Peatlands and Peat Instability

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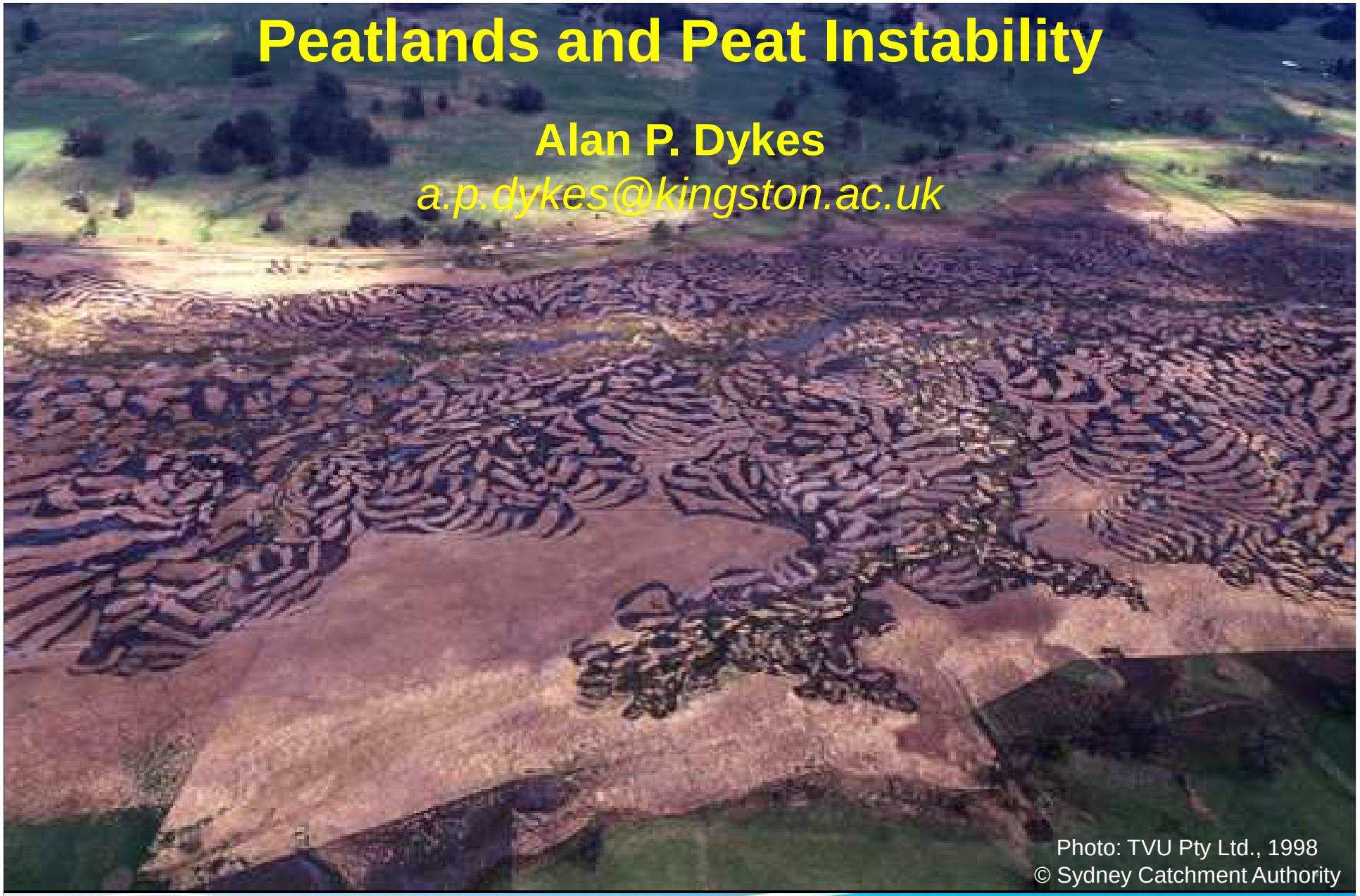

