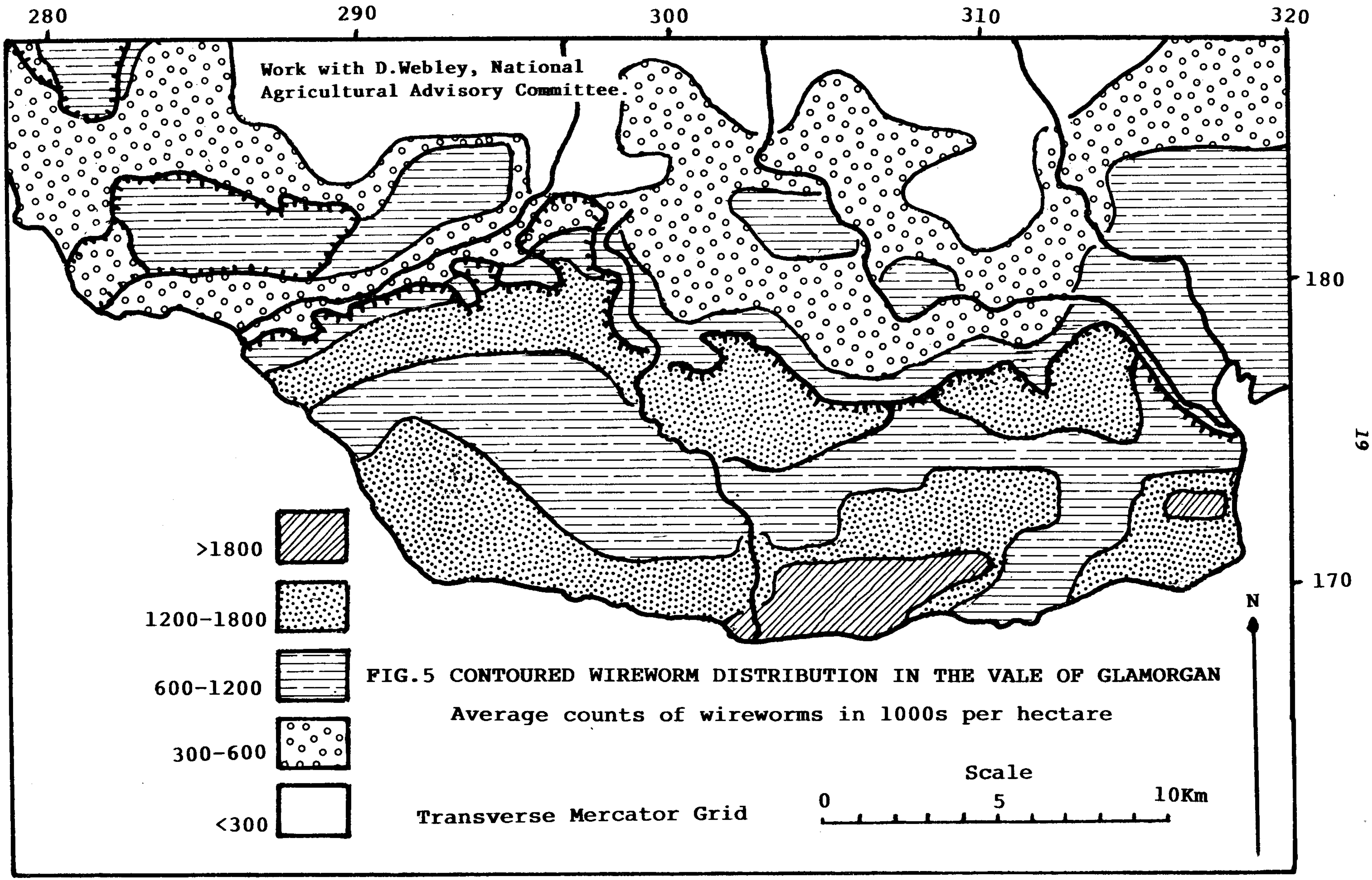


FIG.5 CONTOURED WIREWORM DISTRIBUTION IN THE VALE OF GLAMORGAN

Average counts of wireworms in 1000s per hectare

In Land District 2 defining kame and kettle terrain across the lower foothills of the South Wales Coalfield, the expected texture-drainage relationships prevail, the soils are more acid and infestation is generally less, decreasing northwards with increasing elevation.

THE VALE OF NEATH

The Vale of Neath (Fig.6) is situated within the central South Wales Coalfield, formed of Carboniferous rocks. The strata can be divided into underlying Coal Measures in which shales and coals are more important, and overlying Pennant Grit in which sandstones are more important. The grits form a knot of converging ridges at Craig-y-Llyn (Fig.7), with their plateaus deeply dissected (e.g. Fig.8). The Vale of Neath has been eroded along a major fault, downthrowing the Pennant Grit and its associated landscape to the east (Fig.9A).

Although the Coalfield generated its own ice sheet and glaciers during the last glaciation, more powerful ice movement from the north, off the southern flanks of the Brecon Beacons (Fig.1A) split either side of Craig-y-Llyn, one glacier moving down the Vale of Neath to erode its typical U-shape and to greatly affect soil distribution.

Tributaries of the River Neath that have eroded deep ravines into the valley sides which are difficult to reafforest and which, therefore, have preserved oakwood remnants (Fig.6). In their

Fig.6. View northwest from Rheola Forest across the River Neath valley, showing japanese larch on lower slopes where there is bracken, and scots pine on upper slopes where the vegetation is ericaceous. Oak remnants can be seen alongside the tributary flowing downvalley to join the River Neath.

lower courses false brome-grass and tufted hair-grass testify to the milder climate of Land Region 1 (terrain unit 1230) with about 200 raindays each year, mostly in winter. In their upper courses mat-grass (associated with better soil drainage), or purple moor-grass (associated with poorer soil drainage) testify to the cooler climate of Land Region 2 (terrain unit 2240) in which there may be more than 20 mornings each year with snow lying.

On the till-covered valley bottom not taken over by industry and communication, or too greatly modified for agriculture (Fig.6), the better drained morainal mounds are occupied by generally sandier Dystric Brunisols (terrain unit 1224), and the poorer drained morainal flats by generally siltier Rego and Fera Gleysols (terrain unit 1225). The subsoil is often compacted into a platy structure which is somewhat impervious to water, producing imperfect or poor drainage in the overlying soils which can extend up slopes normally associated with good drainage. It has been proposed that this compaction was produced by compression between expanding ice lenticles during periglacial phases, probably associated with late stages of the last glaciation (Crampton, 1965; 1985). This subsoil compaction also influences higher land on either side of the valley.

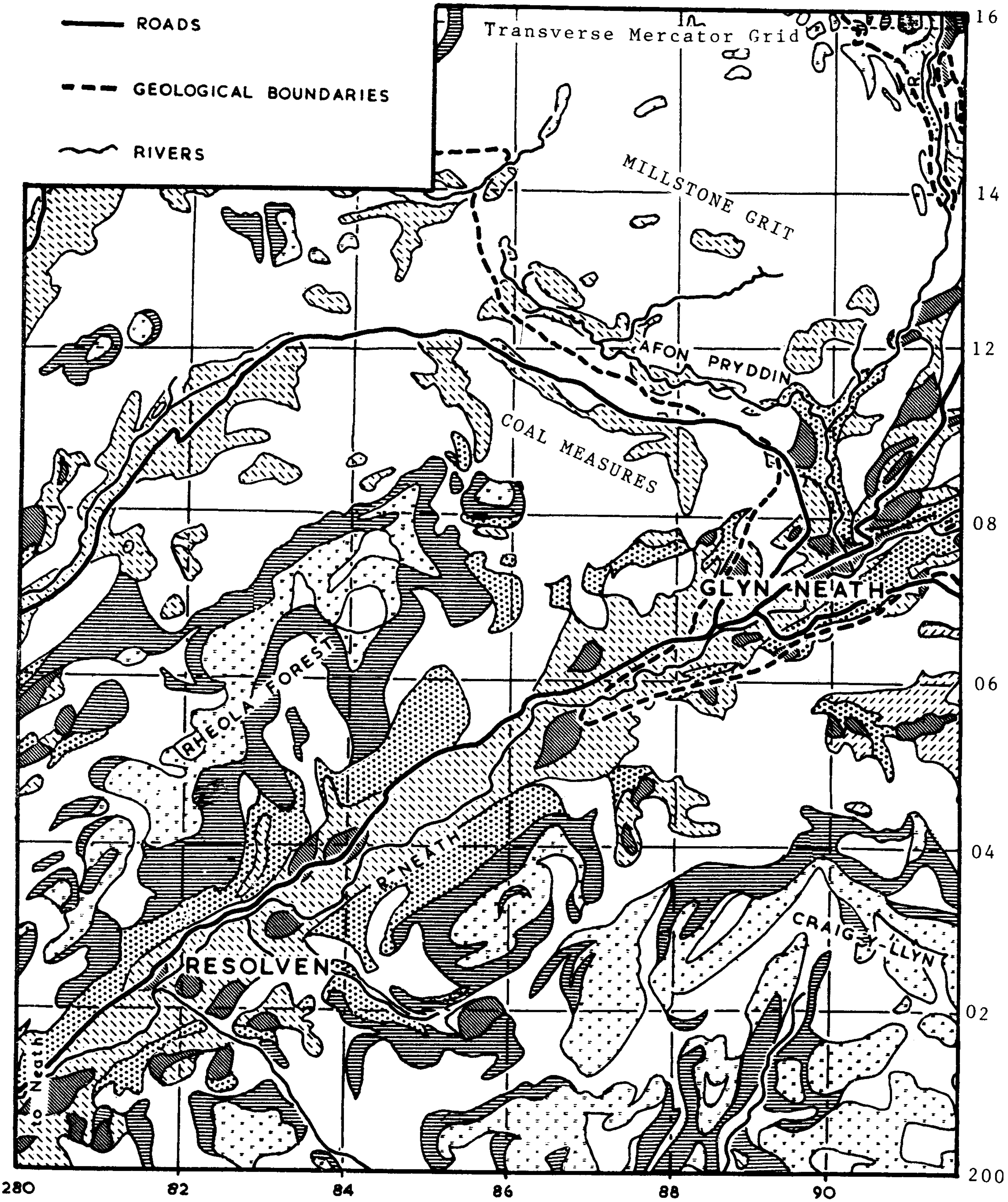
Steep slopes rising from the Vale of Neath have Dystric Brunisols (terrain unit 1223, Figs. 7 and 8) supporting abundant bracken with the tufted hair-grass characterizing better drained sites of

Land Region 1 (Fig.1A). These slopes become gentler as they merge into the higher land of Land Region 2. On these upper slopes carrying Podzols with gleying (terrain unit 1238, merging into 2238) (Fig.9A), with the mat-grass that characterizes better drained sites in the Region there is much bilberry, splashing upper slopes with reds, browns and bright greens during summer. A cooler climate and, presumably, the ericaceous vegetation are associated with the development of a fine prismatic structure in the eluvial horizon (just below the organic layer), the shells of the prisms being humus stained, and separated from anaerobic prism cores by a thin iron pan (Fig.9B). It has been proposed that anaerobic bacterial action with acid organic matter is responsible for this structure (Crampton, 1963). Placic (thick iron pan) Podzols associated with heather occur within a narrow, (generally unmappable) zone (terrain unit 223/49), separating upper, gentler slopes from ridge plateaus carrying Humic Gleysols with molinia (terrain unit 2246).

Productivity around Rheola Forest. Rheola Forest is that part of Coed Morgannwg (Glamorgan Forest) situated astride the Neath River valley in the west-central study-area (Fig.1A). Based on early mixed planting, the Forestry Commission has found that japanese larch grows most successfully on dry, steep lower slopes carrying Dystric Brunisols (compare Figs. 6 and 7). Locally elsewhere larch has been used as a fire break. Scots pine has preferentially been planted on upper, gentler slopes carrying Podzols with gleying because it does not show the check

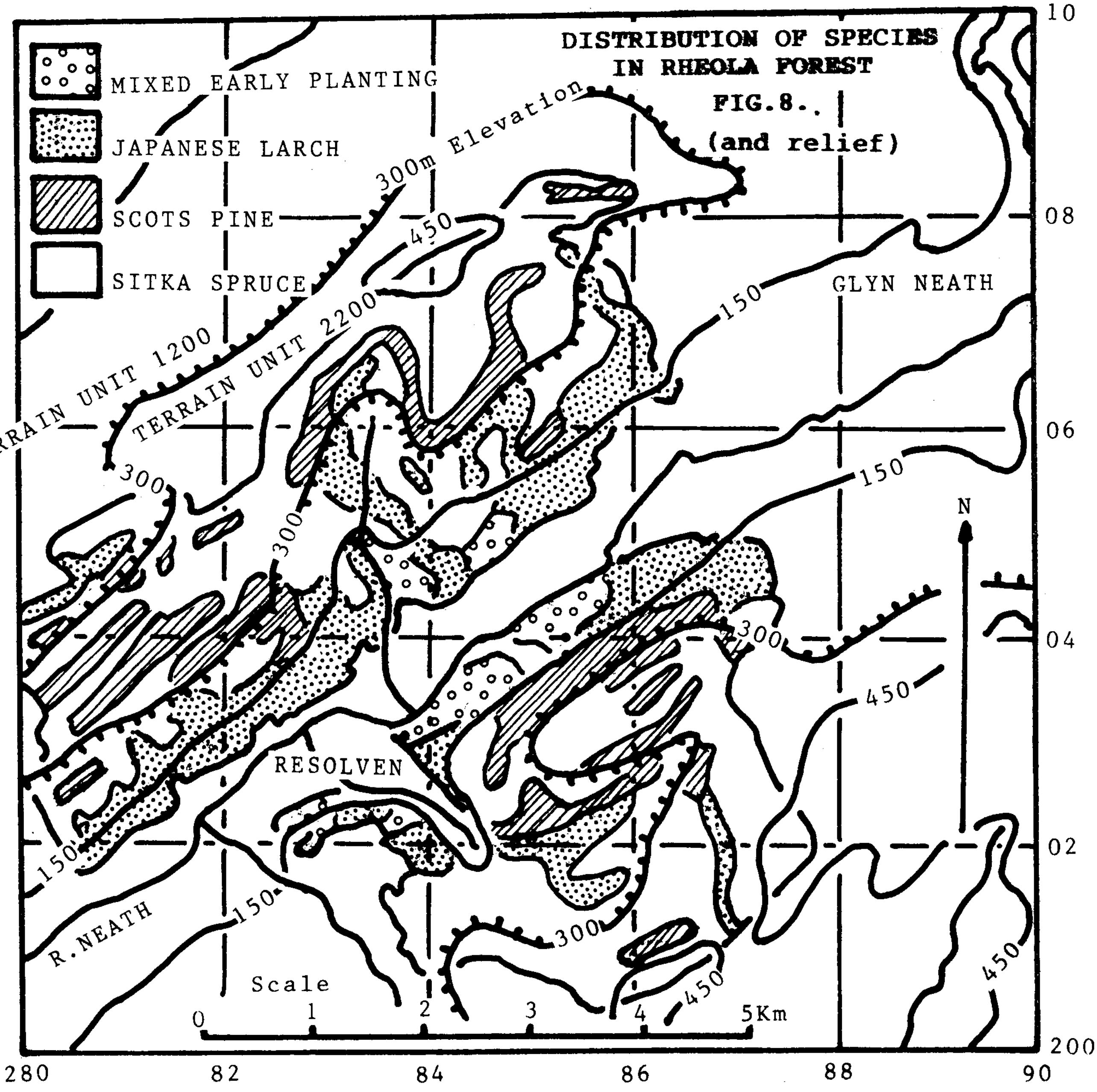
The scale and geographic orientation are the same for Figs. 7 and 8 .

FIG.7. SOIL MAP OF THE RHEOLA FOREST AREA.



LEGEND FOR SOIL MAP OPPOSITE

LAND REGION	LAND DISTRICT	LAND SYSTEM	LAND FACET	SYMBOL	
Lowlands and middlelands	Carboniferous sandstones	Undulating foothills	Dystric Brunisols in moraine	1224	
"	"	"	Rego and Fera Gleysols in moraine	1225	
"	"	Steep slopes	Dystric Brunisols over sandstones	1223	
Lowlands and middlelands to upland ridges and valleys	"	"	"Podzols with Gleying"	1/2238	
upland ridges and valleys	"	Upland plains	Humic Gleysols in moraine	1/2257	
Upland ridges and valleys	"	Ridge plateaus	Humic Gleysols over sandstones	2246	



DISTRIBUTION OF SPECIES IN RHEOLA FOREST
FIG.8..
(and relief)

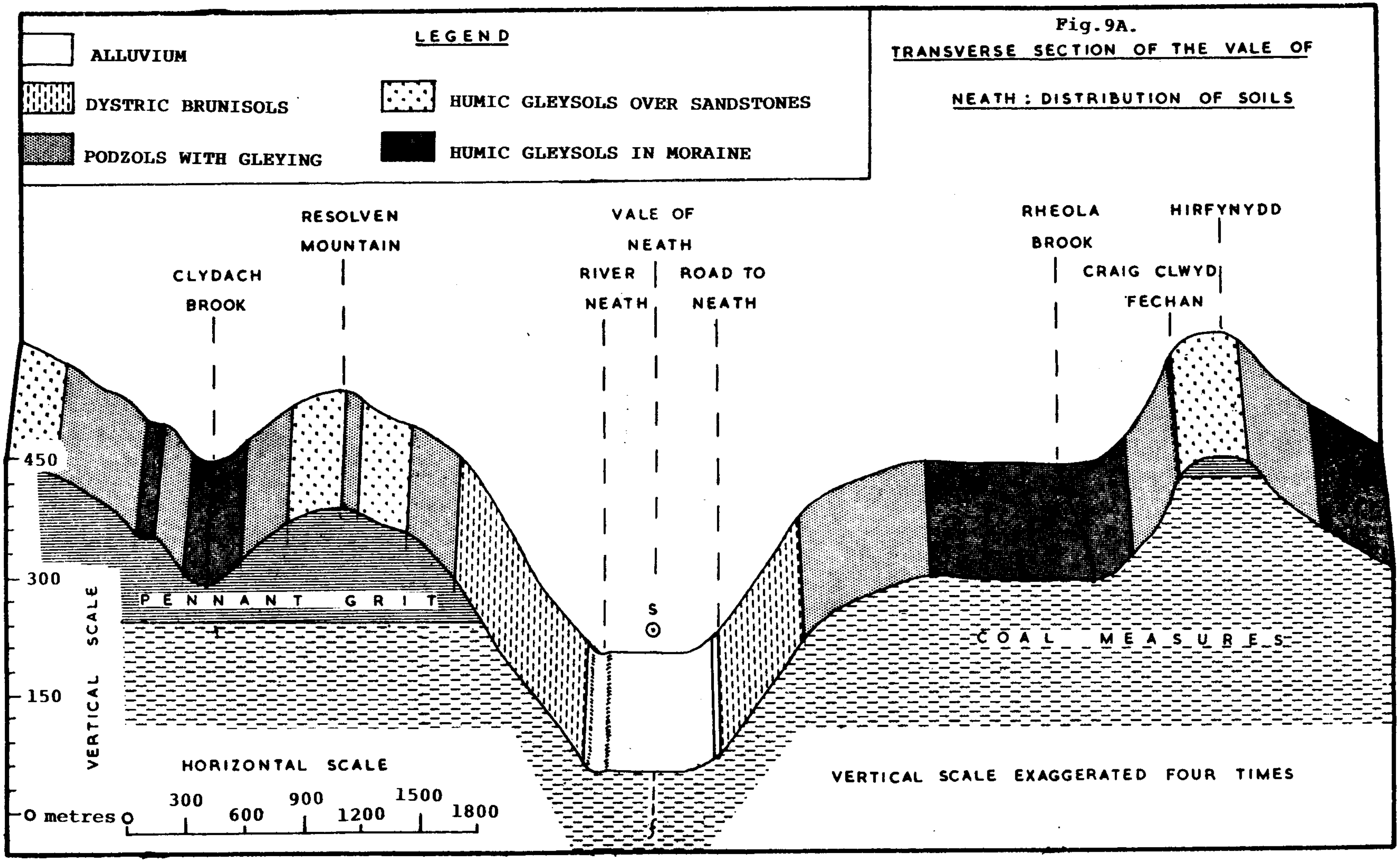


Fig.9A.
TRANSVERSE SECTION OF THE VALE OF NEATH : DISTRIBUTION OF SOILS

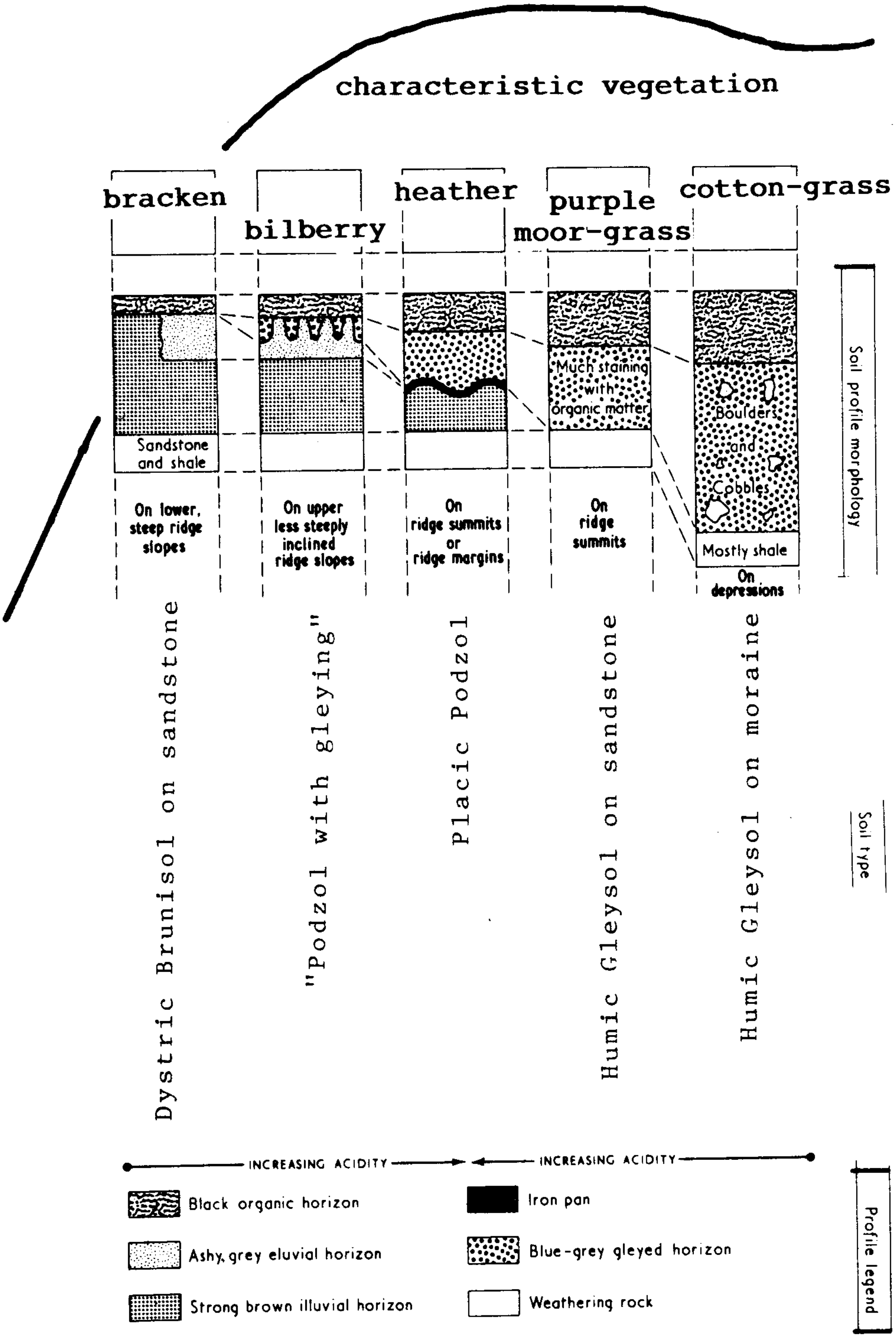


Fig.9B. Diagrammatic representation of typical soil profiles in the Rheola Forest area.

in growth associated with spruce planted in these ericaceous sites, discussed by Weatherell (1953) and Handley (1963). Spruce has been planted in peaty Humic Gleysols occurring on ridge plateaus, sitka spruce on the more exposed parts and norway spruce in broad depressions where there is a frost hazard. Spruce has been planted because, compared with other species, it grows better in these cool, wet soil sites covered with purple moor-grass, and not because peaty soils constitute the most suitable environment for optimum growth.

In the area investigated, forest planting by the Forestry Commission has tended to be related to a particular sequence of soil sites. For example, sitka spruce's good growth requires ample moisture reserves which could not possibly be met on steep, lower slopes. Accepting this policy of planting, and assuming an equal return for equal volumes of all species which is roughly true, the yield per hectare per annum, the mean annual increment tends to increase from steep lower slopes on to high ridge plateaus. Japanese larch planted in Dystric Brunisols on steep, lower slopes yields about 6 cu.m./hectare/annum, compared with about 8 cu.m. for scots pine planted in Podzols with gleying on upper, gentler slopes, compared with about 10 cu.m. for scots pine planted in Placic Podzols on ridge plateau edges, compared with about 16 cu.m./hectare/annum for sitka spruce planted in Humic Gleysols on ridge plateaus (Fig.10).

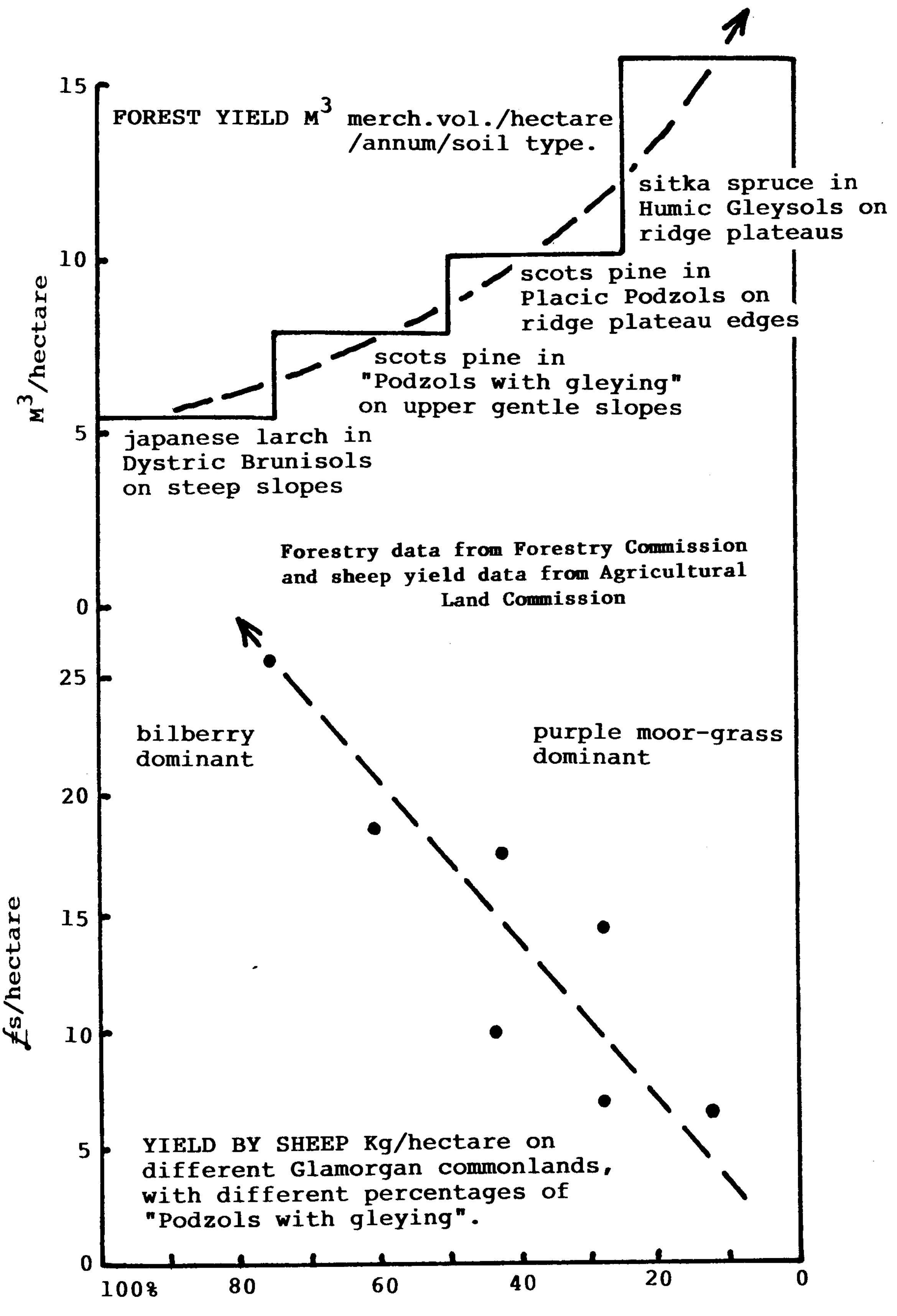


Fig.10. comparative estimates of productivity for use of land as forest or pasture in the South Wales Coalfield area.