Photo: TVU Pty Ltd., 1998

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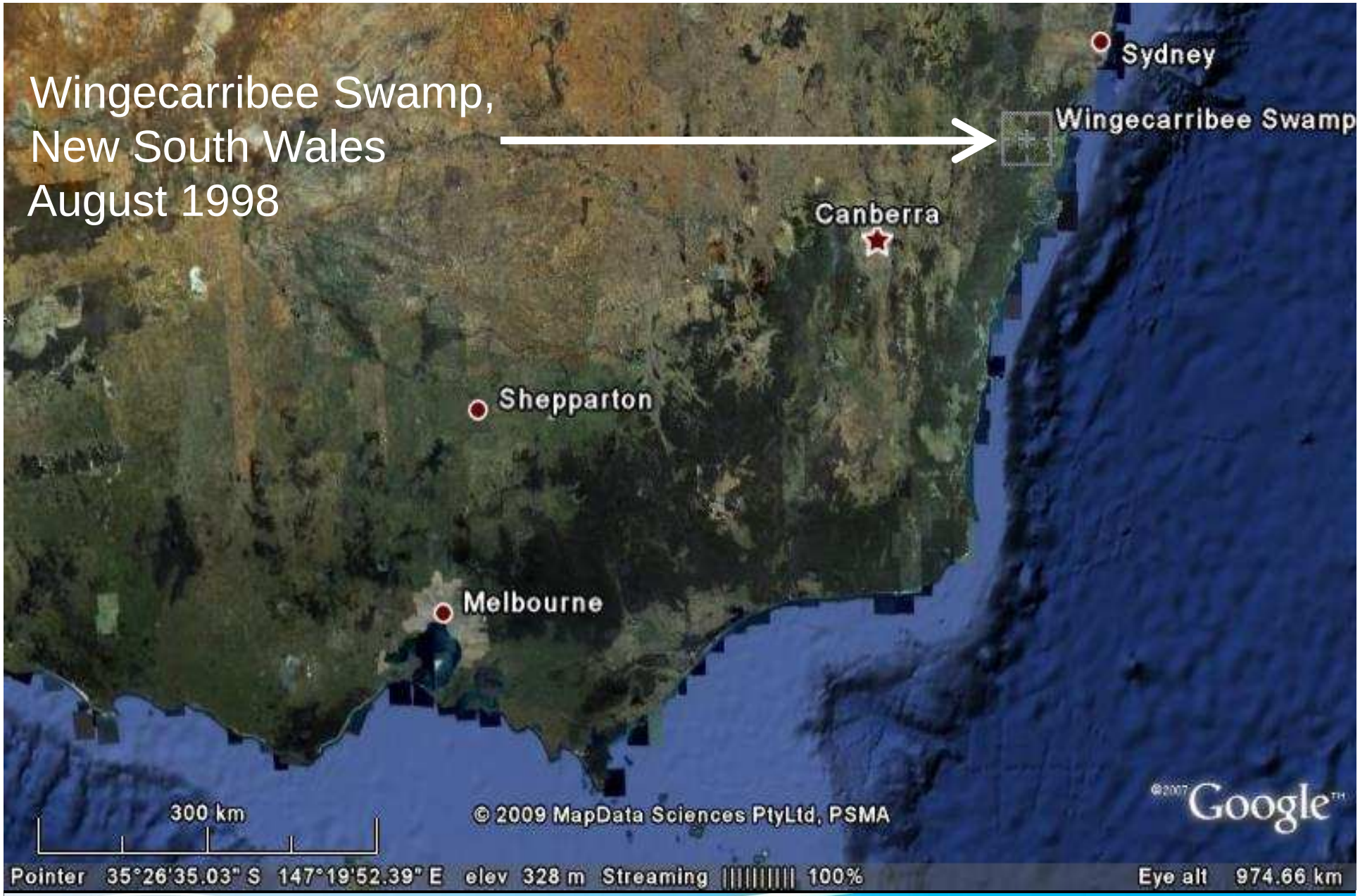
Wingecarribee Swamp,
New South Wales
August 1998
Sydney
Wingecarribee Swamp
Canberra
Shepparton
Melbourne
300 km
© 2009 MapData Sciences PtyLtd, PSMA
©2007 Google
Pointer 35°26'35.03" S 147°19'52.39" E elev 328 m Streaming 100%
Eye alt 974.66 km


Trigger
extreme storm runoff
Underlying cause
peat mining ‘dredge pool’
7–10+ million m3 of peat failed
➔ largest peat failure ever (?)
Photo: TVU Pty Ltd., 1998
© Sydney Catchment Authority

PEATLANDS AND PEAT INSTABILITY

1. Why are we interested?
2. What is peat?
3. Origins and types of peatlands
4. Accumulation and development of peat
5. Peat properties
6. Peatland instability

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1. WHY ARE WE INTERESTED?

➔ ecology and wetland biodiversity conservation

Importance and value of bogs:

ENVIRONMENTAL IMPORTANCE

habitat for flora and fauna

influence local climate

resource for healthcare (e.g. *Sphagnum*)

land resource for agriculture, recreation and water supply

atmospheric carbon sink

influence river regimes

filtering properties

ACADEMIC VALUE OF PEAT ARCHIVE

pollen records of environmental change

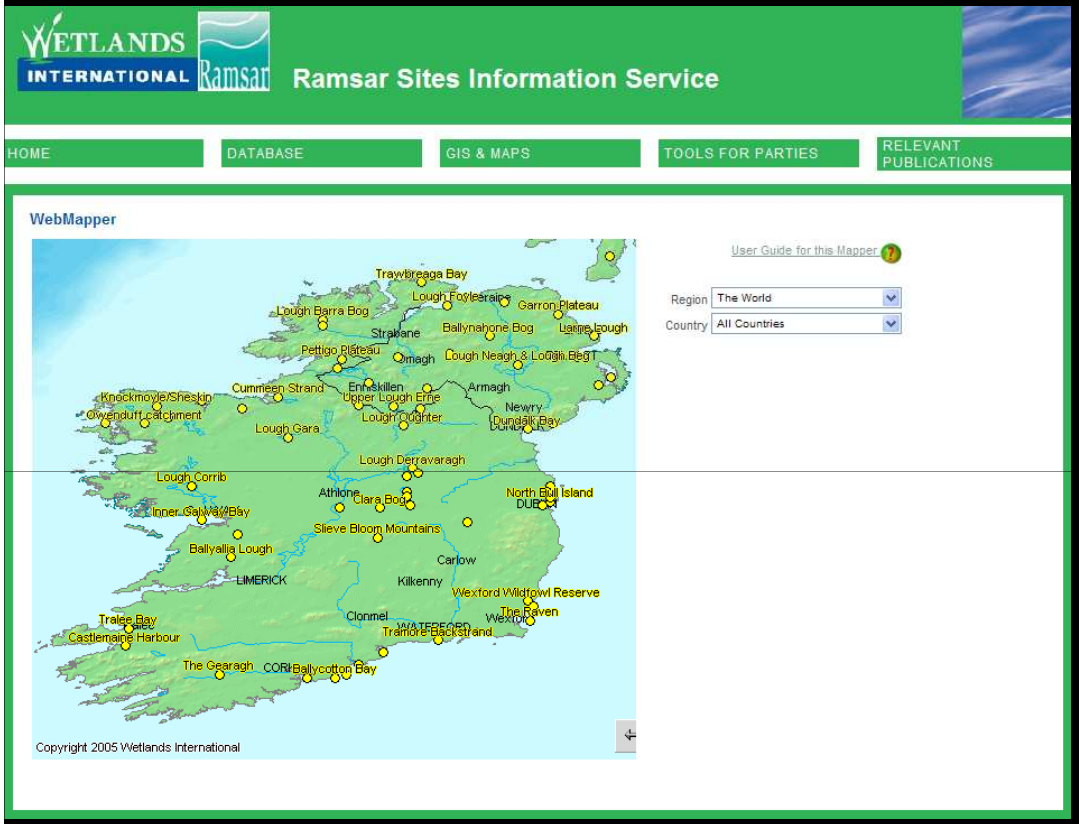
archaeological records of man

biological indicators of climate change and pollution levels

(Kirk, 2001)

1. WHY ARE WE INTERESTED?

➔ ecology and wetland biodiversity conservation



www.ramsar.org and http://ramsar.wetlands.org/

www.ipc.ie

Irish Peatland Conservation Council

IPCC 25 YEARS SAVING BOGS

IRISH PEATLAND CONSERVATION COUNCIL

Welcome to the web site of the Irish Peatland Conservation Council

You can contact us by email using the link at the bottom of this page or you can reach us at the Bog of Allen Nature Centre, Lullymore, Rathangan, Co. Kildare. Tel. +353+(0)45-860133

IPCC is the charity in Ireland that takes Action for Bogs and Wildlife. CHY6829

New for 2010

Visit the IPCC on Facebook

Visit our new online Nature Shop displaying IPCC's full range of environmentally friendly products

International Year of Biodiversity

2010

noticenature

Read more about IPCC's Activities for International Year of Biodiversity

Heritage Week Event

22nd August 2010, 11am to 4pm. Join IPCC and help to rennovate a boardwalk on Lodge Bog so that visitors can enjoy the bog in safety