If, and only if the present better growth of sitka spruce is maintained on ridge plateaus, its eventual yield will be greater than for the other species, despite the fact that japanese larch and scots pine are really better adapted to the soils and sites they occupy. This is because the rate of growth of sitka spruce is so much greater than for the other species, that even where there is poor sitka spruce growth on impoverished sites, its anticipated yield is still greater. However, since the "reservoir" of nutrients is small for Humic Gleysols in the cool climate of Land Region 2, already some of the more mature stands have gone into suppression, and they need thinning to restore good growth. The older stands were planted during the recession of the 1930s to create work, and now the Commission is having to develop new management procedures to harvest this crop. Japanese larch and sitka spruce are growing outside of their natural environment, as is scots pine since it ceased to be able to regenerate naturally long ago (Crampton, 1968).

Outside of reafforested land sheep graze the hill pastures, and their preferred range can be identified by a dense network of tracks which are concentrated upon upper slopes and the lower ridges. Especially in winter sheep withdraw from highly exposed ridges and plateaus, and so an interaction between aspect and elevation is one of several factors that influence sheep preferences. The nutritional value of the pastures is another important influence. These preferred grazings are preferentially dunged, enhancing their nutrient content. Bilberry associated particularly with Podzols with gleying (Fig.2) on upper, more gentler slopes (and with ridges summits at lower elevations) (terrain unit 1/2238) contains a wide variety of minerals, including phosphorus, and is rich in protein (Thomas and Trinder, 1947), which remain in the plant tissues throughout the year (Peart, 1951). Common bent-grass, also present in the pastures on slopes, contributes most to grazing nutrition during its spring growth (Hughes and Munro, 1963). On ridge plateaus (terrain unit 2246) purple moor-grass is abundant. Although the lush spring growth also contains much protein (Thomas and Trinder, 1947), its low palatability for sheep allows this grass to quickly become rank and useless. Thus, upper gentle slopes and the lower ridges carrying Podzols with gleying support the best available pastures for sheep and, in the study-area, are grazed by sheep throughout the year except during extreme weather.

It is possible to plot the changing proportions of Podzols with gleying (having the more nutritious pastures) and, concomitantly, of Humic Gleysols (having the less nutritious pastures), for commonlands around Rheola Forest where data is available regarding their yield in terms of sheep. There is an approximate linear distribution suggesting that the estimated net output per unit area increases from low values where there is little extent of Podzols with gleying, to high values where there is a great extent of these soils. The precise values cannot be considered useful; only the trend, which is the opposite of that for forest yield from these same soils. The yield from sheep increases from ridge plateaus down on to the slopes, whereas the yield from timber increases from the slopes up on to the ridge plateaus. The amount of data available, the very different investments required, subsidies and prices all complicate any attempt to compare relative productivities of these two upland activities, but there would seem to be mutual benefit from some degree of cooperation.

Soil Changes Wrought by Afforestation. Since about 1750 one of the major industrial regions of Britain has developed in the South Wales Coalfield valleys, based chiefly on coal and iron working, although the latter has now largely ceased to operate. Fitzherbert (1964) has described many of the special difficulties that arise in Glamorgan Forest because of the close proximity of forest and industry. Mining operations have created vast areas of disturbed land and, in particular, because the limited space available in the valleys is needed for industry, building and communications, most mining debris has been tipped on to the ridges and their sides which the forests chiefly occupy. Hence, successful afforestation of tips is an important task, one which becomes more important as useful coal seams are exhausted.

As soon as the main body of the tip has stabilized, a treed vegetation should be established. If left unvegetated for too long, compacted sub-surface layers can inhibit rooting. Because tip slopes are often steep, the tree root network helps fix the surface material in place. This surface material is generally dry and a tree canopy helps conserve moisture. A ground litter starts the nutrient cycle in these infertile sites. Birch and alder have colonized tips in Rheola Forest, the grey alder being especially useful because of its nitrogen-fixing capacity. After this pioneer vegetation, it would be an advantage if a commercial crop could be established.

In Rheola Forest mostly pine and a little larch have been used to colonize tips. Their nutritional requirements are not as great as those of the spruces, and they have a rapid early growth. A needle litter layer develops and, together pine and certain fungi help develop micro-biological activity in the tip's surface layers. After 15 years below scots pine a thin but discernible soil profile layering develops (Fig.11). A 4cm thick organic layer consists of surface litter merging down into brown, fibrous material, which rests upon black, well-decomposed organic matter, the whole bound into a tight mat by roots. A 1cm thick mineral soil horizon, stained with humus and showing soil structures, separates this profile from the underlying tip debris. After 15 years there is much less soil profile development below japanese larch, and the needle litter can be easily brushed off the tip. Wavy hair-grass grows profusely below both stands on these dry sites.

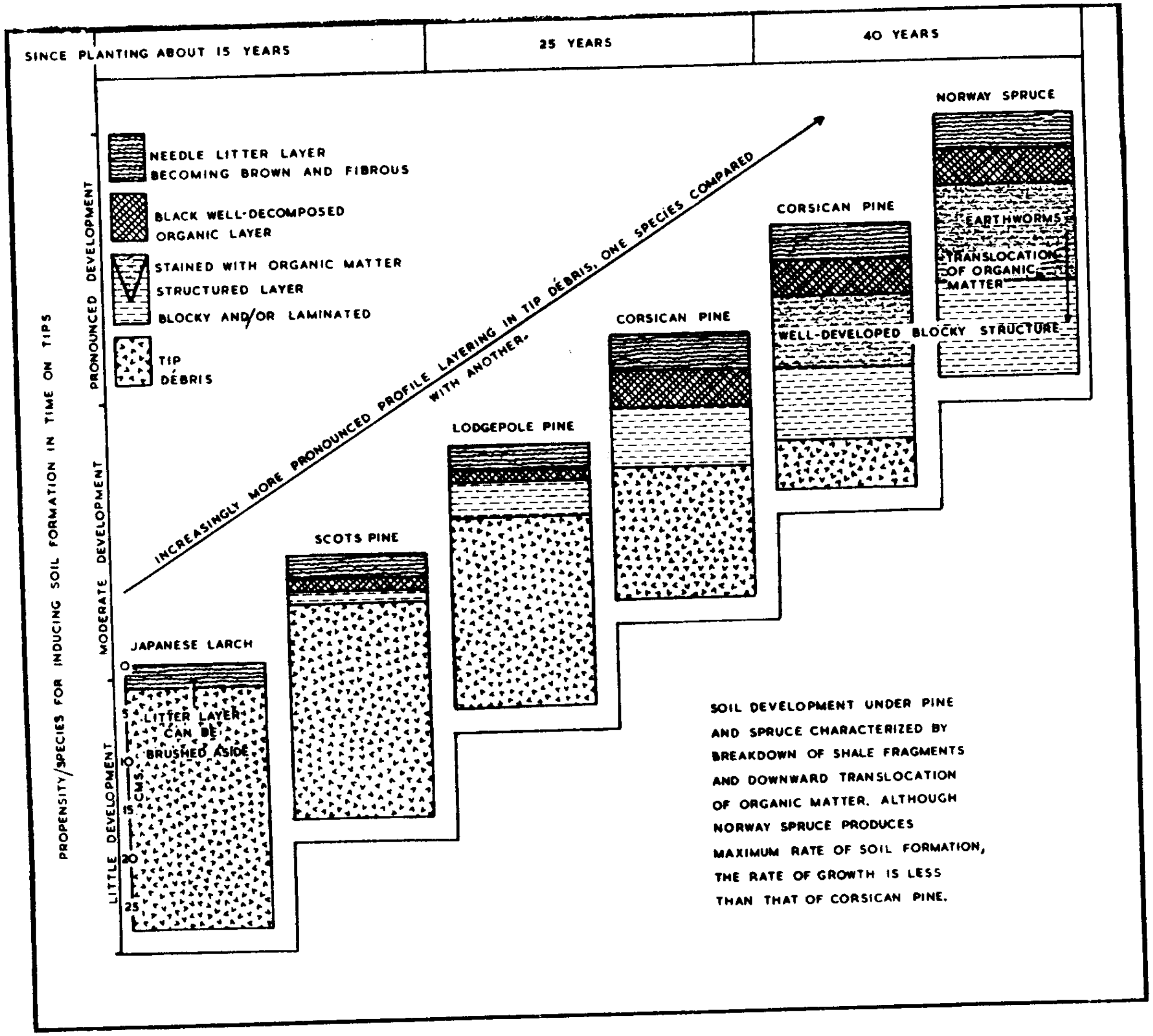


Fig.11.Observed potential of different tree species for inducing soil formation over time on the debris of coal tips.

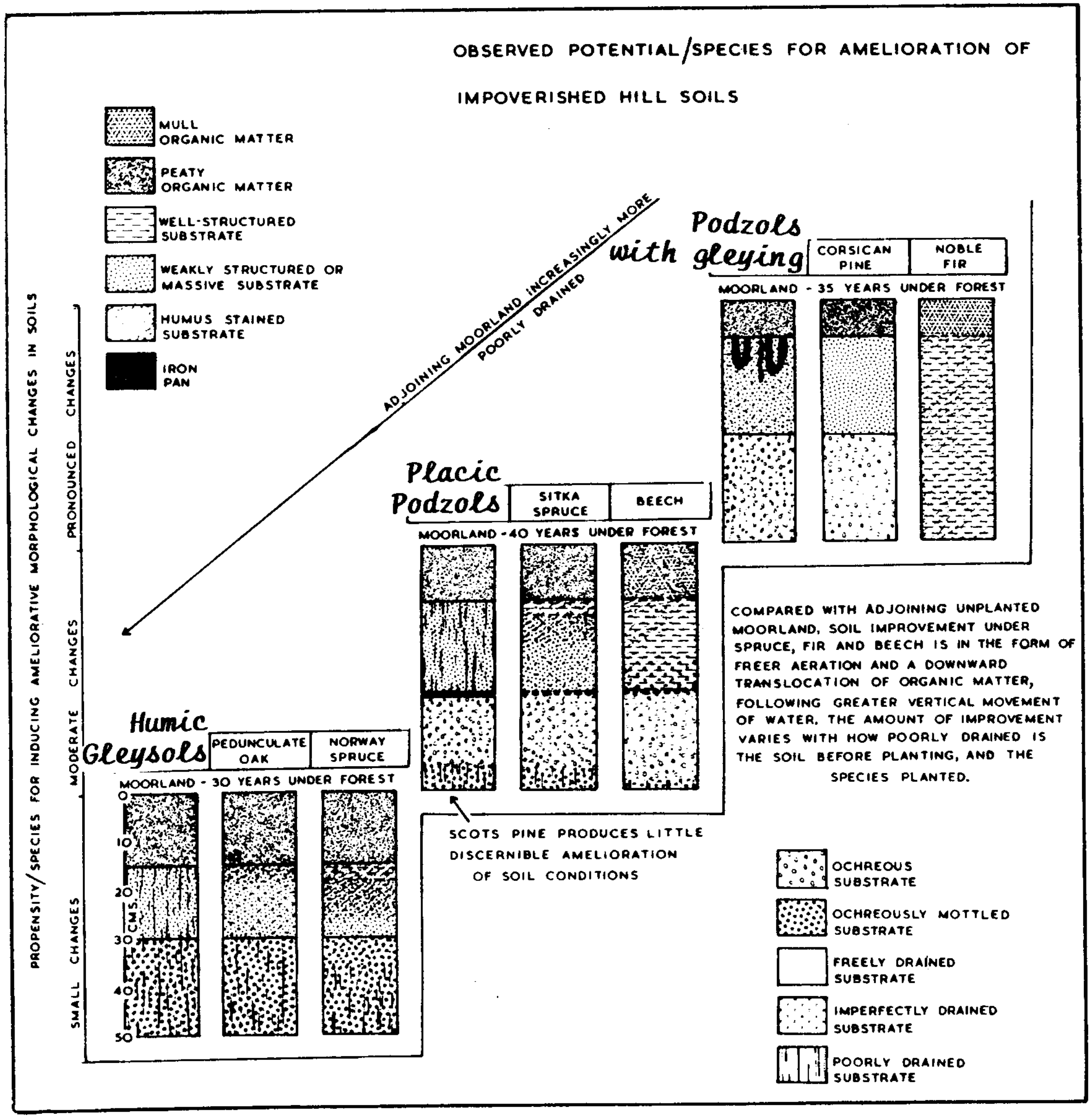
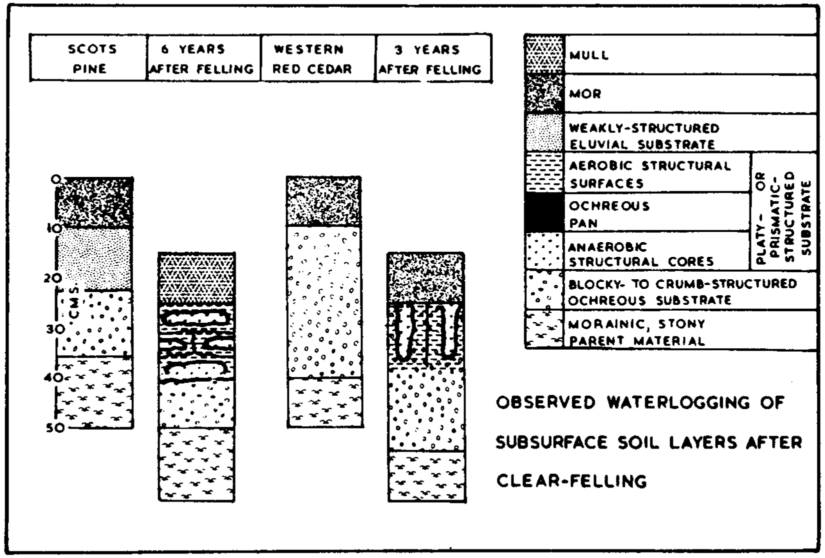


Fig.12.Observed potential of different forest plantation species to ameliorate impoverished hill soils.



Bilberry has spread from the surrounding upper slopes carrying Podzols with gleying to accompany the wavy hair-grass below the lodgepole pine after 25 years of growth. The 8cm thick profile shows distinct layering, with a blocky and weakly laminated structure having evolved in the mineral subsoil. The increasing thickness of profile development is broadly related to an increasing potential rate of growth from larch, through scots pine to lodgepole pine. Lower on the slopes and truly within Land Region 1, after 25 years growth below corsican pine the soil profile is 13cm thick and has a particularly well developed organic horizon of litter over well-decomposed humus, resting upon a 6cm thick mineral horizon having well developed soil structures. The underlying shaly debris is actively weathering and humus is moving down through the profile to further differentiate the profile horizonation. While the tip debris is neutral, upper soil layers have a pH value of 5.5, not too acid for herbaceous plants such as foxglove and wood sorrel to grow. Wood and Thirgood (1955) describe acidification as slower under trees compared with under grass.

40 years under corsican pine (Fig.11) produces a well-developed soil profile 23cm thick, with organic staining penetrating to a depth of about 15cm into blocky-structured subsoil, representing increasing bio-physical weathering and rate of turnover of nutrients. During the same period under norway spruce, although the rate of tree growth is not as good as that of corsican pine, the degree of soil profile development is greater, with

earthworms now moving into the subsoil. Off the tips in good soils, norway spruce is more productive than corsican pine but, if rapid soil formation is the only criterion governing afforestation of tips, then it is better to plant norway spruce.

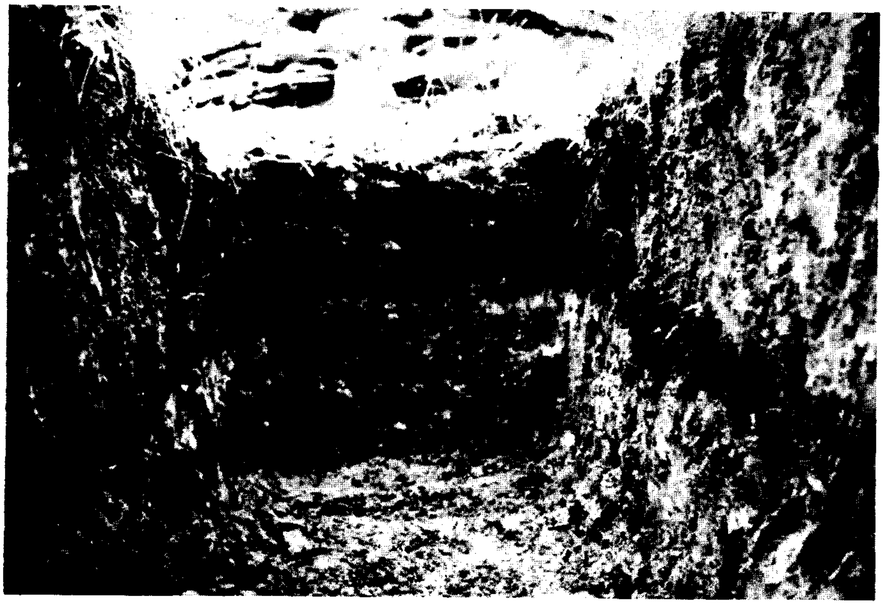
In general, trees use more water than grasses and other low vegetation. Wright (1955) and Rutter and Fourt (1965) found this true for scots pine, there being a noticeable drying out of soils around these tree bases. MacDonald et al. (1957) found sitka spruce and norway spruce particularly demanding of water, more so than the firs. Within the relatively cool and wet climate of Land Region 2, over Carboniferous rocks cropping out on upper steep slopes there are Podzols with gleying (terrain unit 2238). 35 years of transpiration by the forest has removed much more water from the soil compared with the adjoining moorland (Fig.12), drying out the soil to yield a profile more like the normal Orthic Podzol under corsican pine, and a Dystric Brunisol under noble fir with its richer litter.

Around ridge plateaus Placic Podzols under moorland show poor drainage above the iron pan, and in the lower parent material of the soil profile (Fig.12) (terrain unit 2249). Where afforestation of these soils has been undertaken, scots pine has caused little amelioration of poor drainage, while sitka spruce has produced a major improvement of soil drainage, the iron pan disintegrating into sections. Sitka spruce does not grow well in the heather associated with Placic Podzols, but its heavy demands of water for transpiration during 40 years have greatly improved soil conditions. Where Humic Gleysols across ridge plateaus (terrain unit 2246) have been afforested since 30 years ago, norway spruce has improved the drainage in eluvial and illuvial horizons (Fig.12). Although beech and pedunculate oak have produced comparable improvements in profile drainage, it is the spruces that have been chiefly responsible for causing organic matter to start moving down through the profile, a process that will eventually profoundly change the soil.

Just as afforestation extracts substantially more water from the soil compared with open moorland, so clear-felling and compaction of near-surface soil layers by heavy traffic causes a deterioration of drainage. Three to six years after felling western red cedar and scots pine, respectively, the development of anaerobic conditions mobilizes the iron to form pans (Fig.12), probably in a manner described by Crampton (1963), with a vertical configuration in small prisms, or a horizontal configuration within platy structures. Because most herbaceous species are shallow rooting, they are killed by sub-surface anaerobiosis, particularly after winter's snow has been lying for long.

Cross-Ridge Dykes. Dykes or demarcation banks, similar to Offa's Dyke along the Welsh Borderlands occur across the narrowest parts of ridge plateaus of the South Wales Coalfield, abutting against scarps or other natural obstacles, and aligned across the conjectured communication routes where they, presumably, protected the cantref of Glamorgan from the cantref of Brycheiniog to the north during early Medieval times (Fox, 1937). The usual structure is that of bank and ditch as at Bwlch yr Avan (Fig.1) across the ridge Mynydd Blaenrhondda on the west side of Rhondda Valley (Fig.1A). Fox (1937) supposed that a wooden palisade or thorn fence must have been an essential additional defence presented by these dykes. Along the crest of the ridge above Rhondda Valley there are Humic Gleysols over sandstones on Blaenrhondda ridge above the dyke (terrain unit 2249), and Placic Podzols (terrain unit 2249) on upper slopes dropping down below the dyke.

Analysis of pollen in soils on the South Wales uplands (Crampton, 1968) suggests that a spread of oak during Middle Bronze Age times was followed by the incursion of the epiphyte Polypodium during early Roman times, and by an extension of ericaceous species (mostly heather) during Medieval times. Graminoid pollen has dominated during later times. Earlier podzolization developing as heather spread was followed by gleization on less well drained sites as the grasses spread. Within Bwlch yr Avan dyke (and others) there is an upper Orthic (normal) Podzol developed within material thrown up from the ditch to create the bank in which graminoid pollen is dominant, over a very distinct, black organic layer (Fig.13) in which heather pollen is dominant. This buried organic layer represents the original land surface before the bank was constructed over an already-developed Orthic



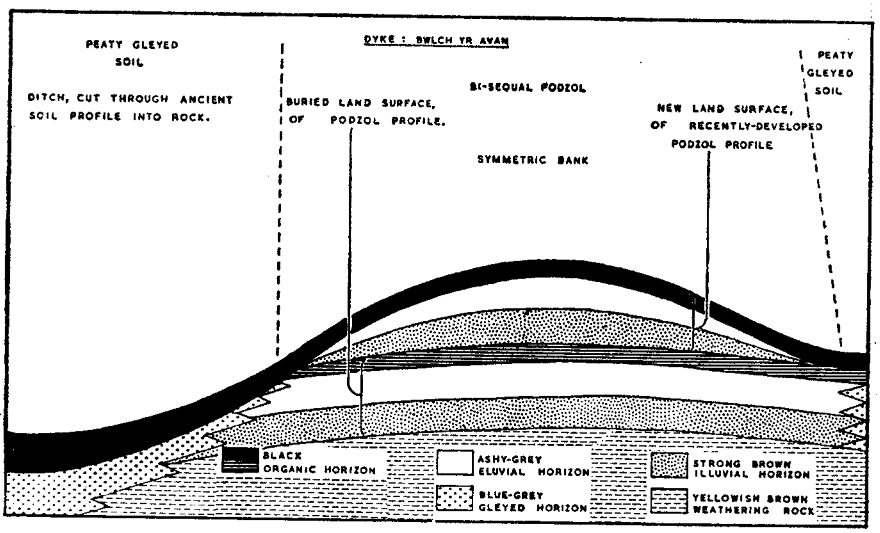


Fig.13. *(Right); section through cross-ridge dyke, Bwlch yr Avan across Mynydd Blaenrhondda to the west of Rhondda Valley (Fig.1A), showing original organic layer as part of a Podzol buried by construction of the dyke, and (left); section through a long cairn on Mynydd Llangorse, with its exposed outer revetment over a compressed organic layer as part of a Brunisol buried by construction of the cairn, and a photomicrograph of the orginal organic topsoil with ash charcoal fragments.*

Podzol, in which the lighter eluvial horizon can be distinguished from the underlying slightly darker illuvial horizon. Contained pollen and the nature of the bisequal soil profile suggests that this dyke was constructed during Medieval times.

THE BRECON BEACONS NATIONAL PARK

The mountainous Brecon Beacons National Park in south-central Wales is split into the Black Mountains to the northeast, and the Brecon Beacons to the southwest by the Vale of Usk (Fig.14A and B), which Vale experiences a protected, mild climate associated with Land Region 1. This relatively mild climate projects along deep valleys into the northern, steep ramparts of the Brecon Beacons. Elevation zones in these valleys separate scattered oakwood remnants, with false brome-grass on better drained sites and tufted hair-grass on poorer drained sites along valley bottoms, with mat-grass and purple moor-grass associated with the cooler climate of Land Region 2 along middle slopes, and with purple moor-grass and deer-sedge associated with the harsh, alpine climate across the windswept crest of an arete.

The north side of this arete defines a series of cwms (corries, cirques) such as Cwm-Llwch (Fig.15), scoured out during the last glaciation by glaciers that discharged into the Vale of Usk, sometimes with sufficient power to mount opposite valley slopes as in the southeast of the map-area, laying a heterogeneous mantle of till. The south side of the Brecon Beacons slopes more

Transverse Mercator Grid

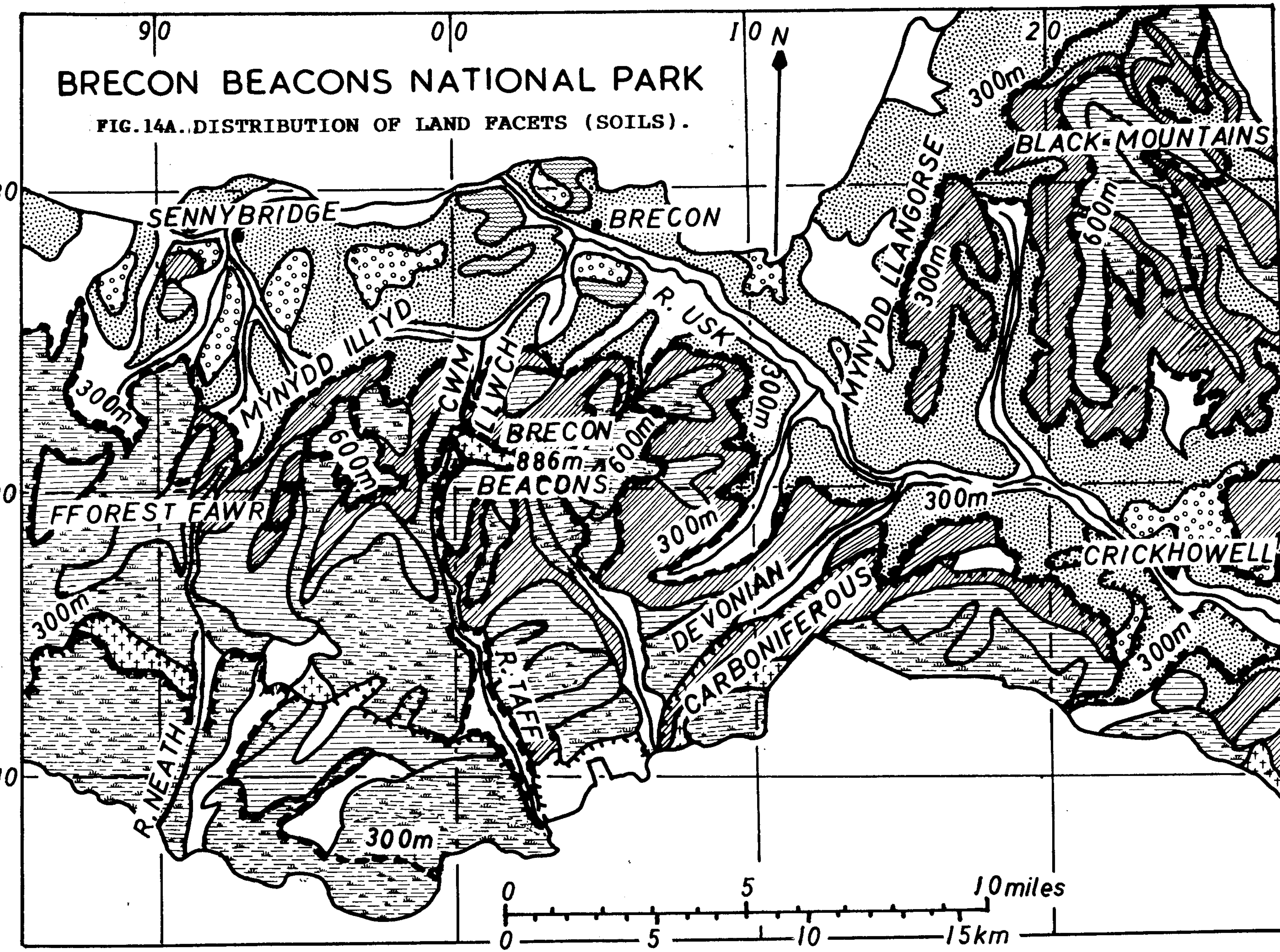


FIG.14B. LEGEND FOR BRECON BEACONS NATIONAL PARK

LAND REGIONS

Lowlands and middlelands
Relatively maritime climate
False brome-grass and
tufted hair-grass. 1

Upland ridges and valleys
relatively cool climate
Mat-grass and purple
moor-grass. 2

Mountains with exposed ridges
Alpine climate
Purple moor-grass and
deer-sedge. 3

LAND DISTRICTS

02
Carboniferous sandstones
and shales, with grits
of the northern crop.

03
Devonian calcareous mudstones
and sandstones, with grits
and conglomerates of the
southern crop.

LAND SYSTEMS

002
Undulating foothills

004
Ridge plateaus

005
Upland plains and gentle slopes

003
Steep slopes

006
Mountain crests

LAND FACETS

DYSTRIC BRUNISOLS ON SANDSTONE 0023

EUTRIC BRUNISOLS ON CALCAREOUS ROCKS 0021

DYSTRIC BRUNISOLS IN MORAINE 0024

REGO AND FERA GLEYSOLS IN MORAINE 0025

HUMIC GLEYSOLS ON SANDSTONE 0046

HUMIC GLEYSOLS IN MORAINE 0057

"PODZOLS WITH GLEYING" ON SANDSTONE 0038

ROCK OUTCROPS 0060

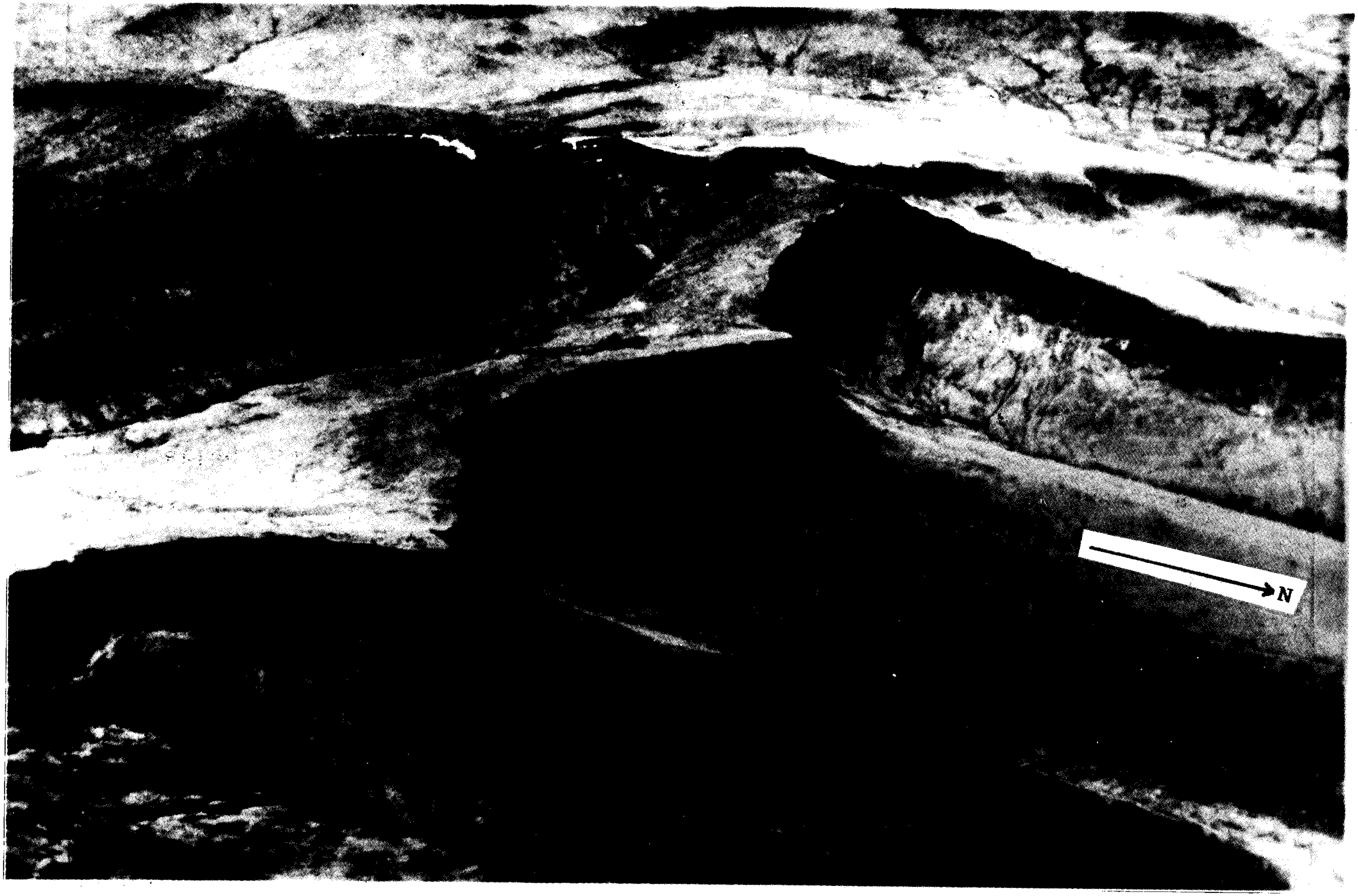


Fig.15. The high (886 m), exposed arete of the Brecon Beacons, with widely scattered, stunted oak (with a few other species) forest remnants, a forest once far more widespread, as indicated by pollen analyses from soils in the area. Notice the mountain,north-south trail across the centre of the foreground; the main highway crosses, north to south within the background valley. Notice horizontal stratification lines near the top of the cwms (corries), produced by "Plateau Beds" of grits and conglomerates forming the Beacons. Early spring snow highlights the crest of the arete.

gently southwestwards over the dip of the Devonian strata, onto Carboniferous strata. Rivers such as the Taff (flowing into the Vale of Glamorgan, Fig.5) and Neath (flowing through Rheola Forest, Fig.7) drain these slopes, cutting into what appears as an open expanse of purple moor-grass associated with the cool Land Region 2.

In the Vale of Usk Dystric Brunisols occur over Devonian sandstones (terrain unit 1323), and Eutric Brunisols over Devonian calcareous strata (terrain unit 1323), although most of these Vale foothills are mantled with till, Dystric Brunisols occurring on slopes where the drainage is good (terrain unit 1324), and Rego or Fera Gleysols occurring in depressions and low flats where water collects and stagnates (terrain unit 1325). The Vale is productive agricultural land, grains and other crops being grown in the Brunisols, and pastures supporting beef being associated with the Gleysols. Steep slopes rising towards the mountains support Podzols with gleying (terrain unit 2338) associated with the brilliantly coloured summer pastures of bilberry. Atop these slopes, ridge plateaus support Humic Gleysols (terrain unit 2-3346 with purple moor-grass. The mountain crests are associated with scattered rock outcrops and Humic Gleysols, carrying clumps of purple moor-grass and deer-sedge (terrain unit 3366-0). Where calcareous bands crop out across slopes, a rich herbaceous sward is clearly discernible from afar (terrain unit 2331). The plains sloping gently southwards from the Brecon Beacons are covered with till,

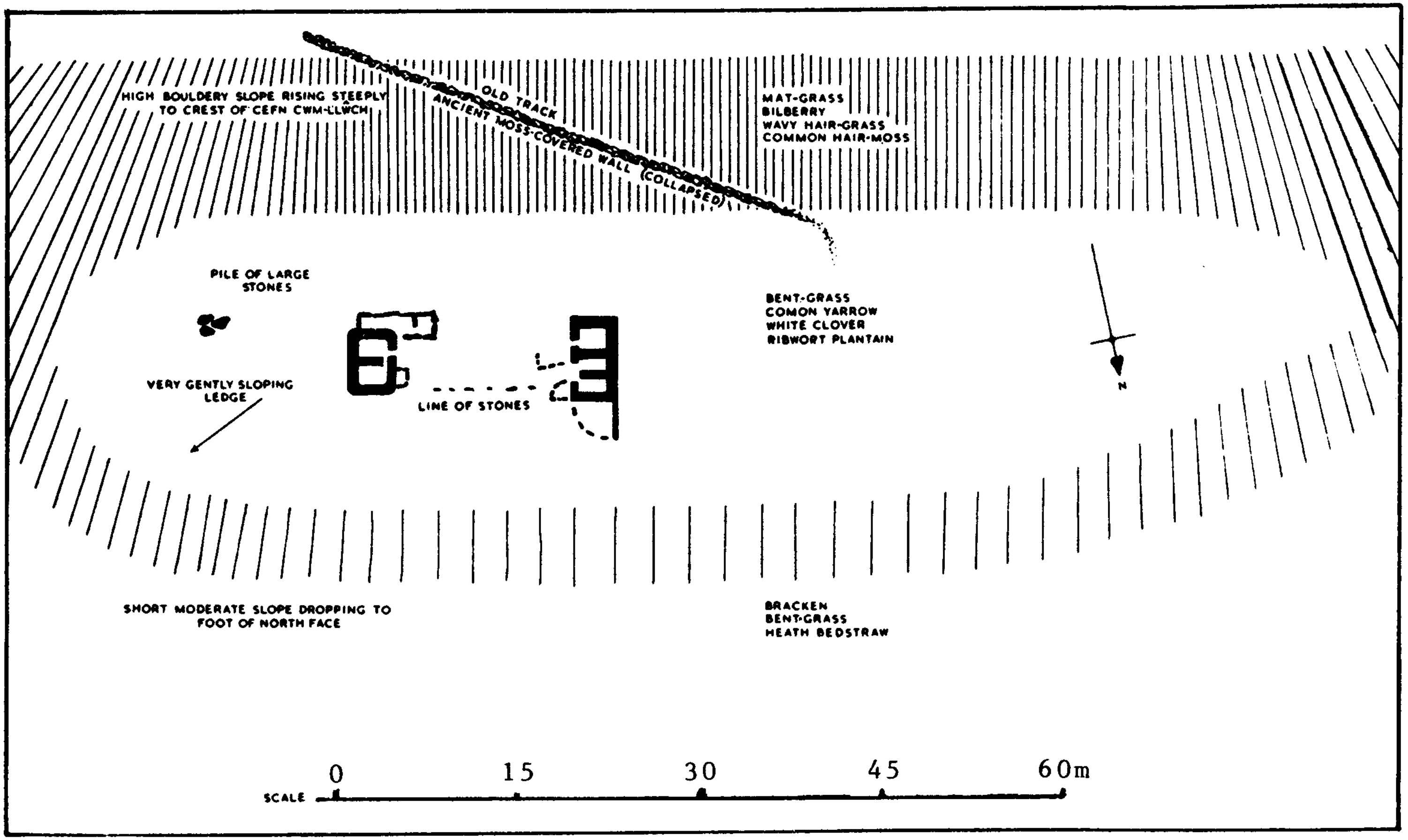


Fig.16. Plan of a hafotai ledge occupying the lower north-facing slope of Cefn Cwm-Llwch (terrain unit 2331, too local to map), Brecon Beacons, showing the different vegetation types upslope and downslope of the ledge with its calcareous rock, dung-, nutrient-enriched pasture.

Fig.17.. View of the larger hafotai with its double-walled structure, giving shelter to sheep herders ranging the upper slopes of the Brecon Beacons during summer transhumance.

carrying Humic Gleysols with purple moor-grass and mat-grass (terrain unit 23-257).

Transhumance and Hafotai. With prevailing winds from the southwest, the crest of the Brecon Beacons tends to produce a partial rain shadow to the north and northeast, slopes that receive much less direct sunlight and are cooler than opposite slopes. Thus, although the steep slopes on the north and northeast side of the Brecon Beacons are relatively drier, their coolness keeps them moist for longer in the year than on the other slopes. Where calcareous bands crop out across these steep slopes, the change of rock type from sandstone usually producing a narrow ledge, water seepage through the rock strata produces less acid Eutric Brunisols on the ledges (terrain unit 2331), contrasting with more acid Dystric Brunisols above and below. On the ledges the flora reflects a relative base enrichment within the soils, containing common yarrow, wild white clover, ribwort plantain, common daisy and self-heal along with common bent-grass, sheep's fescue-grass and crested dog's-tail grass. This contrasts with a much simpler flora containing bilberry and bracken, along with common bent-grass and mat-grass above and below the ledges.

The ruins of two mountain summer dwellings, called hafotai, have been surveyed on a ledge situated low on the steep frontal slopes of the ridge Cefn Cwm-Llwch, to the east of the valley Cwm-Llwch (Fig.14A and 16). The hafotai are associated with several pens, and an old track and collapsed wall leading up onto higher mountain pastures. The walls of both hafotai have largely collapsed, but sufficient masonry has survived to outline the foundations. The larger of the two hafotai is shown in Fig.17. The double-walled structure was been filled with rocky rubble, with some horizontal slabs crossing from outer to inner margins of the walls. The living accomodation is rudimentary, the largest room being only 2 by 2.5m across. The rooms were floored with flagstones. There is no evidence of a fireplace. A crooked bough lay in the ruins.

Transhumance arose primarily to free from grazing the lowlands for cultivation. Rees (1924) describes the hendre or winter house at the base of hillslopes, serving as a permanent dwelling, and the hafod serving as a temporary summer-house on higher ground. Until the eighteenth century cattle were more important than sheep, and so an upland residence was necessary as a summer home and dairy. The Act of Union during the 16th century created new markets and, subsequently, large herds of (shod) cattle were driven as far as London. In South Wales, after the corn was sown on the lowland farm during spring, the animals were driven to the upland pastures, and some members of the household, often the women, moved up the mountain slopes to occupy the hafod during the summer. The women would milk the cattle and make butter and cheese, while the men would temporarily ascend the slopes to harvest "gwair rhossydd" or moorland hay (purple moor-grass, before growth has become rank and the nutrient value poor).

Animals and people returned to the hendre in autumn and the corn was harvested. The animals grazed the lowlands during the winter (Davies, 1937).

Sheep need less regular attendance than cattle and so, during the eighteenth century and onwards, as sheep farming became more important, the need for hafotai declined. At this same time some lower hafotai became independent farms, although many animals had to be taken down on to the lowlands for winter grazing. The higher hafotai were unsuitable for adaption as permanent dwellings and fell into disuse (Davies, 1941).

The absence of a fireplace for the hafotai on the north slopes of the Brecon Beacons indicates that the dwelling was used only during summer; extreme exposure would make winter habitation impossible. Presumably, gwair rhossydd was laid upon the floor for warmth during the summer nights, the double walled structure of the hafotai further improving insulation.

Today in Norway the comparable dwelling, a saeter, consists, like the hafod, of three rooms; the living room, a sleeping room and a dairy. The fire can be outside near the saeter doors. In Ireland the summer dwelling was called the buaile, carried directly into English to describe a temporary milking structure. Buaile has also been anglicized to booley to describe buildings on ledges where the pasture was greener. Booleys often occurred in groups, with pens. Each structure consisted of drystone and earth fill construction. Cooking was outside, and trimmed boughs formed the gabled roof framework, with thatching over sod (Donachair, 1945).

The 1839 Tithe Map does not show any hafotai on the north slopes of the Brecon Beacons, and so they were presumably deserted before that date. Williams (1964) refers to the occupation of a hafod by Sion Dafydd Rhys when writing his Grammer (1534 - 1609) in the upper reaches of neighbouring Cwm-Llwch, under the trees below the heights of the Brecon Beacons. Thus, hafotai were being used in the area during the sixteenth century. Their origins might lie in the fifteenth or fourteenth centuries.

Soils, Vegetation and Aspect. The distribution of Podzols with gleying within belts that widen around north- and northeast-facing slopes across the northern crops of the South Wales Coalfield cannot be explained entirely in terms of the scarps produced by outcrops of Pennant Series sandstones. Although rain comes mainly from the southwest, these north- and northeast-facing slopes are almost continuingly cool and damp because they receive the least insolation, and evaporation is low. This microclimate encourages not only the development of Podzols with gleying, but encourages the growth of bilberry, mat-grass and heather at the expense of the development of Dystric Brunisols associated with bracken, wavy hair-grass and sheep's fescue-grass growing on warmer, south- and southwest-facing slopes.

Pollen analyses reveal that this tendency for relatively acid soils and an ericaceous vegetation to grow on cooler north- and northeast-facing slopes was inherited from the past two thousand or so years ago (Crampton, 1965). This differential distribution of soils and vegetation with aspect, in the past and today, can been seen, and may be established especially well on the conical Sugar Loaf Mountain within the River Usk valley near Crickhowell in the eastern Brecon Beacons National Park (Fig.14A), separated by Grwyne Fawr from the Black Mountains. Zehetmayer (1960) describes an ericaceous flora as generally found on cooler north-facing slopes in Scotland, other slopes bearing grassland or bracken.

On the cold north slopes of the Brecon Beacons, less well drained soils at high elevations are associated with a flora typical of better drained soils elsewhere at lower elevations. Possibly, the cool climate over higher, north-facing slopes on the Beacons has, in part, encouraged grazing and allowed a flora to persist that is normally associated with drier soils. When grazing is restricted, as in forestry enclosures, ericaceaea spreads. The warmer south-facing slopes of the Beacons have a long history of grazing, replacing forests, dating from the establishment of the Cistercian estates. Mat-grass, because of its relative unpalatibility, replaces ericaceae under intensive grazing. In this way, at least the differential distribution of vegetation could, in part, be the superposition of some cultural pressures upon the natural landscape and processes.

THE MYNYDD EPPYNT - DRYGARN HILL-LANDS.

Medieval Settlement. Within the broad term of Medieval settlement, later cultivators of higher lands within Land Region 1, and lower lands within Land Region 2 upon ridge tops ploughed such that the soil was thrown into ridges to create good drainage where productivity was generally greater, and troughs where water collected, to drain away on to lower slopes. Parallel, low ridges and shallow troughs, about 3 - 4m across, can be seen scattered across commonlands of South Wales (e.g. Fig.18B) where greater precipitation than over valleylands has always posed an agricultural problem.

Irish Settlement. On one of the northward directed ridges, Mynydd Illtyd, in the region of the Brecon Beacons (Fig.14A) (terrain unit 2338), examination of greatly enlarged air photographs revealed a field network across the ridge, except where scrub woodland obscured it or where the slopes were too steep. Similarly, in the north of the study-area, near Builth Wells over Silurian shales and grits extending beyond Mynydd Eppynt (Fig.1A), a field network could be discerned on the hill, Garth (terrain unit 2433). Individual fields are very small, with sides 27 to 46m long (Fig.18B), and a fraction of a hectare in area. Locally, there are clusters of 3 to 4 very small enclosures (shaded in Fig.18B). At some places it is still possible to detect with a penetrometer compaction of the subsoil below a field boundary whereby, presumably under pressure of foot

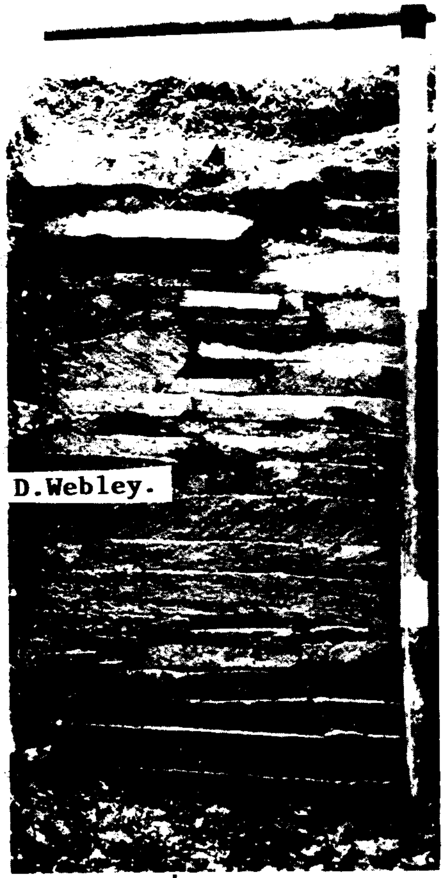


Fig.18A. Outer revetment of Neolithic long cairn showing underlying, compressed organic soil, for which a thin section has been prepared, showing ash charcoal fragments and flint flakes.

'ork with D.Webley.

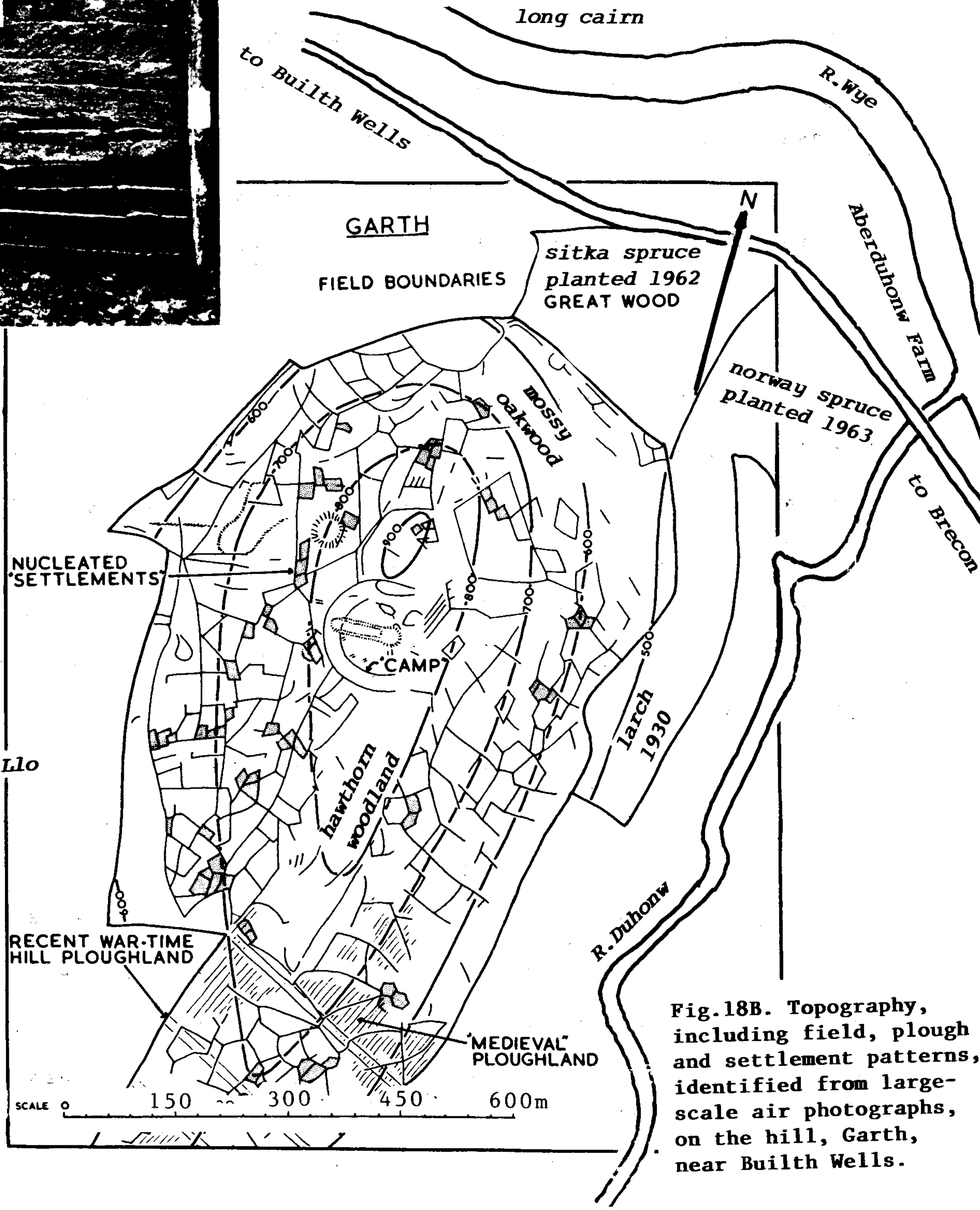


Fig.18B. Topography, including field, plough and settlement patterns, identified from large-scale air photographs, on the hill, Garth, near Builth Wells.

and animal traffic, soil grains were pressed closer to one another, rotating to accomodate individual grain shapes, thus reducing pore space (Crampton, 1985). On both Mynydd Illtyd and Garth, stunted hawthorn locally delineates ancient field boundaries.

The dispersed form of rural settlement which dominates many parts of the Irish landscape today was preceded by nucleated settlements consisting of groups of farmhouses and their associated outhouses, called clachans (Evans, 1939). Almost inseparable from clachans was the Irish openfield system called rundale under which each farmer held his land in a number of scattered plots, often very small and called "gardens" (Mac Aodha, 1965), separated from each other by mearings serving as tracks. Where remoteness has preserved the system until today, closely related kinship clachans can be seen to consist of 3 - 10 farmhouses, and fields are fractions of a hectare in size. A similar farming system was once practised amongst the other Goidelic peoples, in Scotland. Disease, starvation and emigrations have depleted most clachans during recent times.

Ogam script is derived from southern Ireland, and the distribution of Ogam Stones provides evidence of an Irish migration into South Wales about 1,500 years ago. Cnwc and Llwch are Goidelic names, and Cnwc-y-Llo to the east of Garth (Fig.18B), and Cwm Llwch to the east of Mynydd Illtyd (Fig.14A), attest to this migration of Irish into the area (Jones Davies, 1956). It is probable that the field system on Garth (and Mynydd Illtyd) represents the remnants of Irish farming settlement in Wales at about 400 to 500 A.D.