1. WHY ARE WE INTERESTED?

➔ carbon budgets and greenhouse gas releases

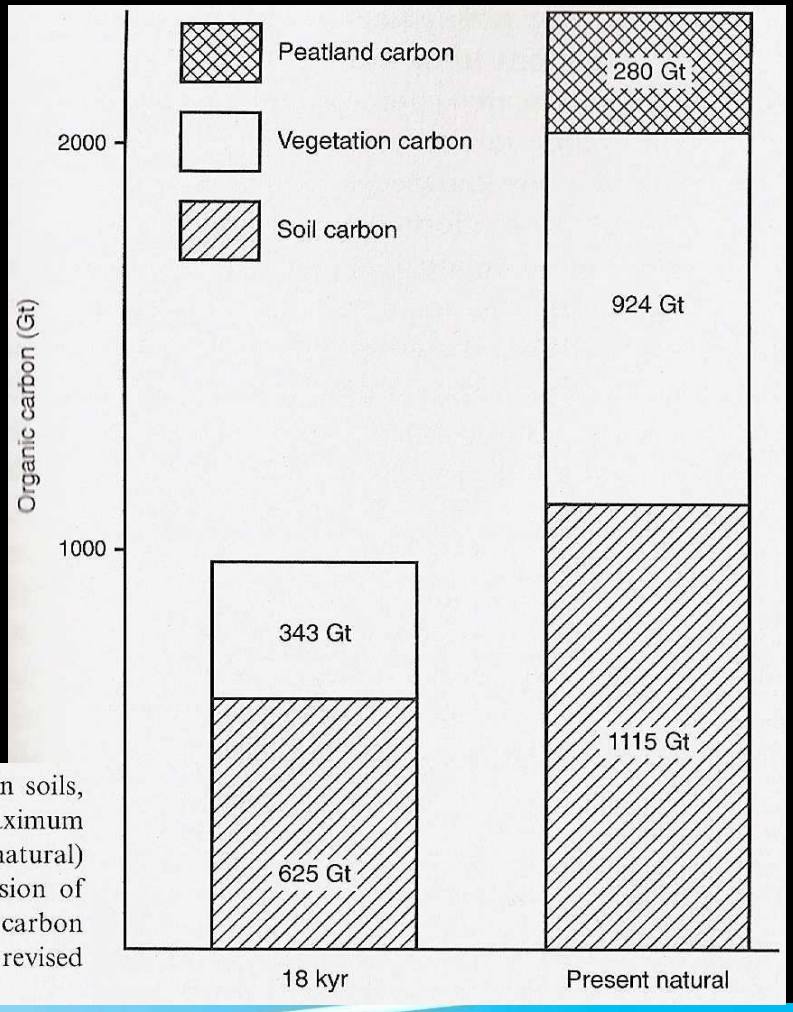


Figure 9.7 Comparison of estimated carbon pools in soils, vegetation and peatlands during the last glacial maximum (18 000 radiocarbon years ago) and the present (natural) state. Redrawn from Adams *et al* (1990) by permission of *Nature*. Note that the estimate of the total peatland carbon pool is probably underestimated here compared to later revised estimates.

Source: Charman (2002)

1. WHY ARE WE INTERESTED?

➔ hydrology and runoff regimes

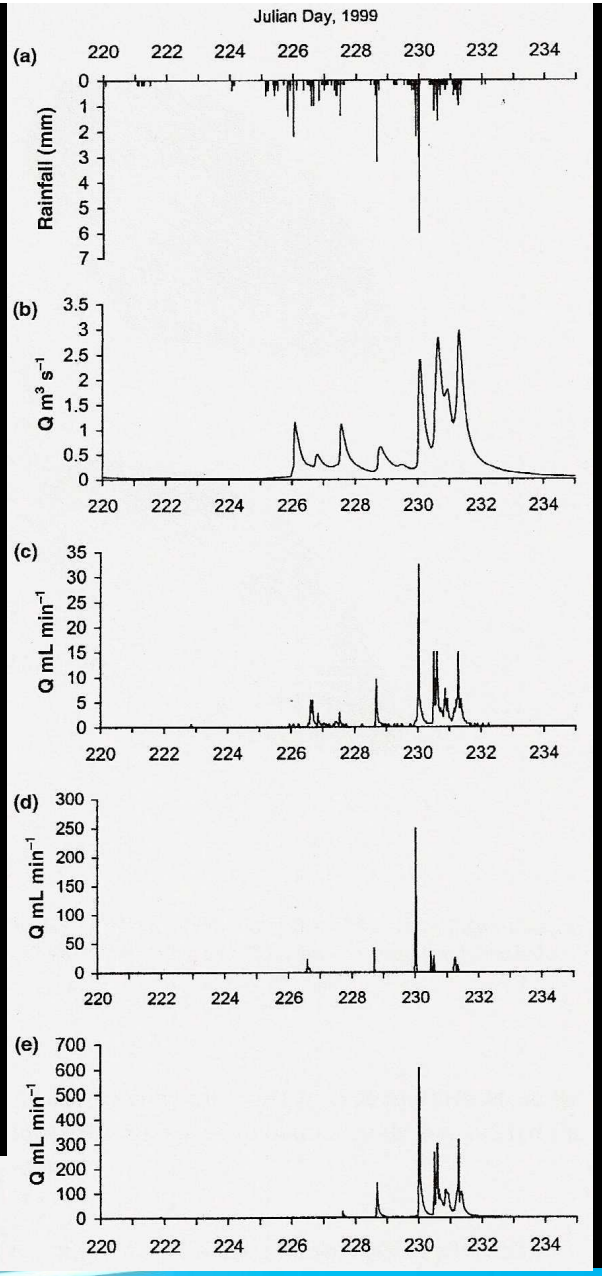


Fig. 4 Runoff production on H1 on days 220–235, 1999. (a) Precipitation. (b) Trout Beck. (c) Topslope overland flow. (d) Midslope overland flow. (e) Footlslope overland flow. (f)