Neolithic Long Cairn. A partial excavation of the long cairn in Fig.18B revealed an outer revetment (Fig.18A) of drystone walling containing 22 courses, separated from an extra-revetment of overlapping flagstones by stony fill. The structure rested upon a compressed but, apparently, an otherwise undisturbed Eutric Brunisol. The cairn was oriented NNE - SSW like many others in the region (Daniel, 1950). Analysis of pollen from the organic layer revealed mostly ericaceae, with some oak, ash and alder. Heathland with open woodland would appear to have been the vegetation at the time the cairn was built. Compared with the other trees, oak is under-represented by its pollen, and so the woodland was probably dominated by oak. The surface vegetation was burnt and the topsoil trampled before construction. Charcoal fragments in the topsoil were mostly ash (Fig.18A). Oakwoods with some ash often occur where limestone bands are intercalated with other rock types, in this case Silurian sandstones and shales. Presumably, as elsewhere, ash was preferentially selected from the surrounding area for burning to clear the site. Ash burns much more readily than oak (although the latter burns at a greater temperature).

Numerous Neolithic A2 sherds and pottery were found trampled into the buried soil, and microscopic flint flakes were revealed in thin sections, particularly obvious between crossed polaroids when the crypto-crystalline nature of flint made them clearly visible. The terrain unit would have been, and still is 2431 in the immediate environs of the cairn, associated with white clover, thyme, ribwort plantain, yarrow, bird's-food trefoil and nettle, merging into 2438, a terrain unit where there are Podzols with gleying over strata with no calcareous bands, associated with bilberry, heath bedstraw, bent-grass and mat-grass.

THE MARITIMES, CANADA.

LAND CLASSIFICATION

Introduction. Using data from many sources, an extensive forest land productivity classification was constructed for the Maritime Provinces of Canada. The land has been classified on the basis of, first, ecological regions (Land Regions) which have been sub-divided into, second, geology and surficial materials (Land Districts) which have been sub-divided into, third, amplitude of relief and slope (Land Systems) which have been sub-divided into, fourth, broad soil drainage classes (Land Facets). Except for soil drainage, successive levels in the classification structure have been culled from existing maps. This land classification was used to stratify the forest, and for each classification unit an estimate of productivity was calculated from tree measurements made across the Maritimes. These estimates were checked and a map was prepared showing areas with similar productivity. The terrain units have been symbolized by digits, in order from the left, first 1 - 11 for Land Regions (Figs.19A and B), second 1 - 5 for Land Districts (Fig.20), third 1 - 6 for Land Systems (Figs.21A and B), and fourth 1 - 3 for Land Facets (Fig.21B). Oblique air photographs (Figs. 22 and 23) show selected landscapes. The final sub-division of the terrain is shown in Fig.24A and B.

Whereas the West British Isles are washed by the relatively warm Gulf Stream from out of the equatorial region, on the other side of the Atlantic the Canadian Maritimes' coastline is washed by the relatively cool Labrador Current from out of arctic waters. Compared with South Wales, in the Maritimes this produces a rapid transition from an oceanic climate to a continental climate inland, associated with an increasingly greater variation of seasonal and daily temperatures. Along the Maritimes coast there is not only a smaller seasonal temperature range, but a considerably greater precipitation compared with inland. The frost-free period for Fundy Bay (Fig.24A) is more than twice that for the Central Highlands of New Brunswick where frost may be expected at any time of the year. Winds blowing across cool water make the Bay of Fundy one of the foggiest localities on earth.

Land Regions. Rowe (1959) placed most of the study-erea within the Acadia Forest Region, except for northwest New Brunswick which was considered part of the Great Lakes - St. Lawrence Forest region. Loucks (1962) developed a forest classification specifically for the Maritimes, and described 11 ecoregions which were distributed within 7 forest zones, equivalent to climatic zones (Fig.19A and B). Broad forest compositional changes have been used to sub-divide the area into Land Regions. Thus, the New Brunswick Highlands Land Region 9 is associated with balsam fir and white or black spruce, with the addition of white birch and white pine on ridges. There is a

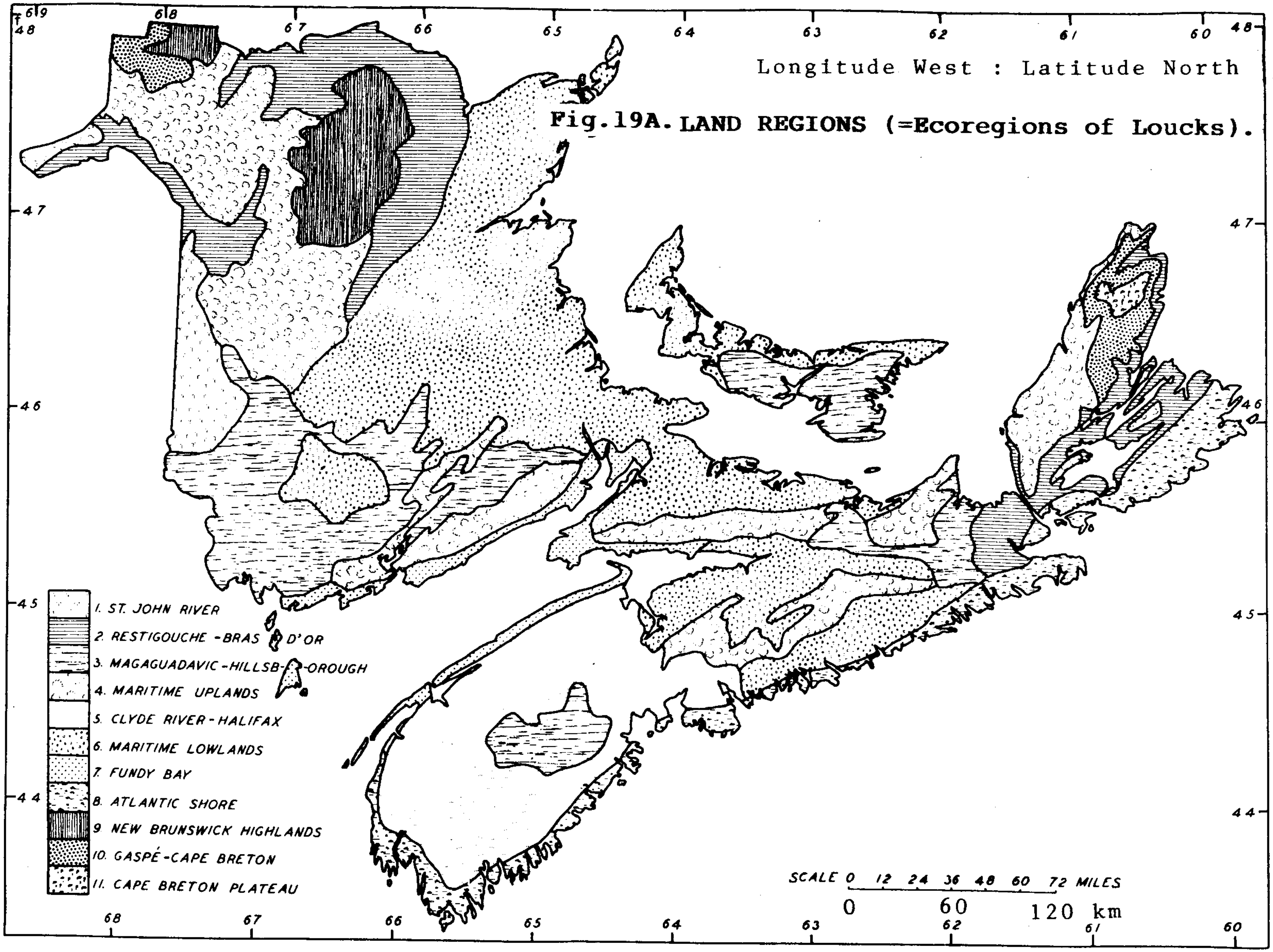


Fig.19A. LAND REGIONS (=Ecoregions of Loucks).

Fig.19B. LEGEND.

Loucks' Ecoregion	Associated Climate	Forest Vegetation on Higher / Lower Land
1. St.John River	WARM AND DRY.	SUGAR MAPLE - BEECH / CEDAR - SPRUCE.
2. Restigouche - Bras D'Or	MODERATELY COOL AND MODERATELY DRY.	BEECH - SUGAR MAPLE / FIR - SPRUCE - PINE.
3. Magaguadavic - Hillsborough	WARM AND MODERATELY DRY.	RED OAK - BLACK CHERRY / FIR - HEMLOCK - SPRUCE - PINE.
4. Maritime Uplands	COOL AND MOIST.	YELLOW BIRCH - SUGAR MAPLE - BEECH / SPRUCE - FIR - PINE.
5. Clyde River - Halifax	WARM AND MOIST, BUT SUMMERS MODERATELY DRY AND HURRICANES FREQUENT.	RED OAK - RED MAPLE / SPRUCE - HEMLOCK.
6. Maritime Lowlands	MODERATELY WARM AND MODERATELY DRY.	SUGAR MAPLE - YELLOW BIRCH / SPRUCE - HEMLOCK - FIR.
7. Fundy Bay	COOL AND WET, FOGGY AND WINDY, BUT FROST-FREE FOR LONGER IN THE YEAR THAN ELSEWHERE.	RED MAPLE / SPRUCE - FIR.
8. Atlantic Shore	COOL AND WET, EXTREMELY WINDY.	YELLOW BIRCH - RED MAPLE / SPRUCE - FIR.
9. New Brunswick Highlands	COOL AND MODERATELY DRY.	FIR - SPRUCE - WHITE BIRCH - WHITE PINE / SPRUCE - FIR.
10. Gaspe - Cape Breton	COOL AND WET.	FIR - WHITE BIRCH - WHITE SPRUCE / SAME.
11. Cape Breton Plateau	COLD AND WET - HIGHLY EXPOSED.	TAIGA OF SHORT, DENSE SPRUCE AND FIR.

LOUCKS (1962)

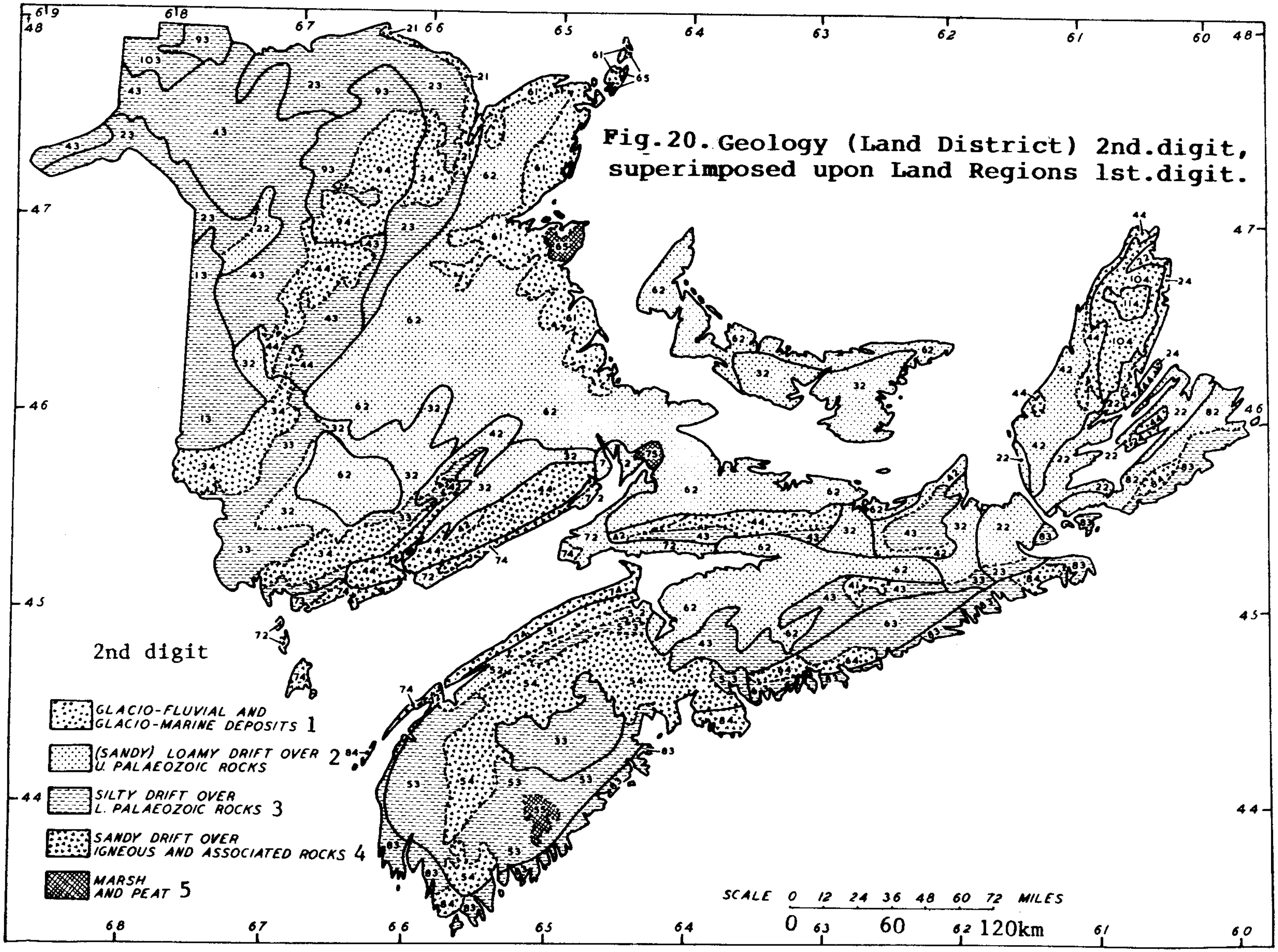


Fig.20. Geology (Land District) 2nd.digit, superimposed upon Land Regions 1st.digit.

transitional zone, an ecotone separating this Region from neighbouring uplands (of lower elevation) to the southwest defined as part of the Maritimes Uplands Land Region 4 where, in addition to fir and spruce everywhere, yellow birch, sugar maple and beech grow on the ridges. Both Land Regions are, relative to elsewhere in the Maritimes, cool but the Maritime uplands Land Region 4 is more moist, a climatic difference which is reflected in the vegetation. Placic Podzols become more common across the mountainous New Brunswick Highlands Land Region 9, compared with the Maritimes Uplands Land Region 4 where Orthic Podzols are more common. It requires arduous bush soil survey to establish these important differences, whereas the vegetational difference between the two Land Regions is obvious from forest roads traversing the area.

Similarly, the Atlantic Shore Land Region 8, that part of Nova Scotia exposed to weather off the Atlantic Ocean is relatively cool, wet and very windy, associated with extensive Regosols and a vegetation of yellow birch and red maple on low ridges, and spruce and fir in shallow valleys. There is a narrow ecotone separating this from the warm, dry and windy Clyde River - Halifax Land Region 5 covering much of the southwest Nova Scotia interior, associated with sandy Podzols (Orthic and Placic) over Devonian granitic rocks, and a vegetation of red oak with the red maple on low ridges and eastern hemlock with the spruce in shallow valley-lands. The latter are the so-called "Barrens" occurring in the centre of the area.

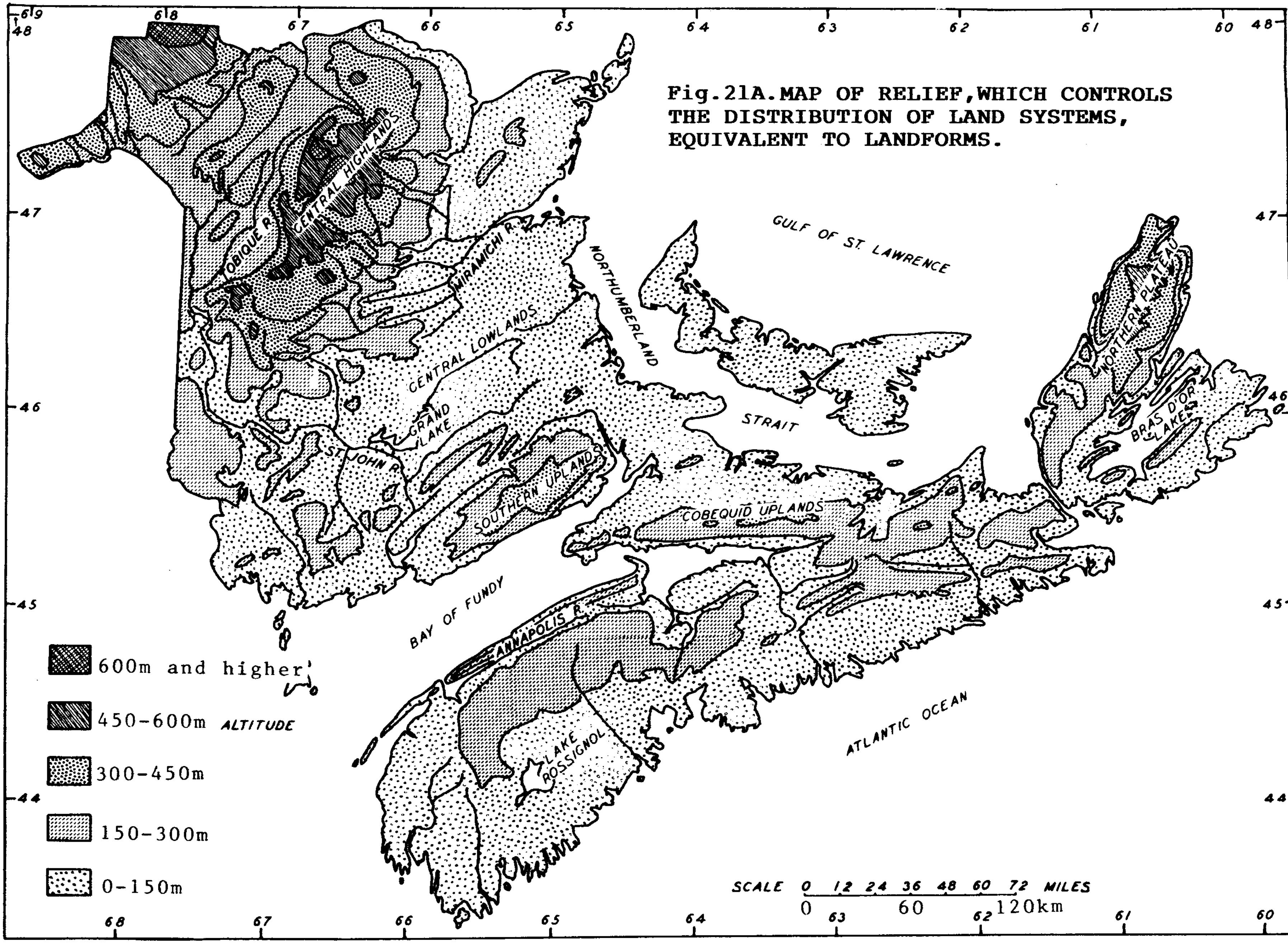


Fig.21A. MAP OF RELIEF, WHICH CONTROLS THE DISTRIBUTION OF LAND SYSTEMS, EQUIVALENT TO LANDFORMS.

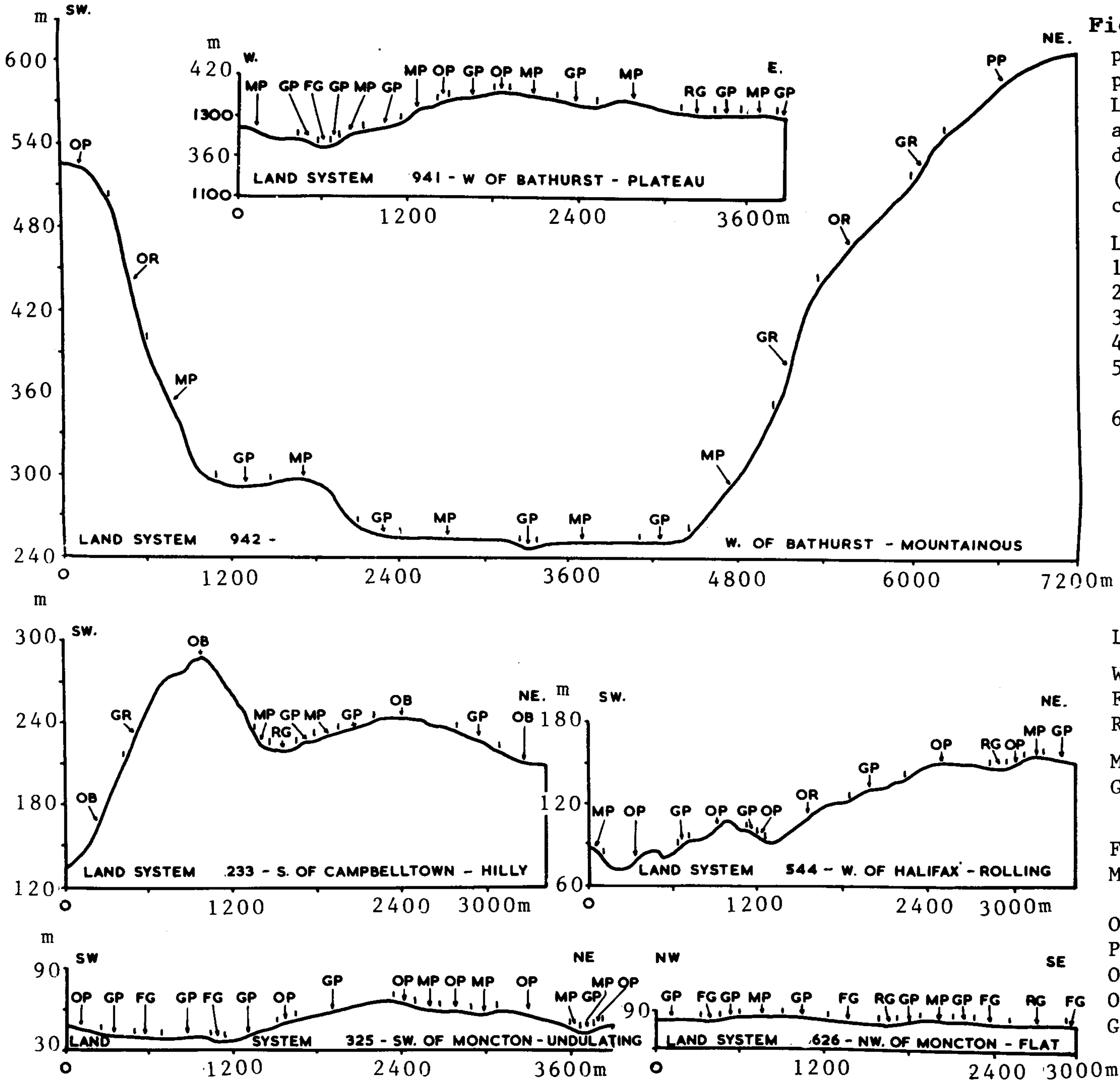


Fig.21B. Levelled traverses presented as longitudinal profiles across six LAND SYSTEMS (=landforms), and showing the distribution of LAND FACETS (= soil types within catenas).

LAND SYSTEMS

1 = mountain plateaus
2 = mountainous terrain
3 = hilly terrain
4 = rolling terrain
5 = gently undulating terrain
6 = flat terrain

LAND FACETS

Wet (poorly drained) 1
FG = Fera Gleysols
RG = Rego Gleysols

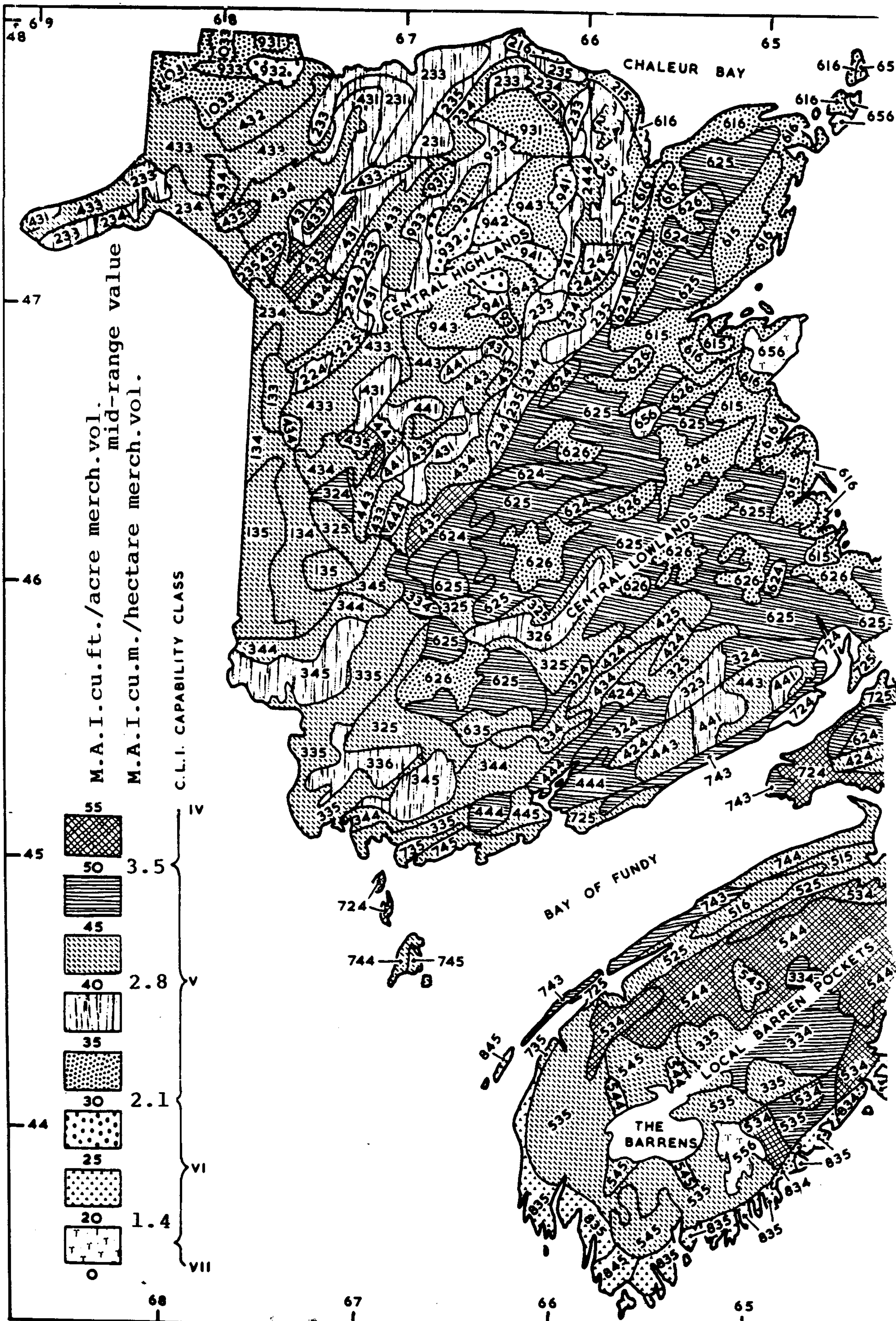
Moist (imperfectly drained) 2
GP = Gleyed Podzols or Brunisols

Fresh (well drained) 3
MP = Eluviated Dystric Brunisols
OP = Orthic Podzols
PP = Placic Podzols
OB = Orthic Brunisols
OR = Orthic Regosols
GR = Gleyed Regosols

Fig.22.

The Central Highlands of New Brunswick, cored with a granitic intrusion, with Bald Mountain in the foreground, the landscape rising towards Carleton Mountain at just over 900m in the background. Except for mountain peaks the landscape is forested and so the species mix within the forest cover constitutes the most suitable expression of climatic variations across the study-area.

Fig.23. Upper photograph, the northern plateau of Cape Breton Island with dense, stunted black spruce and balsam fir adjoining muskeg in Land System 1141. Lower photograph, view down Margaree River, towards Big Intervale on the south side of the Northern Plateau with spruce and fir on mountain tops within Land System 1042 to the left, and mixedwoods of Land System 442 elsewhere, all systems over Devonian granites and Precambrian gneisses and schists.



CHALEUR BAY
CENTRAL HIGHLANDS
CENTRAL LOWLANDS
BAY OF FUNDY
LOCAL BARREN POCKETS
THE BARRENS
M.A.I.cu.ft./acre merch.vol.
mid-range value
M.A.I.cu.m./hectare merch.vol.
C.L.I. CAPABILITY CLASS
55
50
45
40
35
30
25
20
0
3.5
2.8
2.1
1.4
IV
V
VI
VII

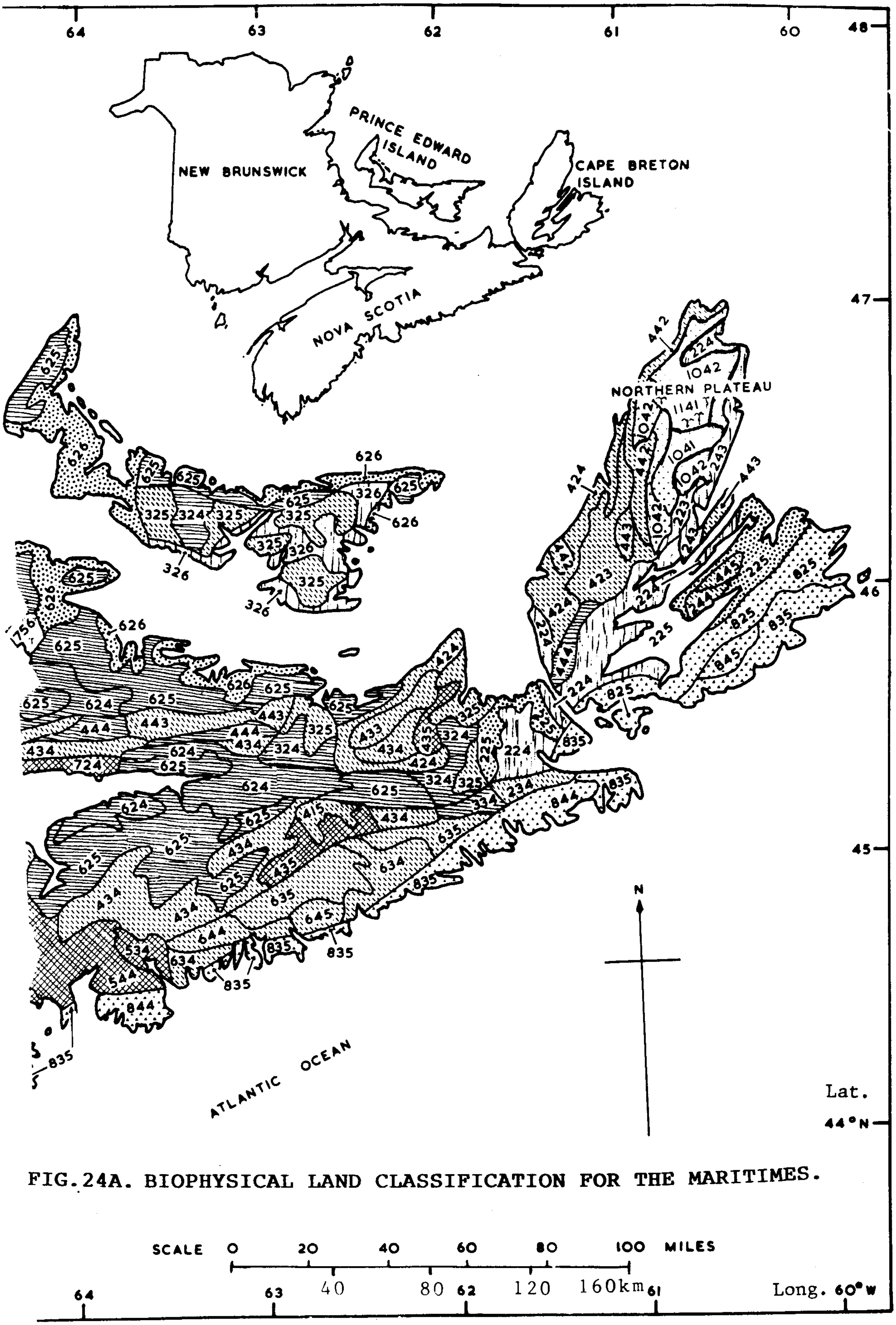


FIG. 24A. BIOPHYSICAL LAND CLASSIFICATION FOR THE MARITIMES.

LAND REGIONS

1.Warm and dry.

2.Moderately cool and moderately dry.

3.Warm and moderately dry.

4.Cool and moist.

5.Warm and moist, but summers moderately dry,often with hurricanes.

6.Moderately warm and moderately dry.

7.Cool and wet, foggy and windy,but frost-free for longer in the year then elsewhere.

8.Cool and wet,and extremely windy.

9.Cool and moderately dry.

10.Cool and wet.

11.Cold and wet,and highly exposed.

LAND DISTRICTS

1.Glacio-fluvial and glacio-marine deposits.

2.(Sandy),loamy till over Upper Palaeozoic sandstones and shales.

3.Silty till over Lower Palaeozoic shales and sandstones.

4.Sandy till over igneous and associated rocks.

5.Marsh and peat.

LAND SYSTEMS

1.Mountain plateaus.

2.Mountainous terrain, with a very great amplitude of relief.

3.Hilly terrain with a considerable amplitude of relief.

4.Rolling terrain, with a moderate amplitude of relief.

5.Gently undulating terrain.

6.Flat terrain.

LAND FACETS

1.Wet,poorly drained soil types,with bog-moss cushions.

2.Moist,imperfectly drained soil types,with scattered pockets of hair-mosses.

3.Fresh, well drained soil types,with an herbaceous ground flora.

FIG.24B. SUMMARY OF LAND CLASSIFICATION UNITS.

The distribution of Land Regions, Districts and Systems only is shown in the map. The distribution of Land Facets is too local to be shown, and has to be determined by site inspection. Hence, the definition of Land Facets is in widely understood field terms.

e.g.A terrain unit 625 has a moderately warm and moderately dry climate, with the landscape mantled by sandy loamy till over Upper Palaeozoic (chiefly Carboniferous) sandstones and shales, consisting of gently undulating terrain. Within this terrain unit there can be wet, moist or fresh lands which must be determined by site inspection.

Land Districts. The area was glaciated during the last (Wisconsin) Pleistocene ephisode, and much of the area is covered with a till derived mostly from the underlying rocks. High plateaus in northwest New Brunswick are an extension of the central upland core of the Gaspe Peninsula, and are formed of silty till over Lower Palaeozoic (Ordovician, Silurian and Devonian) slates and shales, with some sandstones (Fig.20; Land District 3). Elsewhere in the Maritimes, high land is composed mostly of igneous rocks. Sandy till over Devonian granites and related rocks form the core of the Central Highlands in north-central New Brunswick (Land District 4) (Fig.22). Similar rocks form a range of intermittent hills to the southwest. In the Southern Uplands adjoining the south coast of New Brunswick, Devonian granites, gabbros and related rocks crop out, with Precambrian and Lower Palaeozoic sedimentary rocks locally metamorphosed around igneous intrusions. Devonian granites and related rocks form hills extending eastwards into central Nova Scotia, giving rise to the Cobequid Uplands, southwards and westwards to form low hills in western Nova Scotia, and northwards, culminating in the Northern Plateau of Cape Breton Island. Here, granitic intrusions are associated with Precambrian sediments extensively metamorphosed into gneisses (all Land District 4) (Fig.23).

The Central Lowlands of New Brunswick are an undulating plain diverging from near the southwest of the province, towards, and including most of the east coast, and Prince Edward Island. Sandy loamy till overlies Upper Palaeozoic strata of

Pennsylvanian and Mississippian shales, sandstones and conglomerates, which merges into rolling land in central Nova Scotia, and hilly land in Cape Breton Island (Land District 2). Locally in New Brunswick and Nova Scotia the Mississippian contains gypsum and limestones, and the Pennsylvanian, coals, especially around Minto in New Brunswick and Sydney in Nova Scotia. Undulating land in southwest New Brunswick and along the Atlantic coast of Nova Scotia is formed of Lower Palaeozoic sedimentary rocks as previously described, which in Cape Breton Island includes the Cambrian. Where rivers drain slopes of the Central Highlands of New Brunswick, meltwater from Wisconsin ice sheets laid extensive sand and gravel outwash deposits along lower reaches (Land District 1). Near the coast these coarse-textured glacio-fluvial deposits merge into glacio-marine beach deposits and clays. Glacio-marine deposits mantle the Annapolis River valley in western Nova Scotia.

Land Systems. The definition of Land Systems was based primarily upon the amplitude of relief. Low, flat areas, designated 6, were separated from gently undulating terrain with a small amplitude of relief, designated 5 (21A and B). Rolling terrain with an amplitude of relief of about 80m was designated 4, and was differentiated from hilly terrain with an amplitude of relief of about 160m, designated 3 (lower, Fig.23). Mountainous terrain had an amplitude of relief of about 320m, designated 2, and was separated from upland plateaus, designated 1 (upper, Fig.23). Transverse profiles across selected Land Systems illustrate these different terrains.

Land Facets. These transverse profiles also illustrate the distribution of different soils (C.D.A., 1978), that is Land Facets within Land Systems (Fig.21B). However, to keep the classification usable by the layperson, this soil classification has been simplified into three relatively easily identified categories since Land Facets cannot be shown on the maps and must be identified by the fieldperson. The maps can indicate the Land System, District and Region for any particular locality (Figs.24A and B). So-called "fresh", well drained soils tend to be crumbly soils, generally brownish throughout the upper profile, merging into porous, underlying tills and rocks. The ground flora is generally richly herbaceous (designated 1). So-called "moist", imperfectly drained soils show dappled (or mottled) gray and brown colouration, with a ground flora generally rich in hair mosses (disignated 2). So-called "wet" soils are generally fine-textured, wet for much of the year, gray-blue in colouration, and are mostly associated with a ground flora rich in sphagna (designated 3). The transverse profiles show the distribution of some typical soil types within this three-fold classification.

ESTIMATIONS OF FOREST LAND PRODUCTIVITY

The Field Data. Major environmental differences exist, for example, between the Atlantic coast of Nova Scotia with its cool, often powerful onshore winds, and the Central Lowlands of New Brunswick with its more continental climate, reflecting primarily Land Region delineations. Major differences exist, for example, between well to imperfectly drained silty till soils over Lower Palaeozoic rocks, and excessively well drained sandy till soils over granitic and related metamorphosed rocks, reflecting primarily Land District delineations. Major differences exist, for example, between flat lowlands collecting water from adjoining slopes and mountainous slopes shedding water, and between stagnant bogs and porous substrates, which can be observed by any fieldperson as imposing a basic pattern upon land productivity, reflecting primarily Land System and Facet delineations. These differences need to be quantified.

Abundant selected-tree measurements were made as part of the Canada Land Inventory program across the study-erea. Much less numerous unit-area measurements were made within federal and commercial research forests. To take advantage of the extensive former measurements, where these overlap the latter measurements within research stations, the two types of measurements have been regressed (Fig.25), to yield a useful coefficient of determination of 0.72. Henceforward, forest productivity is expressed in terms of volume per unit area.

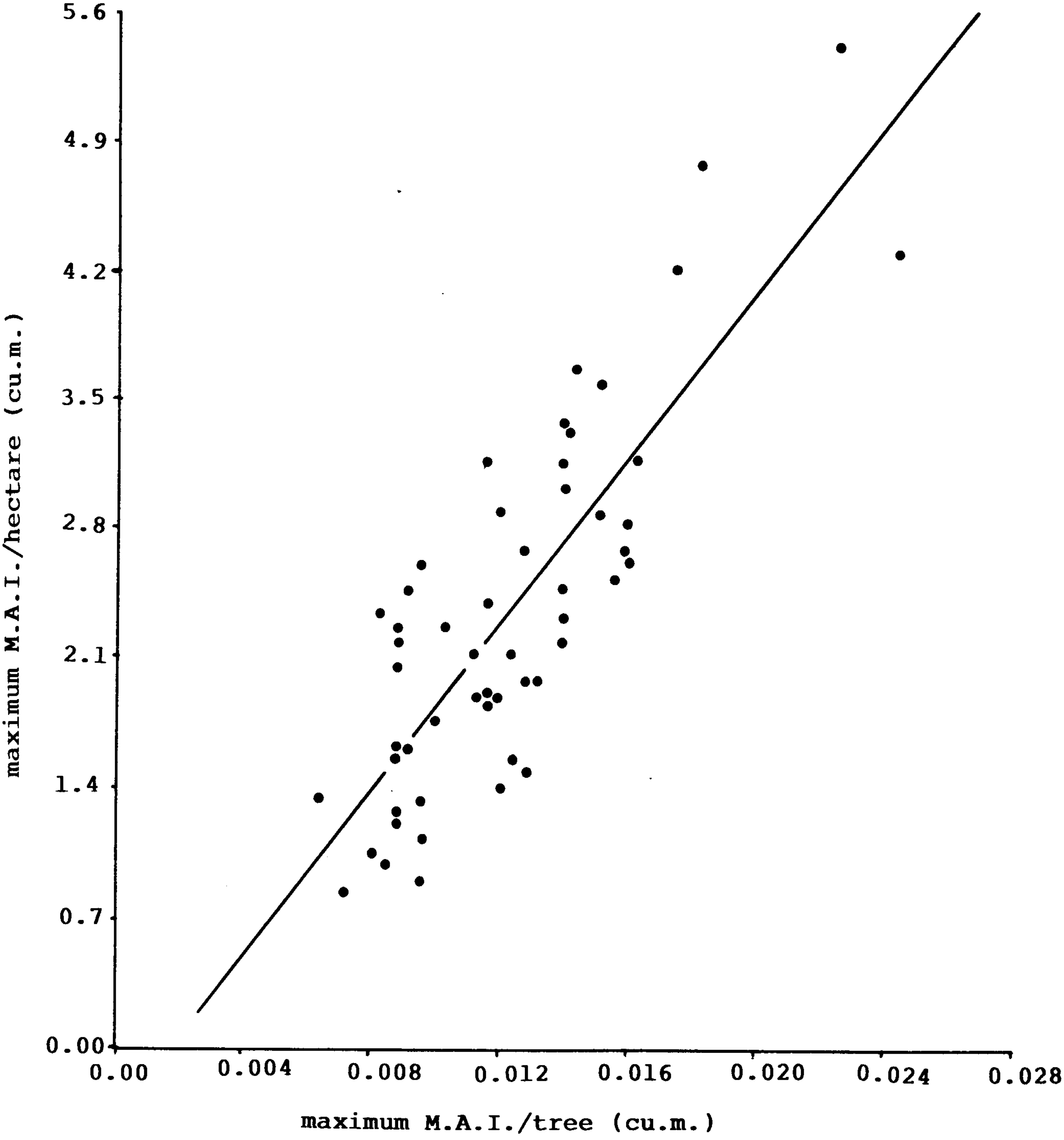


Fig.25. Plot measurements over a period of years from various research stations distributed across the Maritimes. Linear regression of maximum M.A.I. for "good average" trees in each plot, versus maximum M.A.I. for all trees in each plot. Regression equation $y = 1.25x - 5.17$; $R^2 = 0.72$; $N = 54$.

The Unit of Productivity. The mean annual increment (M.A.I.) per hectare measurements for each Land Facet, within each Land System, etc., for each of balsam fir, hybridizing red and black spruce, white spruce and white pine became the imput into a polynomial regression which was used to simulate growth curves typical of each Land Facet. To properly compare the M.A.I./hectare of a particular species on one Land Facet with another Facet, a specific stage in forest growth has to be selected; this is the stage at which the ever-changing M.A.I. per unit area achieves its maximum value, the tangent to the growth curve (Fig.26), the so-called maximum mean annual increment (M.M.A.I./hectare). This is the age, the rotation at which a particular forest achieves its maximum growth rate.

Red-black spruce achieves its M.M.A.I./hectare on the fresh (well drained) Land Facet, within the gently undulating Land System, on silty substrates over Lower Palaeozoic shales, within the cool moist climate on the southeast slopes of the Central Highlands of New Brunswick (terrain unit 4351) at a rotation of about 85 years), similar to the rotation, but much lower M.M.A.I./hectare on the wet Land Facet, within the gently undulating Land System, on sandy loamy substrates over Upper Palaeozoic shales, within the moderately warm and moderately dry climate of the Central Lowlands of New Brunswick (terrain unit 6253) (Fig.26). Obviously the former terrain must be preferred for timber extraction and, as soon as possible for tree farming. These productivity estimates are based on the natural (untended)

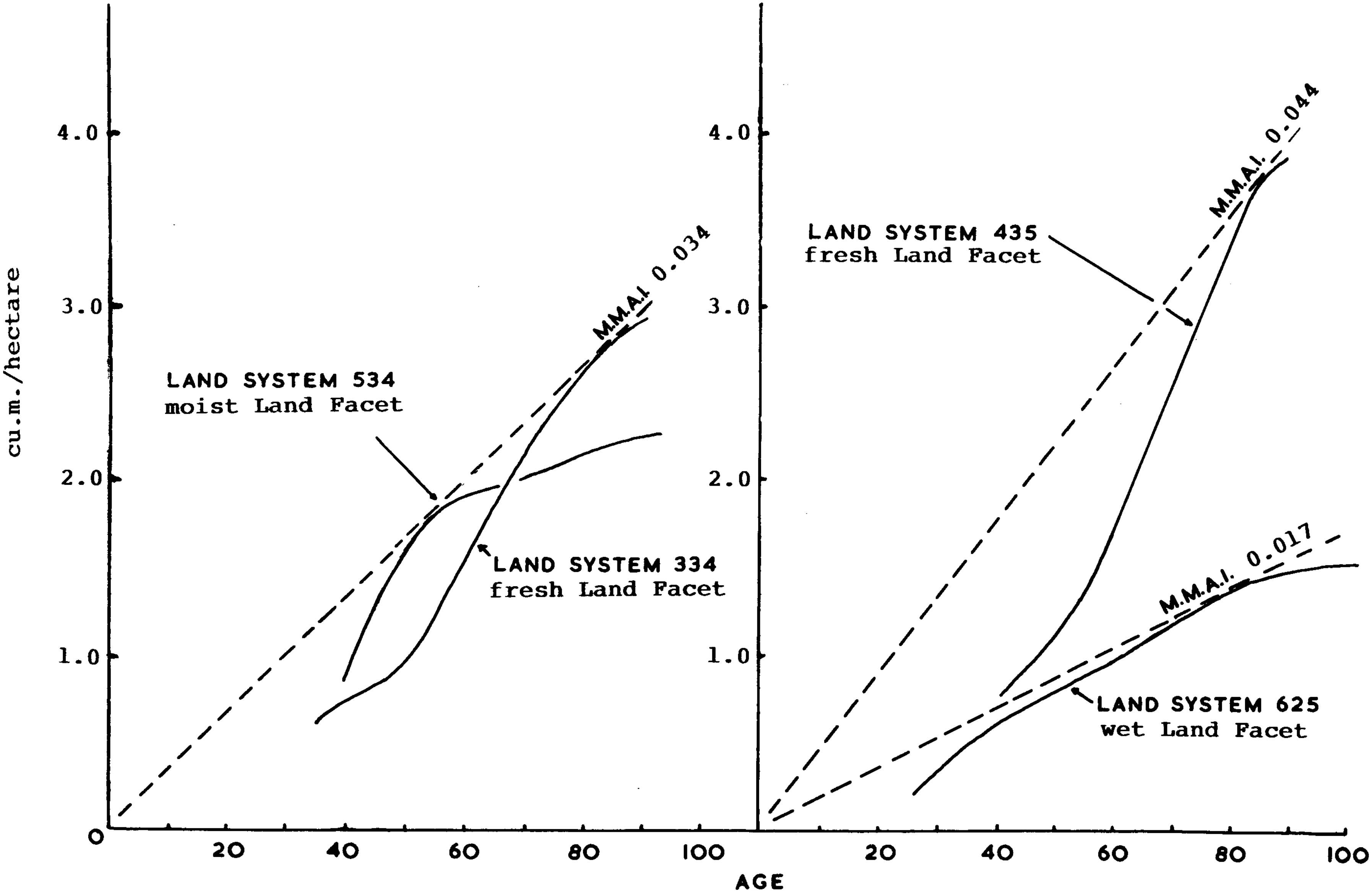


Fig.26. Simulated growth curves, interpreted as cu.m./hectare, for red-black spruce on different Land Facets (soil drainage categories), within different Land Systems (Landforms).

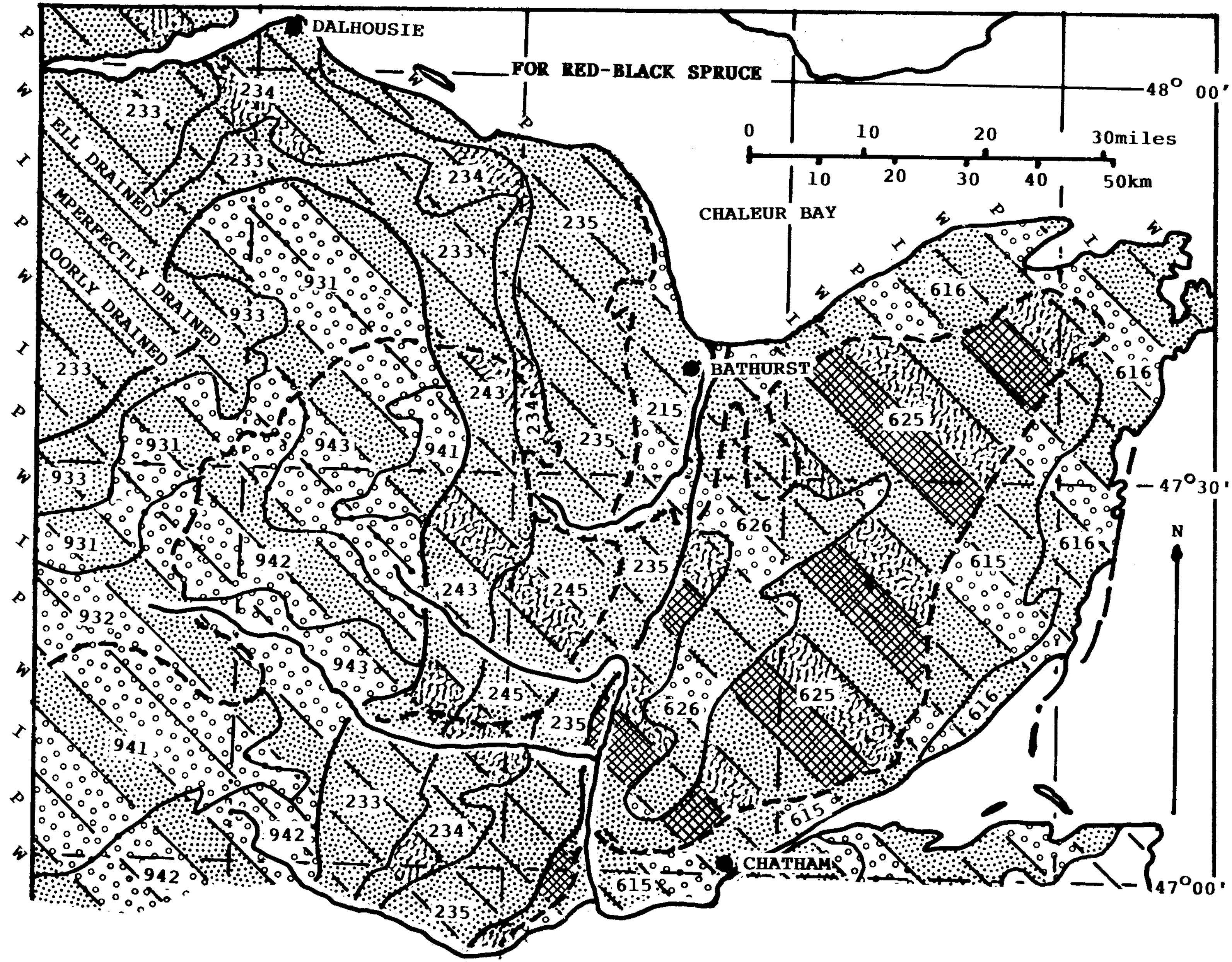
forest, but should have important implications for managed forestry.

As another example, red-black spruce achieves its M.M.A.I./hectare on the moist Land Facet, within the rolling Land System, on silty tills over Lower Palaeozoic shales, within the warm and moist central area of southwest Nova Scotia (terrain unit 5342) at a rotation of about 55 years, similar to the fresh Land Facet, within the rolling Land System, on the same silty tills over Lower Palaeozoic shales, but within the warm and moderately dry climate of southwest New Brunswick (terrain unit 3341) at the much greater rotation of 85 years, which would seem to render the forest in southwest New Brunswick much less economic. However, the pronounced flattening of the growth curve for red-black spruce in southwest Nova Scotia implies that the terrain's reserve of tree nutrients has been exhausted at 55 years, and that either severe thinning or fertilization is needed, both unacceptably expensive operations within the Canadian economic (as distinct from the European) regime.

<u>**Mapping Productivity**</u>. The Central Highlands and Central Lowlands of New Brunswick have been selected for more detailed map representation. It is impossible to show the distribution of Land Facets except within the largest scale of maps. It is possible to show the different M.M.A.I./hectare values for specific forest species in each of the Land Facets, well drained (W), imperfectly drained (I) and poorly drained (P), within

mapped Land Systems (Fig.27A). Striped shading indicates the productivities for hybridizing red-black spruce growing on different Land Facets (essentially, different drainage classes), within each Land System (listed in Fig.27B), the distribution of which can be shown at the scale presented. Thus the range of productivity in each Land System is represented by the range of shading. It is obvious that the Central Lowlands over Upper Palaeozoic shales is more productive land than that within the Central Highlands cored with Devonian granites. It is noteworthy that the productivity of red-black spruce growing on well drained soils within Land Facet 0001 of Land Systems 424, 435 and 624 is more productive than the imperfectly drained counterpart (terrain unit 0002) in these Systems. Within Land System 625 widespread in the Central Lowlands, it is the imperfectly drained Land Facet 6252 that is more productive. This relative productivity, presumably, reflects the drier climate prevailing within the Maritime Lowlands Land Region (6000), compared with Land Systems associated with a greater mean annual precipitation. Imperfectly drained soils are able to conserve moisture during a drier summer more effectively than well drained soils, helping to sustain the considerable water requirements of a growing forest. At higher elevations, for example within the Central Highlands Land Region 9000, lifted air extracts much more rain, and it is the well drained soils 9001 that achieve the greater productivity since they shed the excess water which could produce anaerobiosis, always associated with poor productivity.

FIG.27A. FOREST PRODUCTIVITY CLASSIFICATION, BY LAND FACET.