Source: Holden and Burt (2003)

1. WHY ARE WE INTERESTED?

➔ assessment and management of natural hazards

Photo: A P Dykes

Photo: A P Dykes

1. WHY ARE WE INTERESTED?

➔ engineering risk assessments

Photo: A P Dykes

Photo: A P Dykes

1. WHY ARE WE INTERESTED?

➔ engineering risk assessments

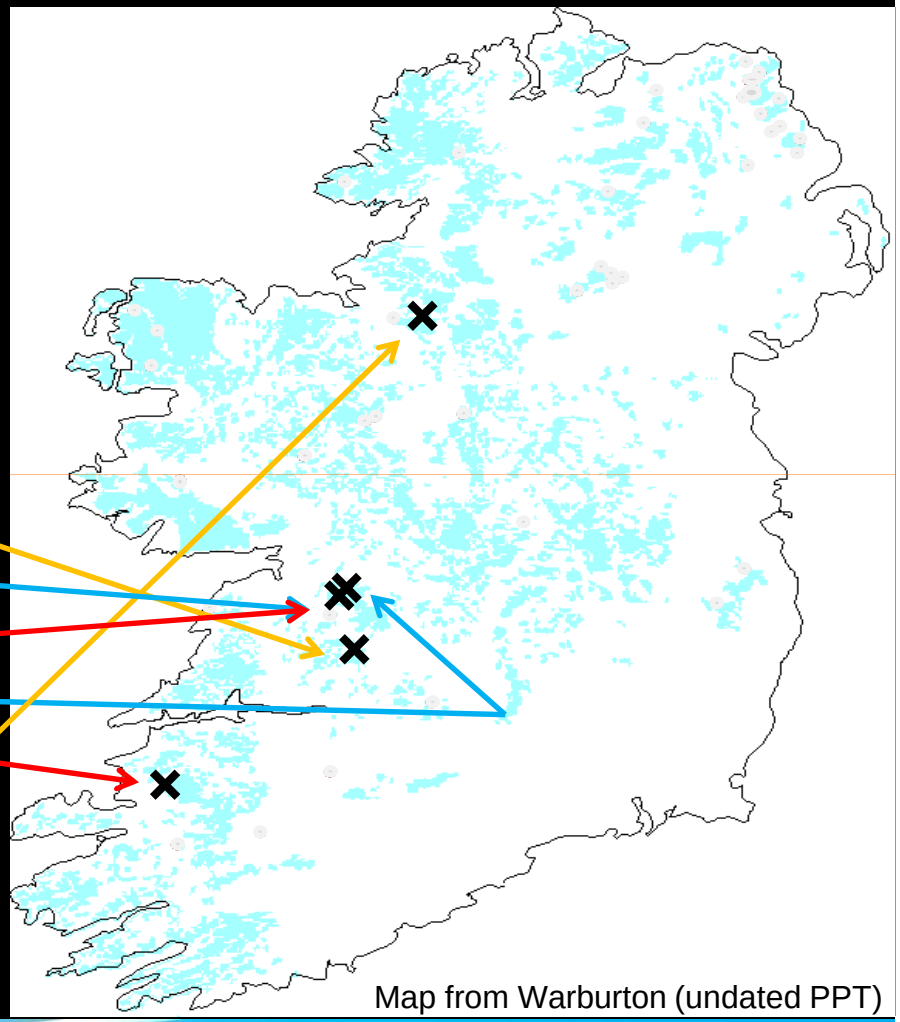
Prince Rupert Island, B.C., Canada, 1978 and 1982 – blanket peat loaded by failing peat spoil tip (Hungr and Evans, 1985)

1. WHY ARE WE INTERESTED?

➔ occurs on uplands suitable for windfarms (and forestry)

Peat failures (caused by engineering works) that developed into peat flows:

Year	Location	Landslide volume (m^3)
2003	Slieve Bearnagh (forestry)	9,000
2003	Derrybrien (small)	2,000
2003	Derrybrien (large)	450,000
2004	Sonnagh Old	6,500
2008	Ballincollig Hill	130,000
2008	Garvagh Glebe North	



Map from Warburton (undated PPT)

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2. WHAT IS PEAT?

➔ as a soil (definitions)

Soil Survey of England and Wales

10. Peat soils: These are predominantly organic soils derived from partially decomposed plant remains that accumulated under waterlogged conditions. Only two groups are distinguished and both appear in the legend. They are subdivided into Oligo- (moist pH<4.0); Eutro- or Eu- (pH>4.0 in some part); fibrous (mainly fibrous or semi-fibrous); -amorphous (mainly humified) and sulphuric (sulphuric subsoil within 80 cm depth) subgroups.