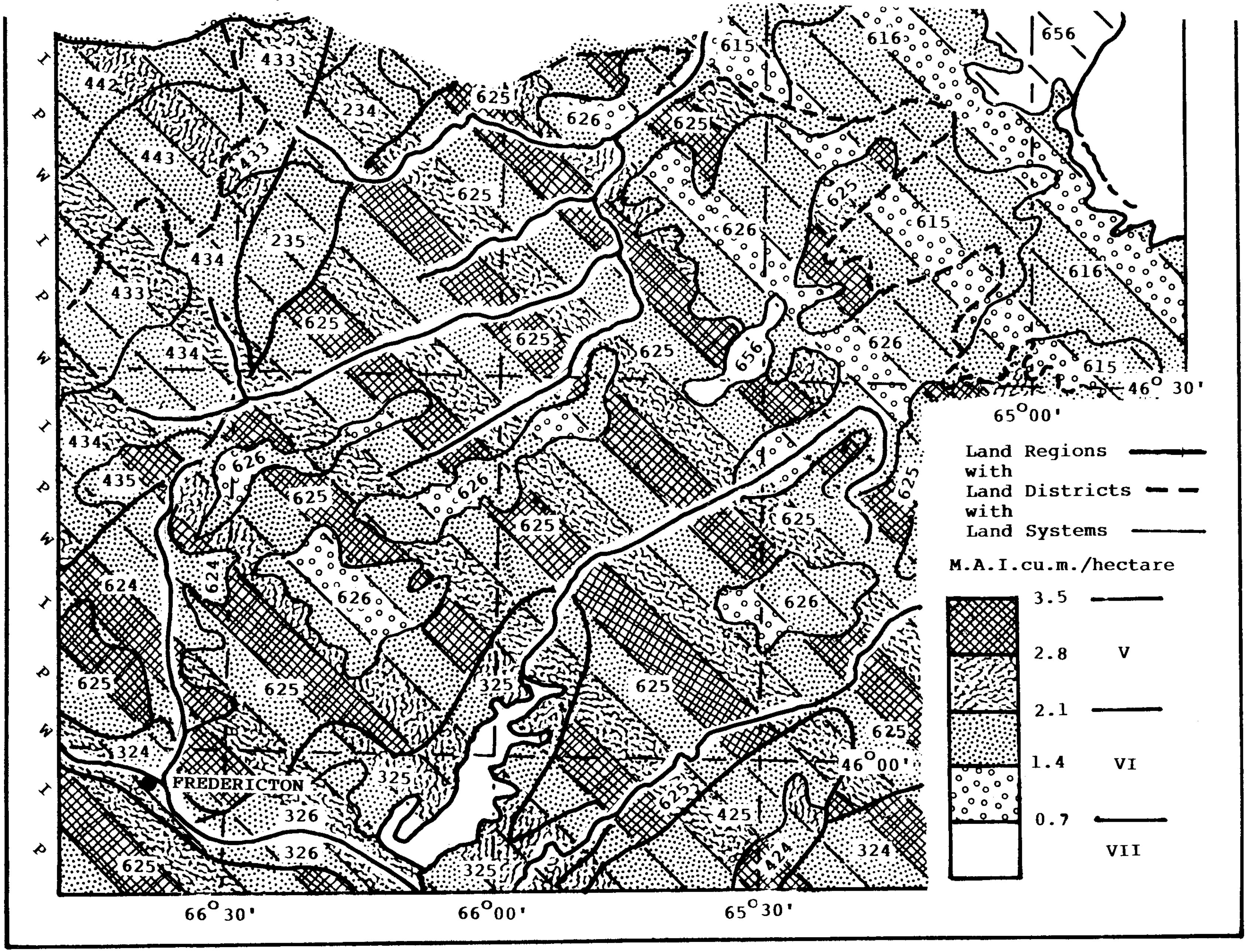

Land Regions
with
Land Districts
with
Land Systems
M.A.I.cu.m./hectare
3.5
2.8
V
2.1
1.4
VI
0.7
VII
FREDERICTON
46° 30'
65°00'
46°00'
66° 30'
66°00'
65°30'

FIG.27B. LEGEND FOR FOREST PRODUCTIVITY CLASSIFICATION MAP.

TERRAIN UNIT	LAND REGION	LAND DISTRICT	LAND SYSTEM	MID-RANGE VALUE LAND FACET/CLASS
215	Mod. cool & mod. dry.	Glacio-fluv.& glacio-mar.	Gently und.	W-upper 6 I-upper 6 P-lower 6
235	"	Silty till/ L.Pal. sh. & sst.	Gently und.	W-upper 6 I-upper 6 P-upper 6
234	"	"	Rolling	W-lower 5 I upper 6 P-upper 6
233	"	"	Hilly	W-upper 6 I-upper 6 P-upper 6
245	"	Sandy till/ igneous rock	Gently und.	W-lower 5 I-upper 6 P-upper 6
243		"	Hilly	W-lower 5 I-upper 6 P-upper 6
326	Warm & mod. dry.	Loamy till/ U.Pal. sst. & sh.	Flat	W-lower 5 I-upper 6 P-upper 6
325	"	"	Gently und.	W-lower 5 I-lower 5 P-upper 6
324	"	"	Rolling	W-lower 5 I-upper 6 P-upper 6
425	Cool & moist.	Loamy till/ U.Pal. sst. & sh.	Gently und.	W-lower 5 I-upper 6 P-upper 6
424	"	"	Rolling	W-upper 5 I-lower 5 P-upper 6
435	"	Silty till/ L.Pal. sh. & sst.	Gently und.	W-upper 5 I-upper 6 P-upper 6
434	"	"	Rolling	W-lower 5 I-upper 6 P-upper 6
433	"	"	Hilly	W-lower 5 I-upper 6 P-upper 6

cu.m per hectare/rotation in years

balsam fir	red/black spruce	white spruce	white pine	red/black spruce % coverage by each LAND FACET		
1.4/30	1.4/50	2.1/40	2.8/60	70	1.4/50	Well drained
				20	1.4/50	Imperfectly drained
				10	0.7/40	Poorly drained
1.4/30	1.4/50	2.8/50	3.5/60	65	1.4/60	W
				25	1.4/50	I
				10	1.4/40	P
2.1/40	2.1/60	2.8/50	3.5/70	60	2.1/60	W
				30	1.4/50	I
				10	1.4/50	P
1.4/30	1.4/50	2.8/40	3.5/60	85	1.4/50	W
				10	1.4/50	I
				5	1.4/40	P
1.4/30	1.4/50	2.8/50	3.5/60	45	2.1/60	W
				35	1.4/50	I
				20	0.7/40	P
1.4/40	1.4/60	2.8/50	3.5/70	75	2.1/60	W
				20	1.4/50	I
				5	0.7/40	P
1.4/40	1.4/60	2.8/50	3.5/60	35	2.1/60	W
				40	1.4/50	I
				25	1.4/50	P
2.1/40	2.1/60	2.8/50	3.5/70	35	2.1/60	W
				35	2.1/60	I
				30	1.4/60	P
2.1/30	2.1/50	3.5/50	4.2/70	75	2.1/50	W
				20	1.4/50	I
				5	1.4/50	P
2.1/40	2.1/60	2.8/50	3.5/70	35	2.1/60	W
				50	1.4/60	I
				15	1.4/50	P
2.1/40	2.1/60	2.8/50	3.5/70	30	2.8/60	W
				60	2.1/60	I
				10	1.4/50	P
2.8/50	2.8/70	3.5/60	4.2/80	65	2.8/70	W
				15	1.4/60	I
				20	1.4/50	W
2.1/30	2.1/40	2.8/40	3.5/50	65	2.1/50	W
				25	2.1/40	I
				10	1.4/40	P
2.1/30	2.1/50	2.8/40	3.5/60	80	2.1/50	W
				15	1.4/50	I
				5	1.4/50	P

TERRAIN UNIT	LAND REGION	LAND DISTRICT	LAND SYSTEM	MID-RANGE VALUE LAND FACET/CLASS
443	"	Sandy till/ igneous rock	Hilly	W-lower 5 I-upper 6 P-upper 6
442	"	"	Mountainous	W-lower 5 I-upper 6 P-upper 6
616	Mod. warm & mod. dry.	Glacio-fluv.& glacio-mar.	Flat	W-upper 6 I-upper 6 P-lower 6
615	"	"	Gently und.	W-upper 6 I-upper 6 P-lower 6
626	"	Loamy till/ U.Pal. sst. & sh.	Flat	W-upper 6 I-upper 6 P-lower 6
625	"	"	Gently und.	W-lower 5 I-upper 5 P-upper 6
624	"	"	Rolling	W-upper 5 I-upper 6 P-upper 6
656		Marsh & peat.	Flat	7
933	Cool & mod. dry.	Silty till/ L.Pal. sh. & sst.	Hilly	W-upper 6 I-upper 6 P-upper 6
932	"	"	Mountainous	W-upper 6 I-lower 6 P-lower 6
931	"	"	Mountain plateaus	W-upper 6 I-lower 6 P-lower 6
943	"	Sandy till/ igneous rock	Hilly	W-upper 6 I-lower 6 P-lower 6
942	"	"	Mountainous	W-upper 6 I-lower 6 P-lower 6
941	"	"	Mountain plateaus	W-upper 6 I-lower 6 P-lower 6

cu.m. per hectare/rotation in years

balsam fir	red/black spruce	white spruce	white pine	red/black spruce % coverage	by each	LAND FACET
				70	2.1/60	W
2.1/30	2.1/50	2.8/50	3.5/60	25	1.4/50	I
				5	1.4/40	P
				75	2.1/50	W
2.1/30	2.1/50	2.8/40	3.5/60	20	1.4/50	I
				5	1.4/40	P
				55	1.4/60	W
1.4/30	1.4/50	2.1/50	2.8/60	25	1.4/40	I
				20	0.7/50	P
				70	1.4/60	W
1.4/40	1.4/60	2.1/50	2.8/70	20	1.4/50	I
				10	0.7/50	P
				40	1.4/60	W
1.4/30	1.4/50	2.1/50	2.8/70	35	1.4/50	I
				25	0.7/50	P
				30	2.1/70	W
2.1/40	2.1/60	3.5/60	4.2/80	55	2.8/60	I
				15	1.4/70	P
				65	2.8/80	W
2.1/50	2.1/70	3.5/60	4.2/80	30	1.4/60	I
				5	1.4/40	P
–	–	–	–	100	-	P
				90	1.4/50	W
1.4/30	1.4/50	2.8/40	3.5/60	5	1.4/50	I
				5	0.7/40	P
				85	1.4/50	W
1.4/30	1.4/40	1.4/40	2.1/60	10	0.7/40	I
				5	0.7/40	P
				80	1.4/50	W
1.4/30	1.4/40	2.1/40	2.8/60	15	0.7/40	I
				5	0.7/40	P
				85	1.4/50	W
1.4/30	1.4/50	2.1/40	2.8/60	10	0.7/40	I
				5	0.7/40	P
				80	1.4/40	W
1.4/30	0.7/40	1.4/30	2.1/50	10	0.7/40	I
				10	0.7/40	P
				70	1.4/40	W
1.4/30	0.7/40	1.4/30	2.1/50	20	0.7/40	I
				10	0.7/40	P

Fig.27B lists the M.M.A.I./hectare, weighted according to the varying proportional areas of the different Land Facets (different drainage categories) within each Land System, for balsam fir, red-black spruce, white spruce and white pine. Balsam fir is generally as productive as red-black spruce, although the best growth of fir is associated with the earlier years (its M.M.A.I./hectare is achieved earlier), after which fir's growth rate slackens considerably. Although productivity of all species is low, it is noteworthy that balsam fir achieves a greater growth rate than that of red-black spruce within the cool and moderately dry climate of Land Region 9 (Fig.24B), in sandy till over granitic rocks (Land District 94), within mountainous terrain and on plateaus (Land Systems 942 and 1).

White spruce is generally more productive than red-black spruce, except within Land System 932 where they are the same, another comparison involving poor productivity across the Central Highlands of New Brunswick. Whatever the relative productivity values between species, these hostile regions are undoubtedly best left as wilderness parks. Clear cutting would yield a small harvest spread over a great area, and forest recovery would be over a very long rotation, or possibly never since the growth potential may be too close to some environmental threshold. (There are historical records suggesting that the "Barrens" of Nova Scotia (terrain unit 5400) once supported trees). White pine is almost twice as productive as red-black spruce, although pine generally occurs as widely separated trees or small stands.

The pulp industry relies primarily on the common spruce and fir, whereas pine is used for saw timber.

The simulated growth curves for each Land Facet can be used for calculating the present worth of costs required to break even at 5% over a rotation of 100 years (the period generally accepted within the Maritimes, and elsewhere). These costs can be weighted according to the different Land Facet areas within each Land System. Certain costs per unit volume of timber can be associated with cutting, increasing with scale of relief and declining volume yield per unit area. The precise costs are unimportant. This calculation suitably penalizes with increasing necessary investment, sites where clear-cutting of poor crops is repeated at short intervals, but favours sites which produce good merchantable crops, possibly over longer rotations. There is a concentration of high necessary investment values across the Central Highlands of New Brunswick and the Northern Plateau of Nova Scotia, and a broad zone of low necessary investment values across the Central Lowlands of New Brunswick and southwestern Nova Scotia, except adjoing the Atlantic coastline (Fig.28).

If the present worth of costs to break even is calculated separately for well drained soils (Land Facet 0001) and poorly drained soils (Land Facet 0003) in areas such as the Central Lowlands of New Brunswick, the difference in values is not great. Different managements are necessary for well drained and poorly drained soils, and so the areas of different Land Facets

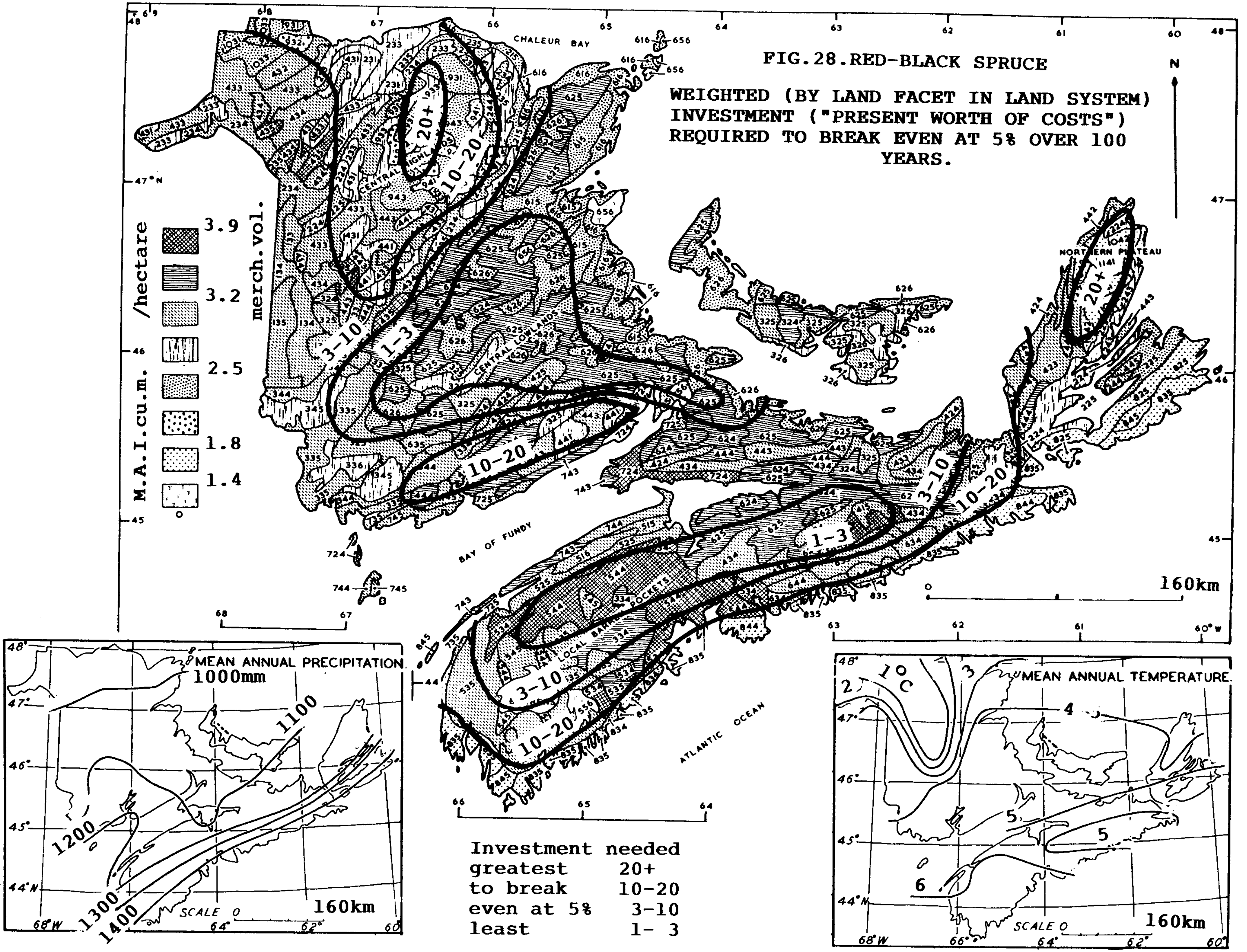


FIG.28.RED-BLACK SPRUCE
WEIGHTED (BY LAND FACET IN LAND SYSTEM) INVESTMENT ("PRESENT WORTH OF COSTS") REQUIRED TO BREAK EVEN AT 5% OVER 100 YEARS.
M.A.I.cu.m. merch.vol. /hectare
3.9
3.2
2.5
1.8
1.4
0
CHALEUR BAY
CENTRAL HIGHLANDS
CENTRAL LOWLANDS
NORTHERN PLATEAU
BAY OF FUNDY
ATLANTIC OCEAN
LOCAL BASIN POCKETS
160km
MEAN ANNUAL PRECIPITATION.
1000mm
1100
1200
1300
1400
SCALE 0 160km
MEAN ANNUAL TEMPERATURE.
1°C
2
3
4
5
6
SCALE 0 160km
Investment needed
greatest 20+
to break 10-20
even at 5% 3-10
least 1- 3

must be reasonably equitable regarding costs associated with different managements; this is so within the Central Lowlands. This is not so within the Central Highlands of New Brunswick where poorly drained soils are far more extensive than other drainage categories. Because poorer drained soils have smaller reserves of essential tree nutrients, repeated cropping over short rotations will quickly exhaust the land.

In support of varying productivity estimates for different parts of the Maritimes, southwest Nova Scotia experiences the highest mean annual temperature, but also the greatest rainfall to help keep the soils soaked (Fig.28). With their much more continental climate, the Central Highlands of New Brunswick are both much drier and cooler. The Central Lowlands of New Brunswick and adjoining Nova Scotia experience a more equitable climate, encouraging greater productivity.

This forest land productivity classification does not predict "potential productivity" since there are insufficient managed stands in the Maritimes to reasonably forecast this potential from Land Facet to Land Facet. Because there has only been extensive management of the forests, and not intensive management as locally in the United States and generally in Europe, even the practice of selecting the best trees in a stand for measurement does not give the potential. The chief purpose of this classification is to show the relative productivities of different lands, based on the present forest, which should be useful now when assessing widely separated parcels of land, and in the future when selecting lands for preferential management investment.

LOCAL STUDIES

Composite Stem Analyses. Stems of black and white spruce, and of jack pine growing within different Land Facets of Land System 625 in the Central Lowlands of New Brunswick were cut into 1.2m bolts, and the radial growth measured at five year intervals for each 1.2m multiple of height. Composite stem profiles were constructed, illustrating the changing form of certain tree species on certain drainage categories with increasing age (Fig.29A and B). Analyses for black spruce on peaty, poorly drained soils (terrain unit 6253), and red spruce on imperfectly drained soils (terrain unit 6252) illustrate the considerable variation in height and form from one drainage category to another. Whereas black spruce on poorly drained soils is, on average, short and approximately cone-shaped, red spruce on imperfectly drained soils is generally taller and approximately bell-shaped, especially when more mature, yielding a greater volume of timber, height for height. While balsam fir shows an evolution of form on imperfectly drained soils like red spruce, the cone-shaped trunk is generally retained by white spruce on the same soils at young and mature stages alike. These natural landscape implications can have profound effects upon multiple regression formulae designed to usefully reflect different growth syndromes.

The temporary slowing of the rate of growth shown by balsam fir at a certain age has been observed in many increment borings of fir and other forest species. If after clearing of the forest by budworm or fire, a dense, even-aged stand develops, at a certain age supression of growth occurs during the time required for natural thinning.

Younger trees (aged 40 years or less) of all the species examined, jack pine, red and black spruce, white spruce and balsam fir, have grown far more rapidly than older trees (aged greater than 40 or 54 years) have grown up to the same growth stage on both well drained (terrain unit 6251) and poorly drained soils (terrain unit 6253) soils (Fig.29B). Additionally, jack pine has a bell-shaped stem, like that of red spruce and balsam fir. White spruce has been observed to grow especially well as it spreads over abandoned farmland, seeming able to efficiently use nutrients accumulated in the soil by farm activity.

Soils, Forest and Aspect. A soil catena from ridge top to valley bottom in Land System 433 of northeast New Brunswick is illustrated in Fig.30A. Sandstones are often interbedded with the Lower Palaeozoic shales across ridge tops in this cool and moist Land Region (Fig.24B), helping the ridges to resist erosion more effectively than slopes where the shales, alone, tend to crop out. Silty till progressively thickens downslope. Placic (iron pan or orstein) Humo-Ferric Podzols occur on ridge crests, giving way to Orthic Humo-Ferric Podzols (C.D.A., 1978) near, and

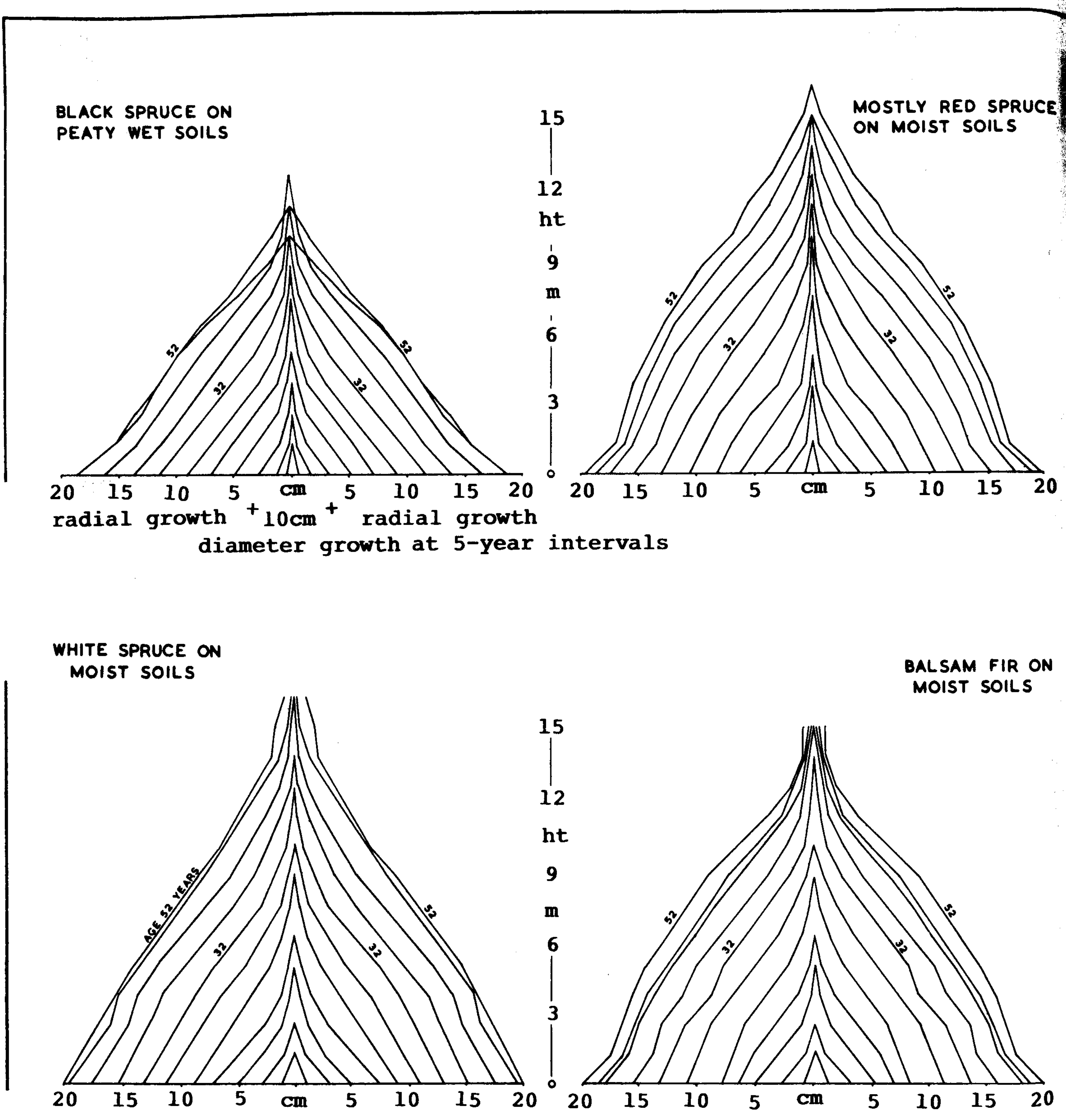


Fig.29A. Composite stem analyses for four common species, aged between 40 and 54 years. The standard error of the mean varies between 0.13 for 31 trees, and 0.32 for 10 trees contributing to each age-height diameter calculation.

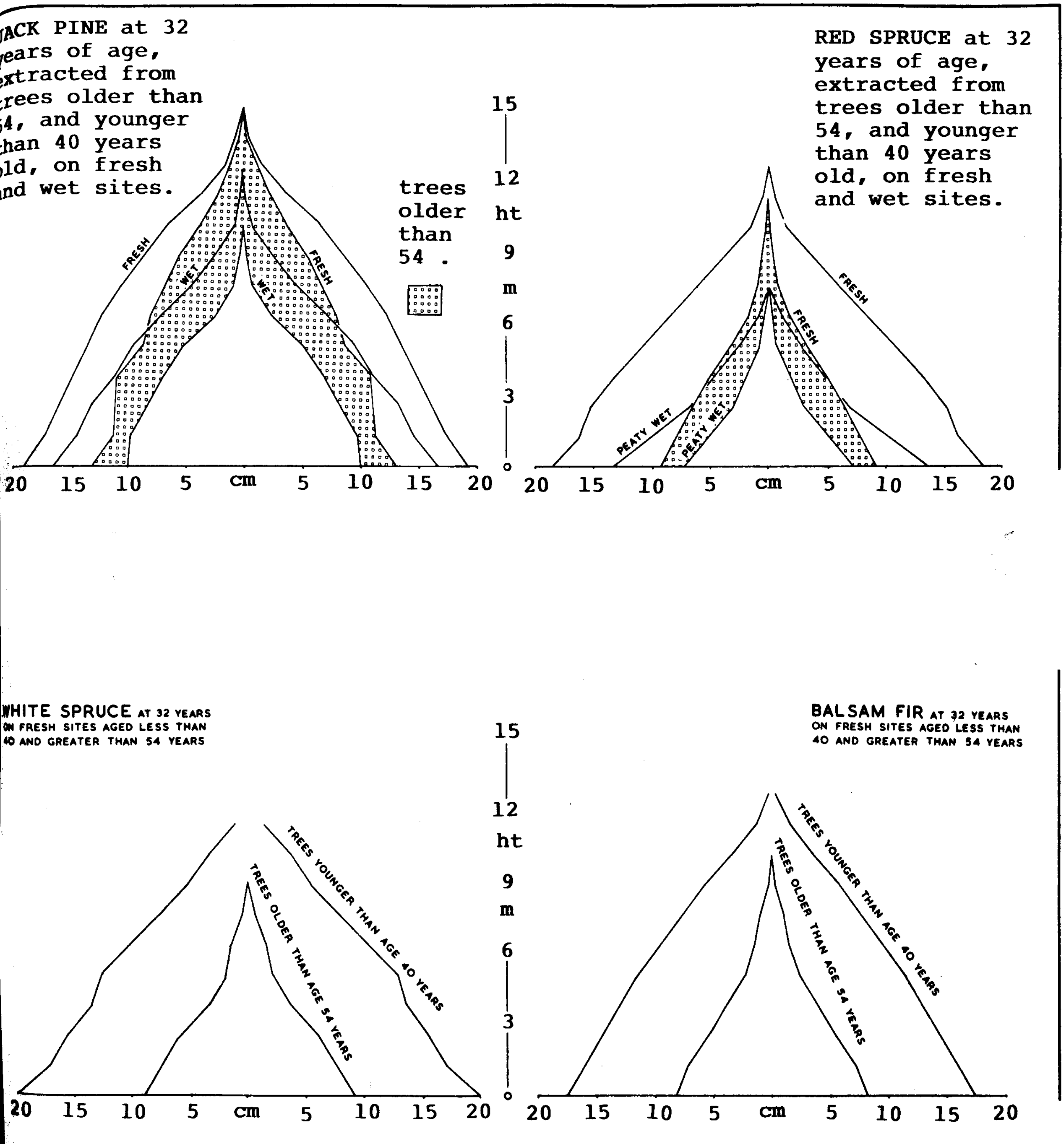


Fig.29B.Composite stem analyses for four common species, older than 54 years, and younger than 40 years of age.