World Reference Base (formerly FAO–UNESCO scheme)

HISTOSOLS: Soils having an H horizon of 40 cm or more (60 cm or more if the organic material consists mainly or sphagnum or moss or has a bulk density of less than 0.1) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil; the thickness of the H horizon may be less when it rests on rocks or on fragmental material of which the interstices are filled with organic matter.

US Soil Taxonomy

Definition of Organic Soils: Organic soils have organic soil materials that:
1. Do not have andic soil properties in 60 percent or more of the thicknes between the soil surface and either a depth of 60 cm or a densic, lithic, or paralithic contact or duripan if shallower; *and*
2. Meet *one or more of the following:*

2. WHAT IS PEAT?

➔ as a soil (definitions)

... but what constitutes an ‘organic soil’ or ‘peat’?

most common criterion = ash content (mineral content)

e.g. geotechnical classification of Landva et al. (1983) then Carlsten (1993):

‘peat’ = ash content <20%

‘peaty organic soils’ = ash content >20% but ≤50% fibres

➔ easily determined (550°C for 3 hours + estimate fibres)

Hobbs (1986) – does it behave (geotechnically) like an organic material?
➔ use morphological stage of development of peat deposit to identify ‘peat’

Dykes & Warburton (2007) – 20% ash content criterion could usefully separate thin peats from peaty soils and true peats from mineral sub-peats (in fens)

2. WHAT IS PEAT?

➔ as a soil (definitions)

Most surviving peat in the UK and Ireland comprises ombrotrophic blanket bog that may exceed 2–3 m in thickness and which typically grades into thin peaty soils at the margins.

Minimum depth to be classified as a peat deposit:

ENGLAND	**0.4 m**	Soil Survey of England and Wales (Cruickshank and Tomlinson, 1990; Burton, 1996)
SCOTLAND	**0.5 m**	(Burton, 1996)
IRELAND	**0.45 m**	(Hammond, 1979; Bord na Móna, 2001)

2. WHAT IS PEAT?

➔ as an engineering soil (definitions)

‘surficial deposit which can be moved without blasting’

May include some low-strength rock, even if unweathered (e.g. brown coal)
May include unconsolidated, unweathered material (e.g. dune sands, **peat**)
May *exclude* indurated, highly weathered material

North American engineers use the Unified Soil Classification System (USCS). This has three major classification groups:

1. coarse-grained soils (e.g. sands and gravels)
2. fine-grained soils (e.g. silts and clays)
3. highly organic soils (referred to as ‘**peat**’)

These are further subdivided for clarification.

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British Soil Classification System (BSCS)

Table 1 British Soil Classification System for Engineering Purposes

SOIL GROUPS			SUB-GROUPS and in laboratory identification			
GRAVEL and SAND may be qualified sandy GRAVEL and gravely SAND where appropriate			Group Symbol	Sub-group symbol	Fines (% less than 0.06 mm)	Liquid limit
COARSE SOILS less than 35% of the material is finer than 0.06 mm	GRAVELS More than 50% of coarse material is of gravel size (coarser than 2 mm)	Slightly silty or Clayey GRAVEL	GW G GP	GW GPu GPg	0 to 5	
		Silty GRAVEL Clayey GRAVEL	G-M G-F G-C	GWM GPM GWC GPC	5 to 15	
		Very silty GRAVEL Very clayey GRAVEL	GM GF GC	GML, etc GCL GCI GCH GCV GCE	15 to 35	
	SANDS More than 50% of coarse material is of sand size (finer than 2 mm)	Slightly silty or clayey SAND	SW S SP	SW SPu SPg	0 to 5	
		Silty SAND Clayey SAND	S-M S-F S-C	SWM SPM SWC SPC	15 to 35	
		Very silty SAND Very clayey SAND	SM SF SC	SML etc SCL SCI SCH SCV SCE	15 to 35	
FINE SOILS more than 35% of the material is finer than 0.06 mm	Gravelly or sandy SILTS and CLAYS 35% to 65% fines	Gravelly SILT Gravelly CLAY	MG FG CG	MLG etc CLG CIG CHG CVG CEG		< 35 35 to 70 50 to 70 70 to 90 > 90
		Sandy SILT Sandy CLAY	MS FS CS	MLS etc CLS etc		
	SILTS and CLAYS 65% to 100% fines	SILT (M SOIL) CLAY	M F C	ML etc CL CI CH CV CE		< 35 35 to 50 50 to 70 70 to 90 > 90
ORGANIC SOILS		Description letter ‘O’ suffixed to say group or subgroup symbol		Organic matter in significant amount e.g. MHO – organic silt of high LL		
PEAT		Pt – consists predominantly of plant remains (fibrous or amorphous)				