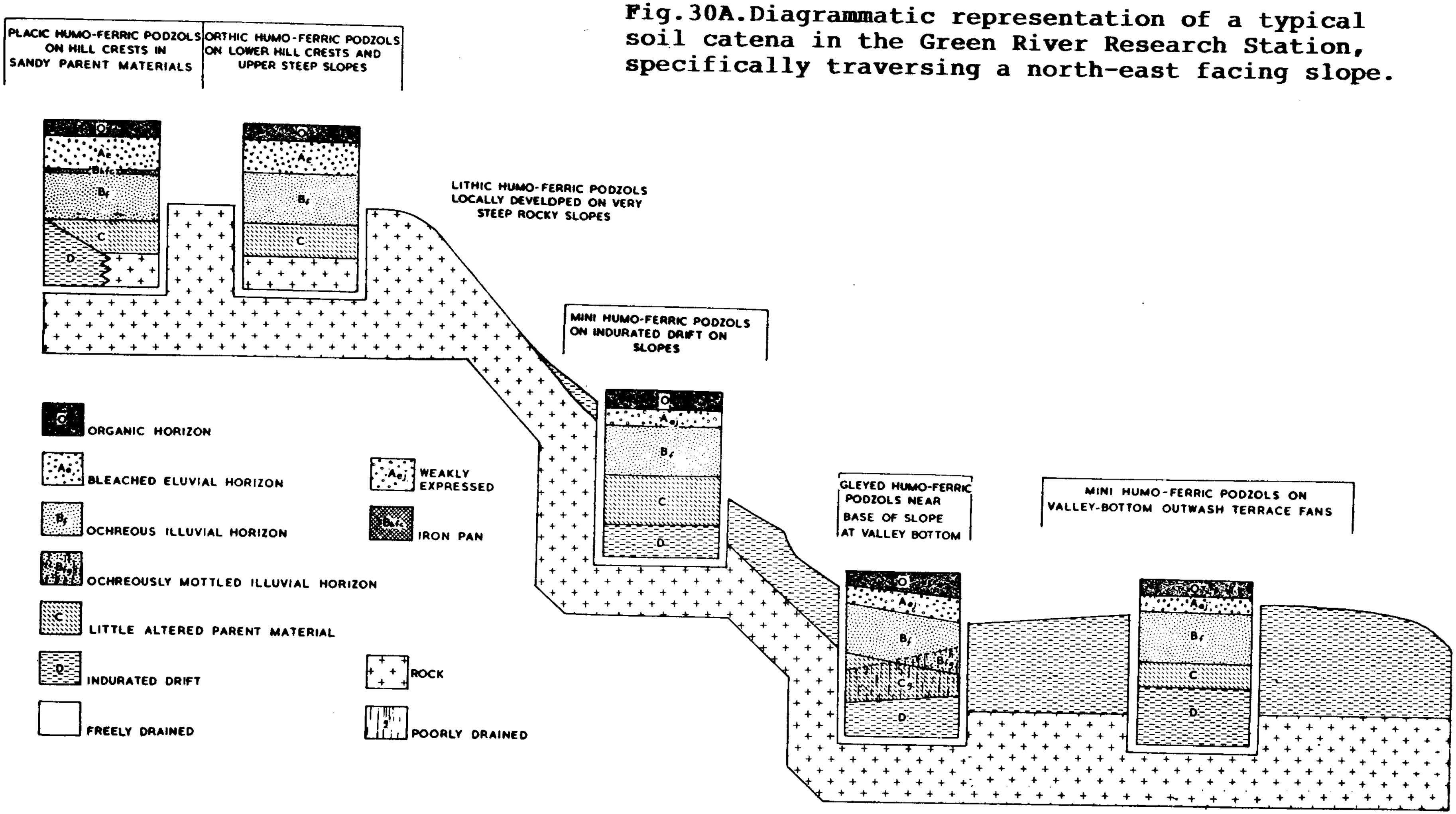


Fig.30A. Diagrammatic representation of a typical soil catena in the Green River Research Station, specifically traversing a north-east facing slope.

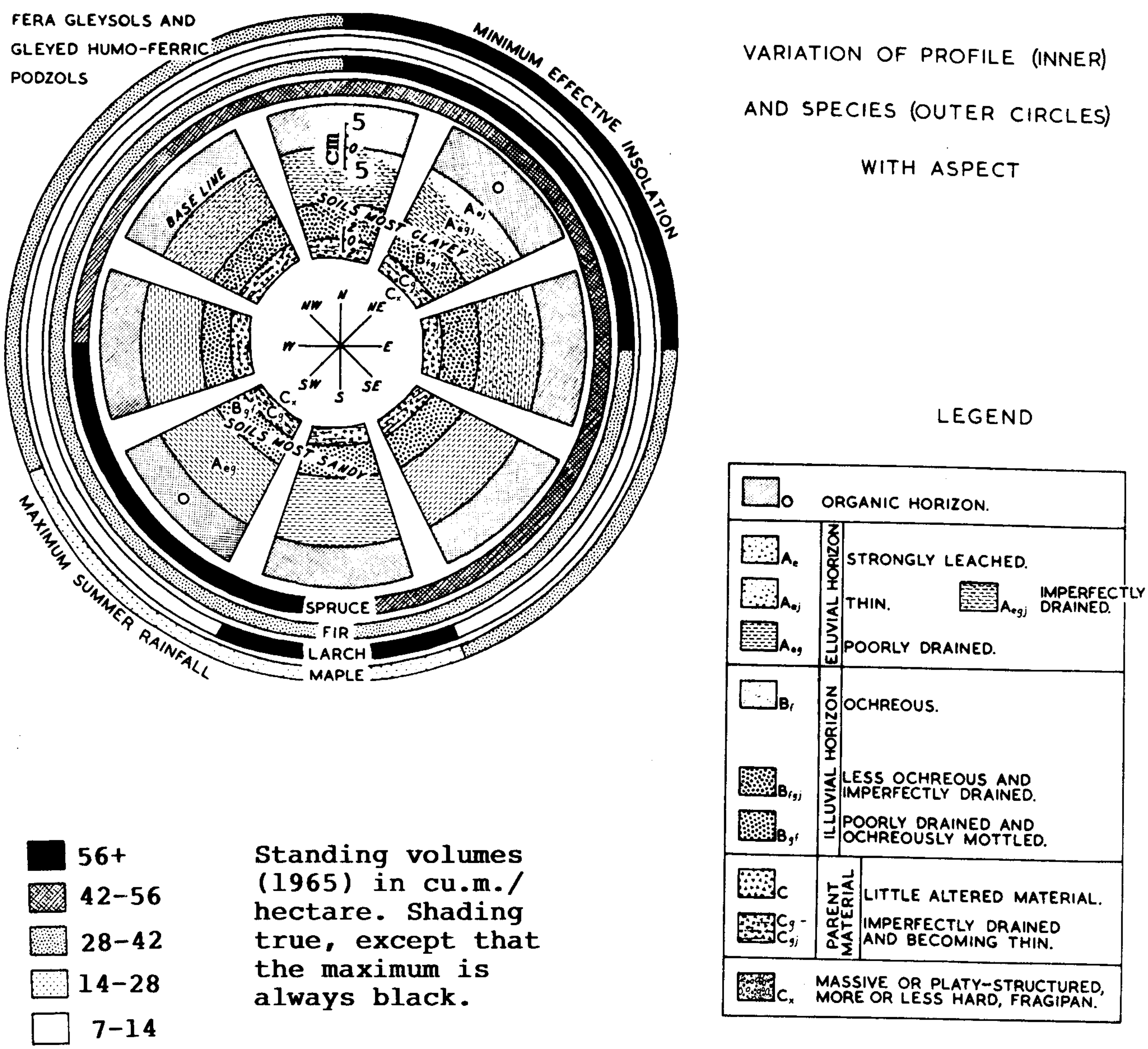


Fig.30B. Variations in standing timber with changing aspect and soil distribution, for four different species within the Green River Research Station.

on upper slopes. The leached eluvial horizon thins downslope. Imperfect drainage occurs in these Podzols at the base of the slopes, yielding Gleyed Humo-Ferric Podzols which also occur in the wetter valley-bottom soils. Where glacio-fluvial outwash deposits occur in the valley, there are Mini Humo-Ferric Podzols. Lower slope and valley bottom soils often have a compacted subsoil with a platy structure, relatively impervious to water and generally associated with some imperfections of drainage (Crampton, 1985), also described in the Vale of Neath of South Wales.

On northeast-facing slopes the soil profiles have thicker organic and illuvial horizons (Fig.30B). The well drained Podzol eluvial horizon is also best developed on the cool, northeast-facing slopes. Tree species respond more distinctly to differences of aspect; balsam fir and red maple achieve their greatest yields on the cool, northeast-facing slopes. Compared with red-black spruce, across the neighbouring, cool Central Highlands of New Brunswick balsam fir also shows better comparative growth than elsewhere. White spruce commonly grows on the ridge tops and slopes in the Green River area, and this species, along with eastern larch shows better growth on southeast- and south-facing slopes.

Nutrient Uptake by the Forest. Upper Palaeozoic shales, with some sandstones crop out across the Acadia Forest Research Station, within Land Region and District, 620. The area achieves its highest elevation across Bull Pasture situated on the central-north boundary. The Station undulates as it falls gently (Land System 625) southwards towards Two Forks Brook (Fig.31). The distribution of soils is shown in Fig.31, and of forest species in Fig.32. The nature of the terrain is shown in Fig.33. The well drained, upper, low ridge slopes where sandstones crop out carry Orthic Humo-Ferric Podzols (terrain unit 6251). These merge into similar Podzols with a reduced thickness for the eluvial horizon. On lower slopes imperfections of drainage lead to the formation of Gleyed Humo-Ferric Podzols (terrain unit 6252). In the flatter catchments between brooks there are poorly drained Fera gleysols, merging locally into peaty Rego Gleysols (terrain unit 6253).

Mixed red spruce and balsam fir stands tend to occur in the better (well and imperfectly) drained areas alongside brooks (compare Figs.31 with 32). Hardwood stands tend to occur across imperfectly drained areas. Red and black spruce stands tend to dominate across the flat catchments of poorly drained soils between brooks, black spruce and some hardwoods with eastern white cedar where there are peaty Rego Gleysols.

At 380 sites within the Research Forest the contents of selected chemicals such as calcium and nitrogen within the foliage of red-black spruce and fir, and within the organic, eluvial and illuvial horizons of soils were determined. In addition, within the soil horizons determinations were made of the contents of

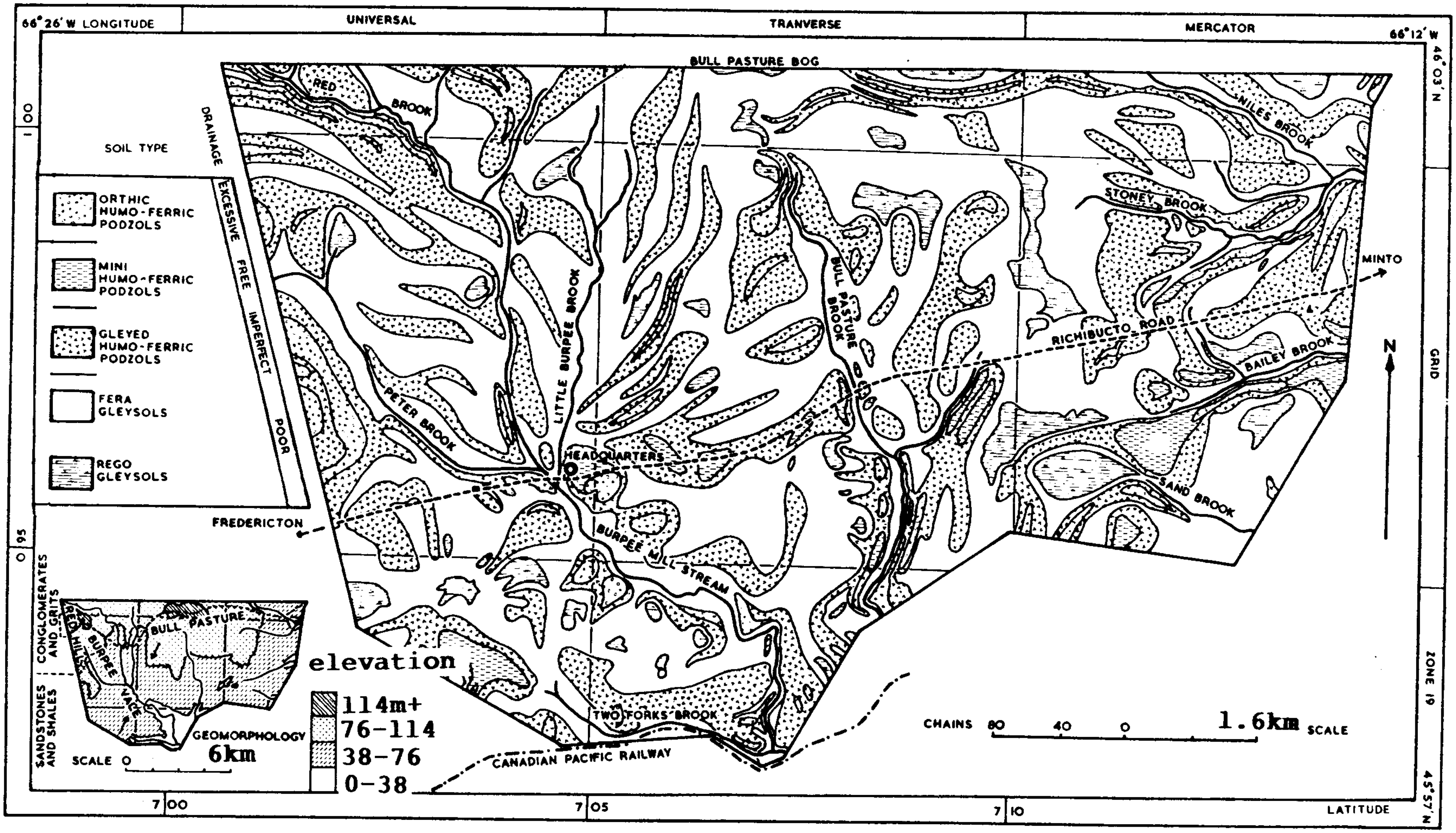


Fig.31.Distribution of soils in Acadia Forest Research Station.

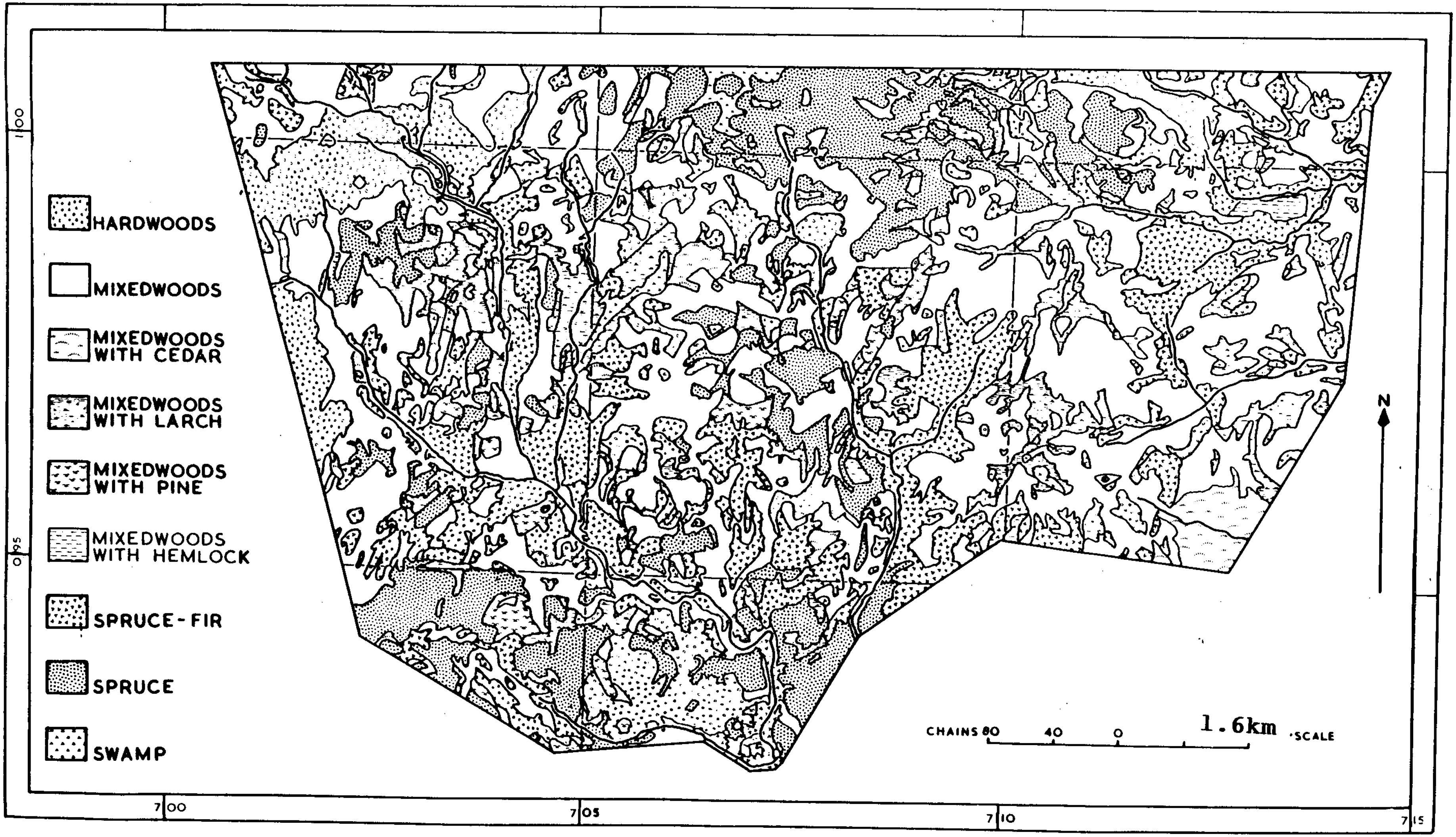


Fig.32.Distribution of forest types in Acadia Forest Research Station.

Fig.33.Serpentine Lake
in the area of Acadia Forest Research Station.

clay, silt and sand, and of the physico-chemical attributes of field capacity, exchange capacity and pH.

The interaction between all possible paired combinations of these independent variables and the dependent variable was determined by constructing a two-dimensional matrix for each pair of independent variables, within which matrix the means for the dependent variable were categorized into three classes to allow surrogates of the paired variables to be processed similarly to single variables. The matrix was intended as a mathematical analog of an experienced person's judgement when attempting to evaluate the synergistic interactions which permeate the natural world. Although single and paired independent variables were processed on an equal basis, it was always paired variable surrogates that yielded the greatest coefficiant of determination within the regression, emphasizing the importance of synergism.

Synergistic organic horizon calcium content and eluvial horizon clay content appear to be the most important influence on foliage nitrogen content of trees growing in well drained soils (Fig.34), foliage nitrogen content increasing with increasing values for both variables. Only clay in the soil can hold potential forest nutrients. Too much clay will produce imperfections of drainage, but these well drained, Brunisolic and Podzolic soils contain little clay, especially in the eluvial horizon. In such soils it is often the organic horizon that contains most potential forest nutrients, and is best able to hold on to moisture during a long

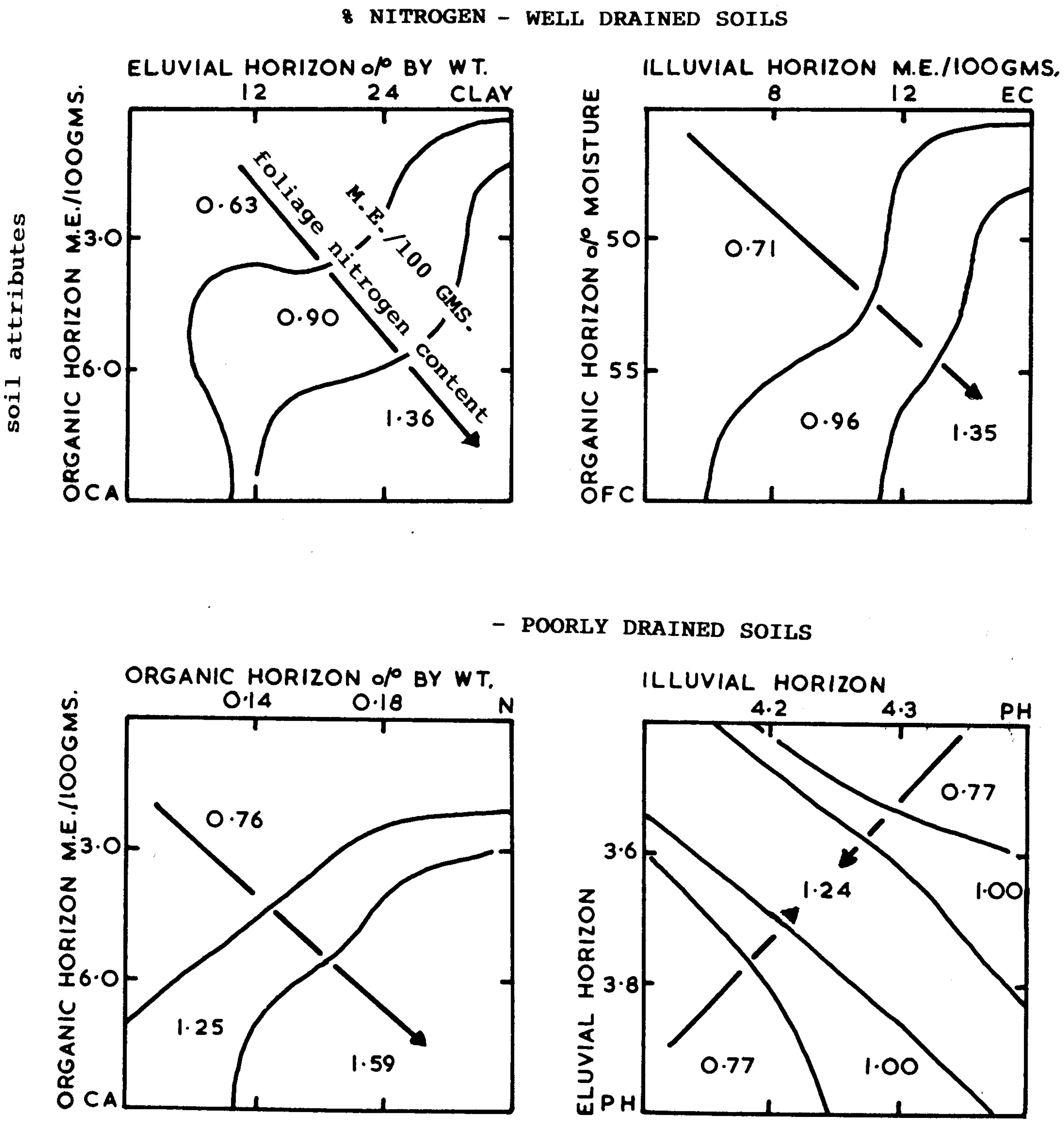


Fig.34. Interaction diagrams for physical and chemical attributes of well and poorly drained soils, as they affect foliage nitrogen content. EC = exchange capacity; CA = calcium; N = nitrogen; FC = field capacity ; PH = acidity.

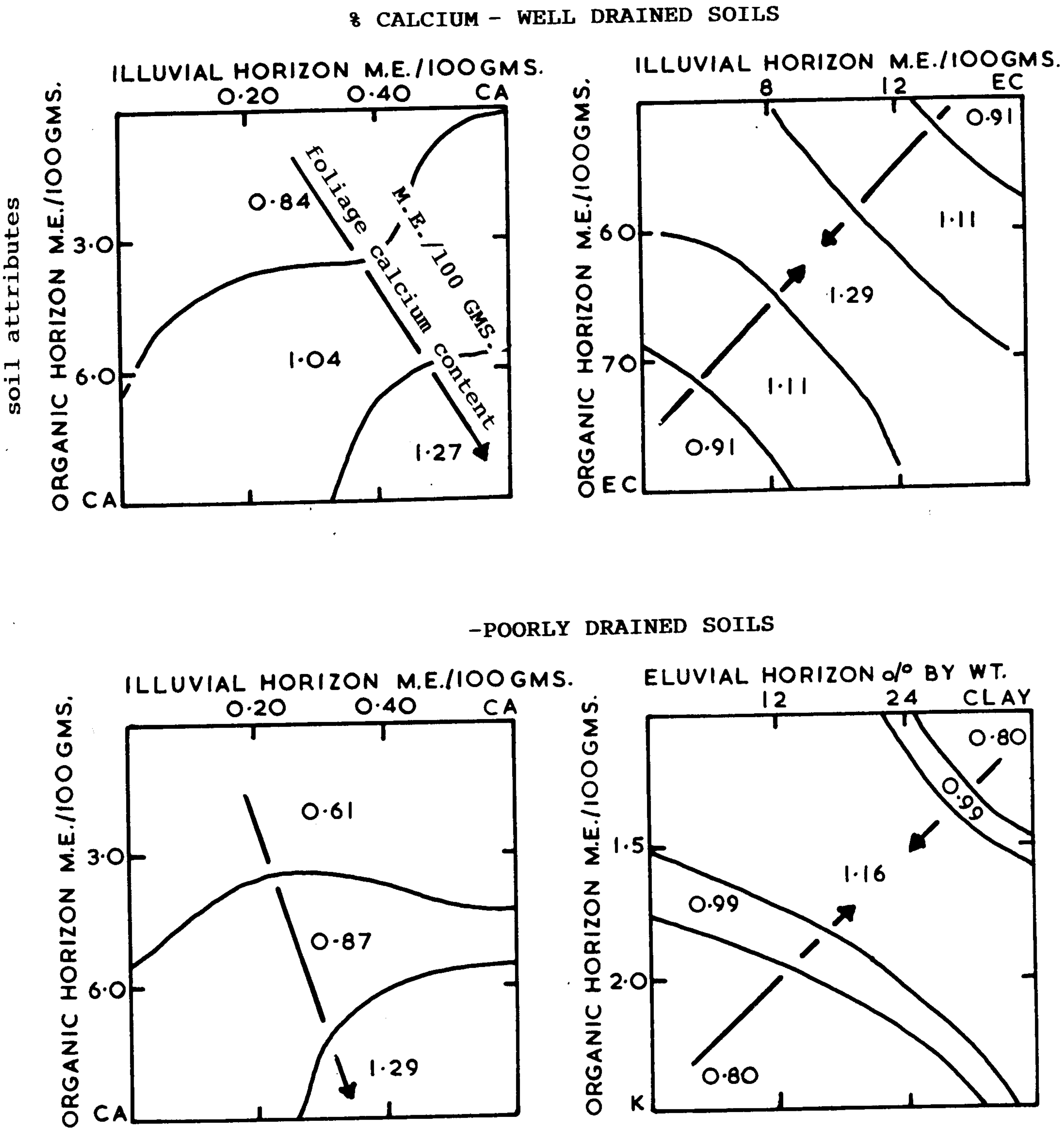


Fig.35. Interaction diagrams for physical and chemical attributes of well and poorly drained soils, as they affect foliage calcium content. EC = exchange capacity; CA = calcium; K = potassium.

Analyses by C.Macdonald.

dry summer. Hence, it is understable that the field capacity (to hold moisture) of the organic horizon, and the exchange capacity (of the clay) in the illuvial horizon constitutes the second most important interaction influencing foliage nitrogen content, foliage nitrogen increasing with increasing organic horizon field capacity and illuvial horizon exchange capacity.

Within soils leached to a greater or lesser extent within the coarser-textured eluvial horizon, it is the less leached illuvial horizon that often acts as an alternative source of nutrients compared with the primary source, the organic horizon. Thus, it is not surprising that it is the increasing calcium contents of the organic and illuvial horizons that determine the increasing calcium content of the foliage (Fig.35). A balanced relationship of organic and illuvial horizon exchange capacities is the second most important interaction influencing the foliage calcium content.

In poorly drained soils the foliage nitrogen content is chiefly influenced by a synergistic interaction between the calcium and nitrogen contents of the organic horizon, the calcium seeming to act as a catalyst for nitrogen uptake (Fig.34). Calcium often acts in this role for the uptake of many elements, and it also helps produce better structured soils. A balanced synergistic interaction between the pH values of the eluvial and illuvial horizons also influences foliage nitrogen contents.

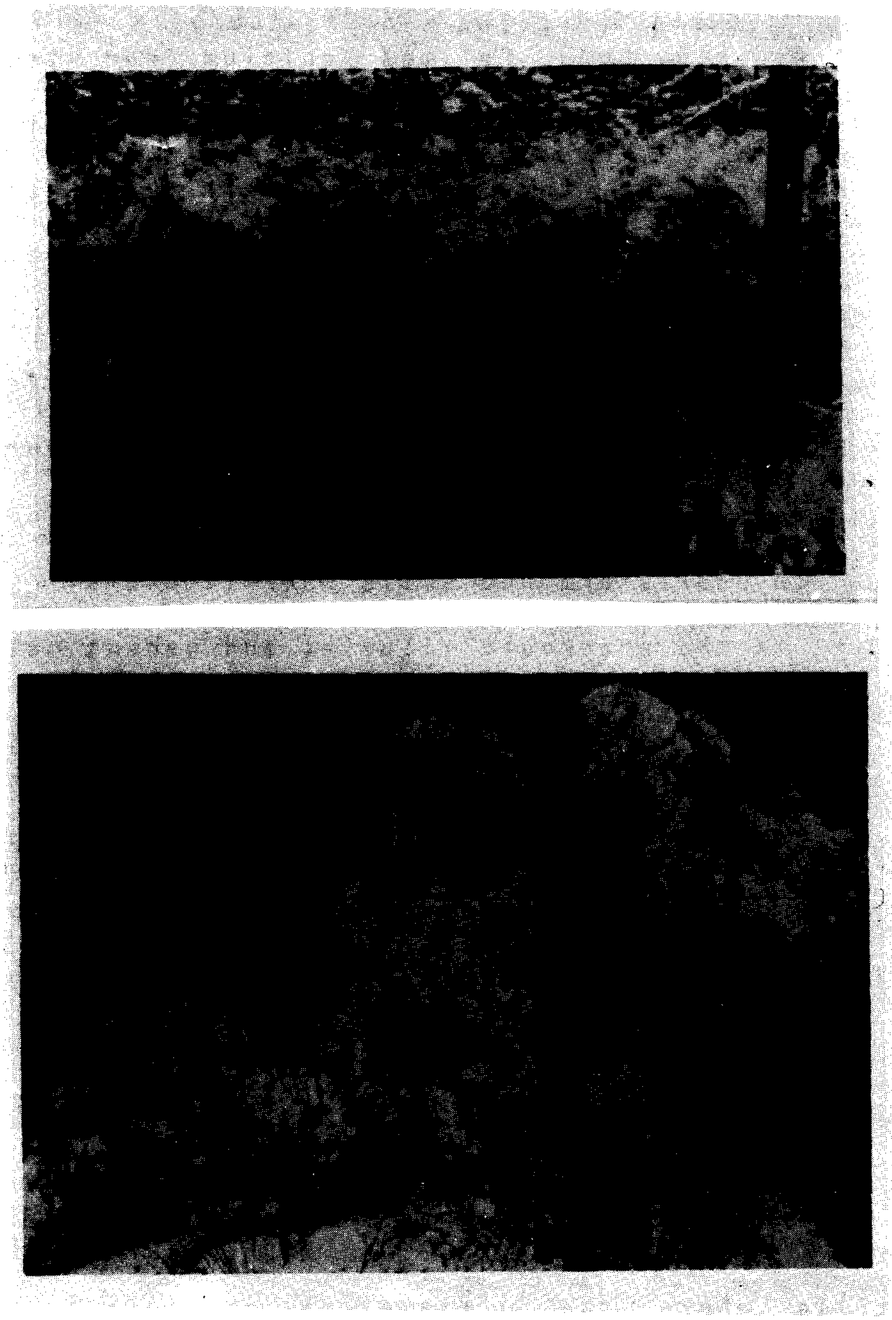


Fig.36.(Upper)Podzol,showing white (leached) eluvial horizon, over ochreous (darker) illuvial horizon; (below) jack pine blown down during hurricane, to expose most roots radiating horizontally within the white eluvial horizon, able to tap nutrients released within the organic layer by ascending roots, over the slightly darker illuvial horizon with fewer roots (right centre), in Acadia Forest Research Station.

Another influence upon foliage calcium for trees growing in poorly drained soils is a synergistic interaction between the calcium contents of the organic and illuvial horizons, foliage calcium content increasing with increasing calcium contents within the soil horizons. Another synergistic interaction seems to be a balance between increasing clay content within the eluvial horizon and potassium content within the organic horizon. Potassium seems to be acting as a catalyst for the uptake of calcium. In poorly drained soils where the clay content is often great, it is the anaerobic illuvial and parent material horizons that constitute the greatest impediment to tree rooting. Most roots occur within the eluvial horizon where ascending rootlets can tap nutrients in the organic horizon and, where anaerobiosis is not too severe, some descending rootlets can tap nutrients in the illuvial horizon. A shallow concentration of roots within the eluvial horizon creates potential instability, and a strong wind can locally uproot trees in these soils (Fig.36).

Polygonal Ground Patterning. In central southwestern Nova Scotia where the climate is relatively dry, and where granite crops out to form a rolling landscape chaotically littered with massive granitic blocks (terrain unit 544 - Fig.24A), there occurs an area mostly unforested called "The Barrens". Local folklore suggests that this area was once forested, but repeated fires were accompanied by a steady deforestation until, today, stunted trees remain mostly within prominent troughs dissecting the landscape. These troughs seem to be roughly aligned within a polygonal network, picked out in aerial photographs by the presence of the trees (Fig.37). On a larger scale these polygons can be seen to often have star-like grooves radiating out from the domed-up centre of each polygon (Fig.38). Stunted black spruce and red maple align within the troughs. Black Huckleberry forms a thick scrub over the domed polygon centres. Placic Podzols (with an iron pan or, where thick, an ortstein) occur across the domes, whereas bouldery Rego Gleysols occur in the troughs.

At several localities in New Brunswick forested primary polygons (Fig.37) could be seen sub-divided into smaller secondary polygons (Fig.38) and, sometimes, this secondary network could be seen sub-divided into a smaller tertiary network of polygons. Red maple and other hardwoods dominated the forest on the polygon domes, whereas red and black spruce dominated in the troughs. Orthic Podzols mostly occurred across the polygon domes, with bouldery Rego Gleysols in the troughs. Where the forest had been cleared for agriculture, as around Fredericton in central-eastern New Brunswick, the clustered farmhouse and associated buildings were sited on the central polygon dome, away from drainage problems associated with the troughs.

Within the periglacial climate prevailing across the Canadian north most ground below the active layer, that surface thickness that thaws in the summer and freezes in the winter, is permanently frozen. The low winter temperatures, in some places

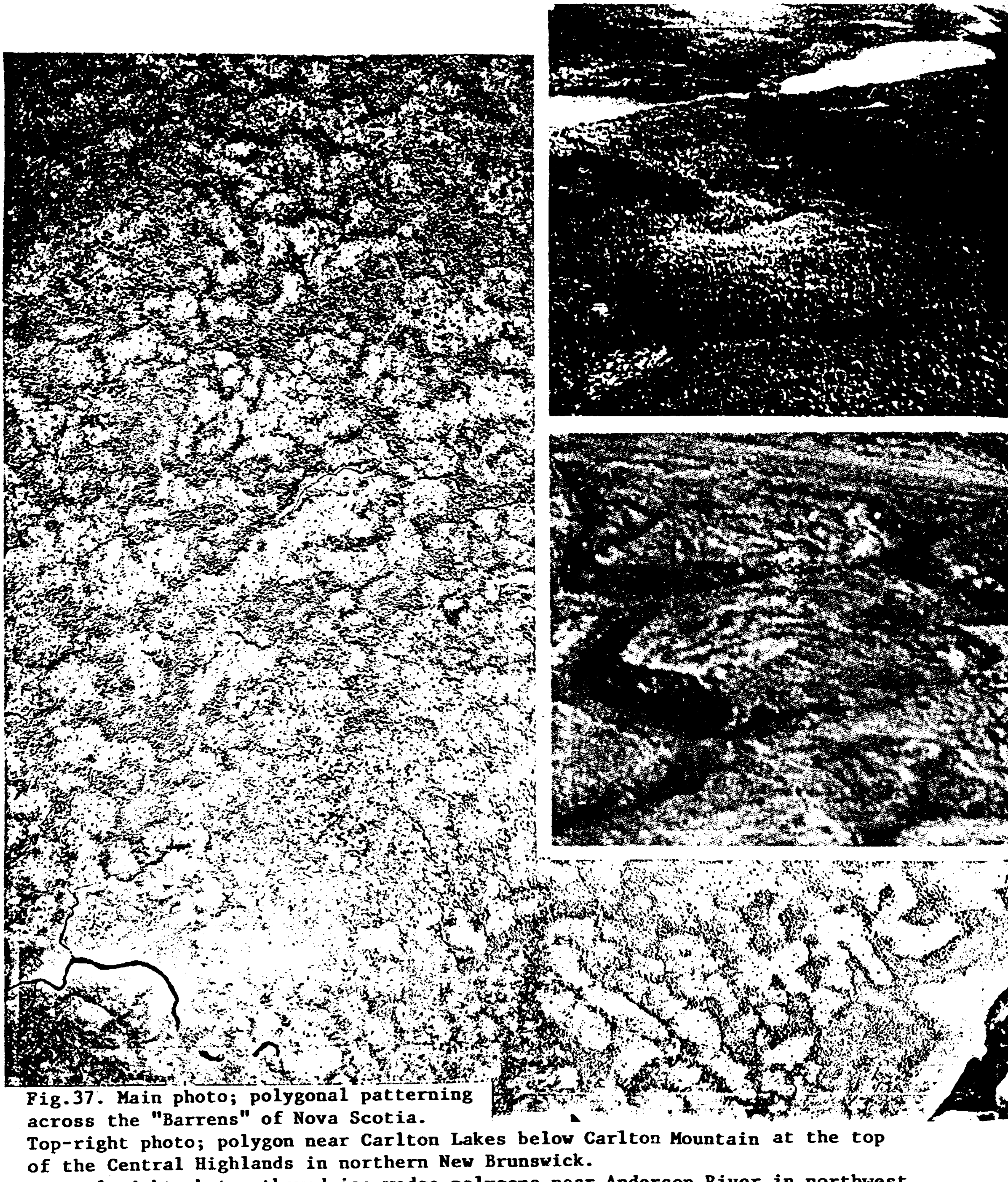
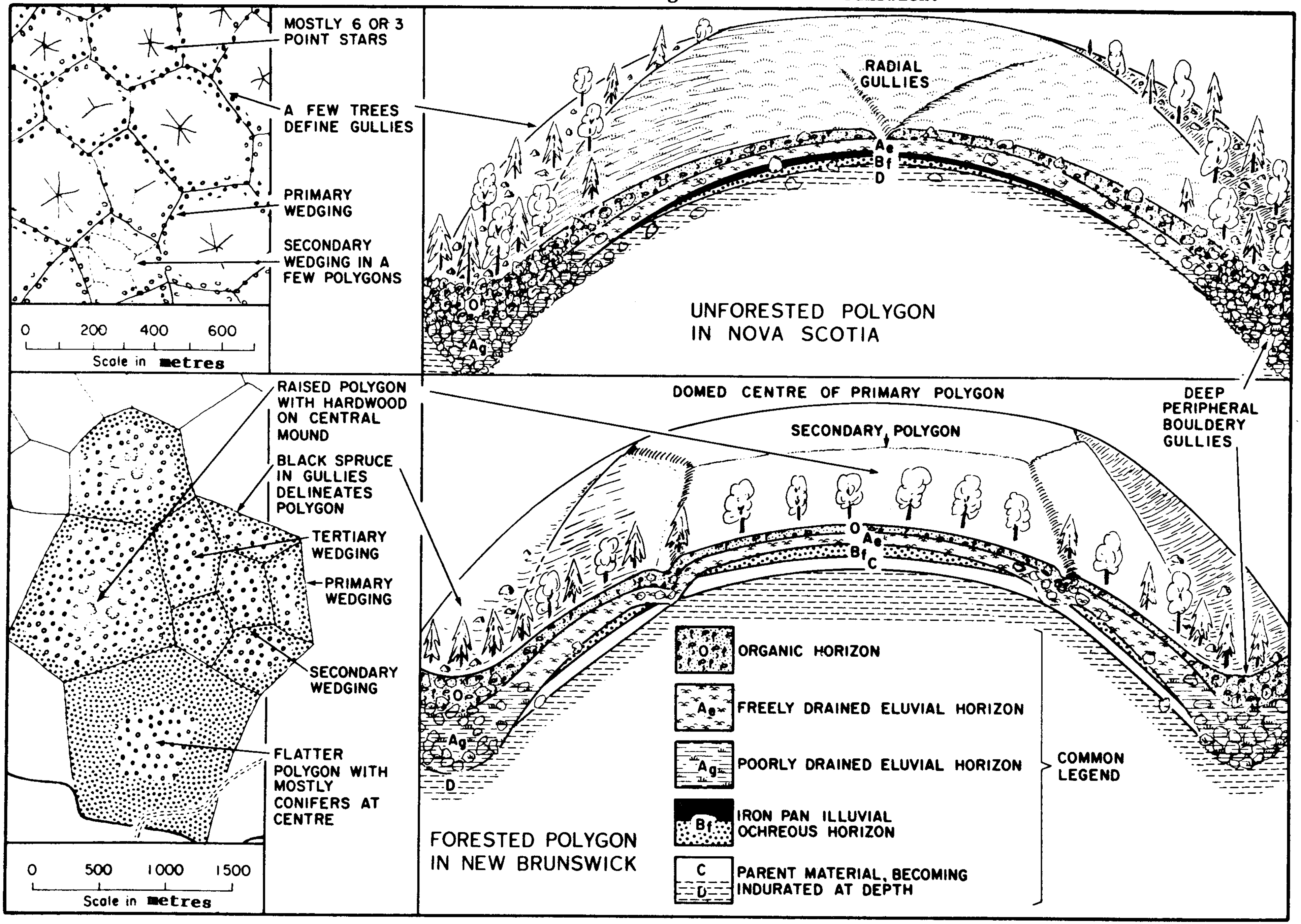


Fig.37. Main photo; polygonal patterning across the "Barrens" of Nova Scotia.
Top-right photo; polygon near Carlton Lakes below Carlton Mountain at the top of the Central Highlands in northern New Brunswick.
Central-right photo; thawed ice-wedge polygons near Anderson River in northwest Northwest Territories.

(Air photo A14706 74)

Fig.38. Polygonal patterning across the "Barrens" of Nova Scotia, and within the area of the Carlton Lakes in the Central Highlands of New Brunswick.



as cold as -40 degrees C or F and below, cause the ground to contract and crack. These cracks, once established, tend to be followed during subsequent winters and align within a polygonal network. Thawing at the surface during spring releases water which trickles into the cracks, but freezes immediately on contact with the still-frozen substrate. Thus, when the summer warmth produces expansion of the ground, this expansion cannot be accomodated by closure of the cracks which are filled with ice, called ice wedges, and so the polygon centres are pushed up. So-called "raised-centre" polygons develop steadily over the years. Where the ice has been thawed by surface disturbance, the wedges collapse into troughs, clearly delineating the polygons (Fig.37). These polygonal networks may have primary, secondary and tertiary sub-divisions. The centre of any domed structure is the weakest part, and often cracks.

A periglacial climate developed locally during the late Wisconsin glaciation could have produced the polygonal patterning seen scattered across several parts of the Maritime Provinces. Subsequent thawing would emphasize the troughs, as near Anderson River (Fig.37).

It has been widely postulated that repeated burning helped produce some of the European heathlands. Within the dryish climate of northeast New Brunswick repeated burning of the natural vegetation, sometimes as unofficial make-work projects, is causing a progressive stunting of the forest. Presumably, in time, this practice could produce a landscape similar to the barrens where heathland becomes the dominant vegetation, especially where there are granitic rocks (terrain unit 240) which tend to weather into coarse-textured soils over gaping joints, allowing excessively rapid drainage. Without repeated burning, farmland in this landscape, abandoned because the very acid soils are "hungry" and need excessive amounts of fertilizers, is revegetated by white spruce.

AFTER-THOUGHTS

Because South Wales has been mostly deforested during historic times, the use of graminoid species associated with oakwood remnants scattered across the study-area was found to be the most effective way of sub-dividing the landscape into Land Regions which are intended to reflect the more important climatic variations across the area. The density of meteorological stations in this area is much greater than in the Maritimes of Canada but, nevertheless, this distribution in South Wales still does not allow the tracing of readily observable, continuous boundaries through the landscape separating different local climates. Although the Land Regions are defined in terms of graminoid species within oakwood remnants in order to maintain some environmental constancy from place to place, at least some of these graminoid species always extend beyond the oakwoods (except where the land has been greatly disturbed), such that the boundaries can be walked between the oakwood remnants or, if the terrain is difficult to walk, the boundaries can be traced by eye with reference to the local landscape. Within the Vale of Neath, South Wales, major climatic, Land Region differences between the valley sides (terrain unit 1238), compared with the ridge plateaus (terrain unit 2246), produce most of the productivity variation between sheep farming and forest plantations.

The Maritimes of Canada are still largely forested. A sub-division of forest types with reference to climatic variations had already been undertaken, involving eleven sub-divisions (Loucks, 1962). If these ecoregions are translated directly into Land Regions, the number involved is unusually great for a biophysical classification since it introduces complication where the chief objective should be one of simplification (the natural landscape is already sufficiently complicated). However, the research supporting this forest mapping had been based on thoughtful field work and it seemed impertinent, without duplicating the author's experience, to block together groups of terrain units into a more convenient small number. The climatic extremes in the Maritimes illustrated by comparing Land Region 9 on the Central Highlands of New Brunswick, and Land Regions 10 and 11 on the Northern Plateau of Nova Scotia, with Land Region 6 in the Central Lowlands of New Brunsick, extending into adjoining Nova Scotia, account for the extremes of forest productivity.

In South Wales the definition of Land Districts had been based primarily upon a greatly simplified, four-fold sub-division of the geology. Within the Mesozoic, for example, the smaller area of the Rhaetic outcrop consisting mostly of shales, giving rise to a terrain relatively richer in clay, was combined with the greater area of Liassic, interbedded limestones and shales. Within the Carboniferous the Coal Measures interbedded shale and sandstone lithology dominates, but in the Pennant Grit and, especially, in the Millstone Grit formations thick sandstones produce soils richer in sand, while the Carboniferous Limestone outcrop produces soils richer in silt left after solution of the calcium carbonate. However, to introduce sub-divisions of the Mesozoic and Carboniferous to allow for local textural differences from the normal would have greatly complicated the terrain classification. The intercalation of thin limestone bands within the Devonian, Silurian and Ordovician marls or shales has a profound local effect upon upland soils, but this effect is impossible to show on maps. However, this important effect can be described in terms of vegetation, soils and local landform so that it can be easily identified in the field.

Similarly, the sub-division of the Maritimes of Canada into Land Districts based upon the geology was kept simple, based primarily upon till textures over the different rocks and surficial materials. Sandstones and conglomerates intercalated within otherwise shaly formations introduce into the soils coarser textures, but to allow for these local textural varitions would have greatly complicated the biophysical classification. It is better to illustrate the effects of these local geological outcrops with large scale maps for selected areas.

Keeping the classification flexible, as a matter of practical use, in the land classification of the Vale of Glamorgan, South Wales, Land District 1 encompassing Mesozoic shales and limestones coincided with Land System 1 for the coastal plain (terrain unit 1110), whereas Land District 2 encompassing till over Carboniferous sandstones and shales coincided with Land System 2 for the adjoining mountain foothills (terrain unit 1220). This classification best defined wireworm infestation.

In both the South Wales and the Maritimes biophysical classifications, it is possible to show Land Systems usefully based upon the distribution of landforms and local relief for selected study-areas in South Wales, and upon the amplitude of relief for the Maritimes. The definition of Land Systems was deliberately adapted to suit local scales of mapping and the purpose of the biophysical classification. Without flexibility, these classifications would have become clumsy and difficult for the intended users to understand. Precision is for the expert; but it confounds the lay-person.

REFERENCES

C.D.A., 1978. Canada Soil Survey Committee. The Canadan Dept. of Agriculture, Publication No.1646.

Crampton,C.B. 1960. Petrography of the Mesozoic succession of South Wales. Geol. Mag., 97, 215-228.

Crampton,C.B. 1961. An interpretation of the micromineralogy of certain Glamorgan soils: the influence of ice and wind. J. Soil Sci., 12, 158-171.

Crampton,C.B. 1963. The development and morphology of iron-pan podzols in Mid and South Wales. J. Soil Sci., 14, 282-302.

Crampton,C.B. 1965. Vegetation, aspect and time as factors of gleying in podzols of South Wales. J. Soil Sci., 16, 210-229.

Crampton,C.B. 1965. An indurated horizon in soils of South Wales. J. Soil Sci., 16, 230-241.

Crampton,C.B. 1968. Prehistoric flora on S.Wales uplands, Britain. Adv. Front. Sciences, 21, 15-30.

Crampton,C.B. 1973. Studies of Vegetation, Landform and Permafrost in the Mackenzie Valley; Landscape Survey in the Upper and Central Mackenzie Valley. Report No. 73-8, Task Force on Northern Oil Development.

Crampton,C.B. 1975. Landscape mapping in the Mackenzie River valley. Arctic, 28, 284-294.

Crampton,C.B. 1985. Compacted soil horizons in western Canada. Catena Supplement 6, Soils and Geomorphology, 85-93.

Daniel,G.E. 1950. The Prehistoric Chamber Tombs of England and Wales. The University Press, Cambridge.

Davies,E. 1937. The Black Mountain: a study in rural life and economy. Trans. Carm. Ant. Soc. 64, 53-64.

Davies,E. 1941. The patterns of transhumance in Europe. Geography, 26, 155-168.

Donachair,C. 1945. Traces of the Buaile in the Galtee Mountains. J. Roy. Soc. Ant. of Ireland, 75, 248-252.

Evans,E.E. 1939. Donegal survivals. Antiquity, 13, 207-222.

Fitzherbert,J.T. 1964. Forestry in South Wales. Sylva, No.44, 29-31.

Fox,A. 1937. The "Short Dykes" of Glamorgan. Current Works in Welsh Archaeology, Bull. Board Celtic Stud., viii, 280-282.

Galloway,R.W., van de Graaff,R.H.M. and Story,R. 1963. Land Systems of the Hunter Valley Area, New South Wales, Australia. Land Reseasrch Series No.8, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia.

Handley,W.R.C. 1963. Mycorrhizal Associations and Calluna heathland Afforestation. For. Comm. Bull., No36, H.M.S.O.

Heginbottom,J.A. 1973. Some Effects of Surface Disturbance on the Permafrost Active Layer at Inuvik, N.W.T. Report No. 73-16, Task Force on Northern Oil Development.

Hughes,R. and Munro,J.M.M. 1963. The improvement of herbage varieties for hill reseeding. Rep. Welsh Plant Breeding Station, 72-75.

Hunt,A.D., MacNabb,G.M. and Tener,J.S. 1974. Mackenzie Valley and Northern Yukon Pipelines; Socio-economic and Environmental Aspects. Report No.74-17, Task Force on Northern Oil Development.

Jones Davies,J. 1956. The Kingdom of Brycheiniog in the Age of the Saints. The Brecon and Radnor Express and County Times, The Bulwark, Brecon.

Kurfurst,P.J. 1973. Terrain Disturbance Susceptibility, Norman Wells Area, Mackenzie Valley. Report No. 73-24, Task Force on Northern Oil Development.

Mac Aodha,B.S. 1965. Clachan settlement in Iar-Chonnacht. Irish Geogr., 5, 20-28.

MacDonald,J. Wood,R.F., Edwards,M.V. and Aldous,J.R. 1957. Exotic Forest Trees in Great Britain. U.K. Forest Comm. Bull. No.30.

Loucks,O.L. 1962. A Forest Classification for the Maritime Provinces. Proc. Nova Scotian Inst. Sci., 25, 85-167.

Peart,J.N. 1951. The effect of heather on the role of hill lambs. J. Brit. Grass. Soc., 6, 219-248.

Rees,W. 1924. South Wales and The March 1284-1415. A Social and Agrarian Study. Oxford University Press.

Rowe,J. 1959. Forest Regions of Canada. Can. Dept. Northern Affairs and National Research. Res. Forest Branch, Bull. 123, Ottawa.

Rutter, A.J. and Fourt, D.P. 1965. Studies in the water relations of Pinus sylvestris in plantation conditions 111. A comparison of soil water changes and estimates of total evaporation on four afforested sites and one grass-covered site. J. Applied Ecology, 2, 197-209.

Thomas, B. and Trinder, N. 1947. The ash components of some moorland plants. Emp. J. Exp. Agric., 15, 237-248.

Weatherell, J. 1953. The Checking of Forest Trees by Heather. Forestry, 26, 37-41.

Wood, R.F. and Thirgood, J.V. 1955. Tree Planting on Colliery Spoil Heaps. Res. Branch, Paper No.17, Forestry Commission.

Wright, T.W. 1955. Profile development in the sand dunes of Culbin Forest, Morayshire. J. Soil Sci., 6, 270-283.

Zehetmayr, J.W.L. 1960. Afforestation of Upland Soils. Forestry Commission, Bull. No.32.