Primary Letter		Secondary letter	
G	Gravel	W	Well graded
S	Sand	P	Poorly graded
M	Silt	M	With non-plastic fines
C	Clay	C	With plastic fines
O	Organic Soil	L	Of low plasticity (LL<50)
Pt	Peat	H	Of high plasticity (LL>50)

2. WHAT IS PEAT?

➔ as a physical material (composition)

decomposing remains of dead plant matter + water

occasionally with some mineral material transported onto the site by water or wind

Photo: J M Selkirk-Bell

Photo: A P Dykes

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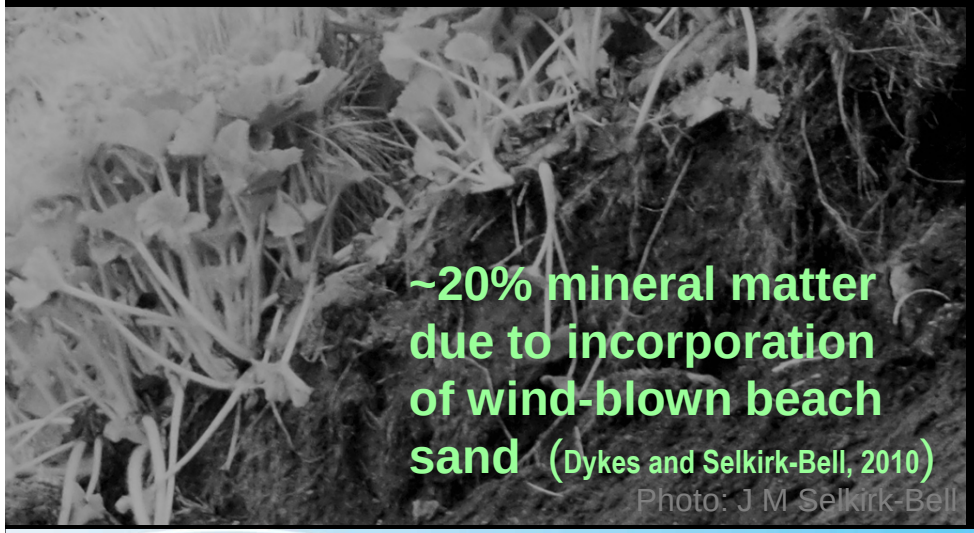
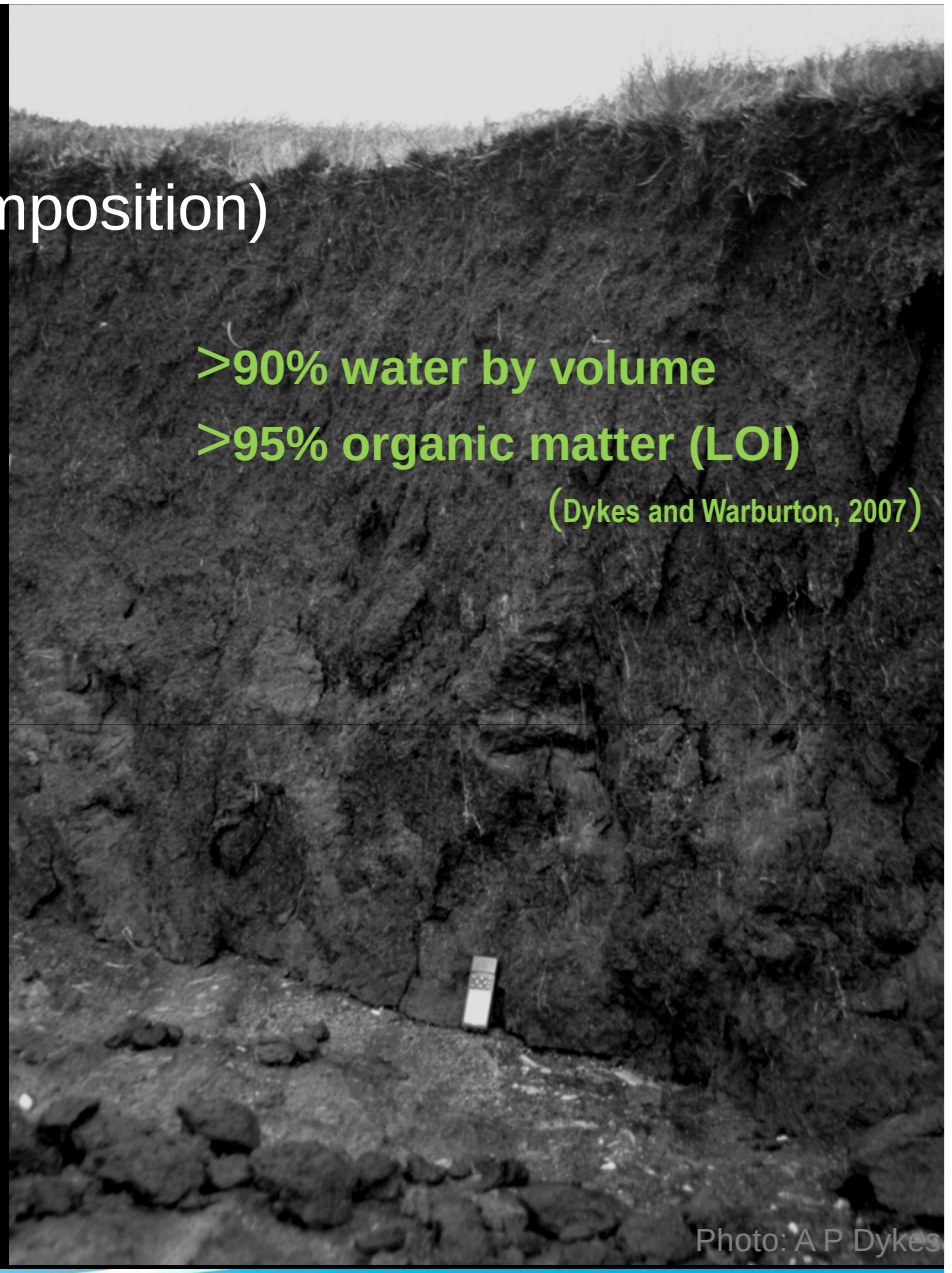


~20% mineral matter due to incorporation of wind-blown beach sand (Dykes and Selkirk-Bell, 2010)

Photo: J M Selkirk-Bell



>90% water by volume

>95% organic matter (LOI)

(Dykes and Warburton, 2007)

Photo: A P Dykes

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3. ORIGINS AND TYPES OF PEATLANDS

➔ but what is a ‘peatland’?

Wetland Land with the water table close to or above the surface or which is saturated for a significant period of time. Includes most peatlands but also ecosystems on mineral substrates, flowing and shallow waters.

Peatland Any ecosystem where in excess of 30–40 cm of peat has formed. Includes some wetlands but also organic soils where aquatic processes may not be operating (e.g. drained or afforested peatlands).

Mire All ecosystems described in English as swamp, bog, fen, moor, muskeg and peatland, but often used synonymously with peatlands. Includes all peatlands, but some mires may have a mineral substrate.

Fen A mire which is influenced by water from outside its own limits.

Bog A mire which receives water solely from rain and/or snow falling onto its surface.

Marsh Loose term usually = fen with tall herbaceous vegetation, often mineral substrate.

Swamp Loose term usually = fen, often implying forest cover.

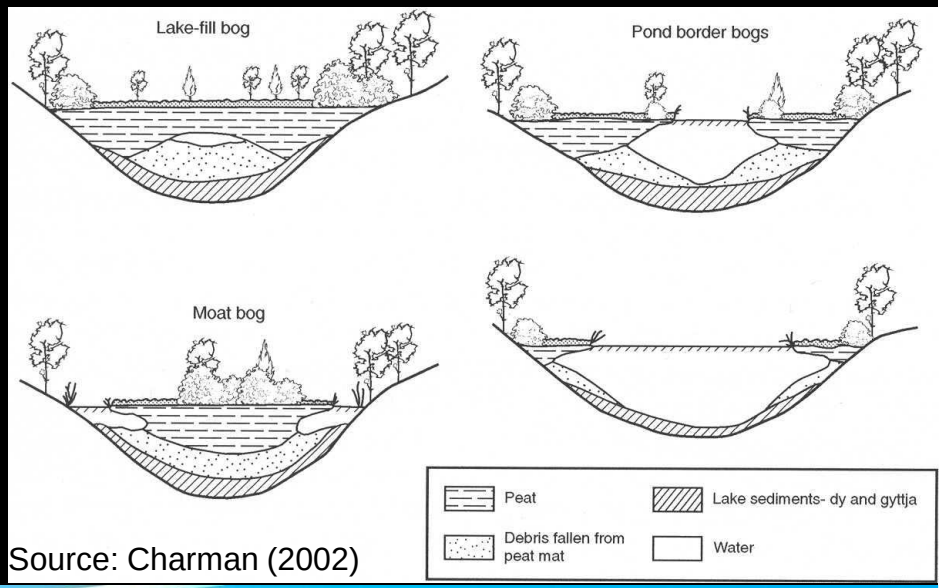
(Charman, 2002)

3. ORIGINS AND TYPES OF PEATLANDS

➔ plants grow on (usually) wet surface on impermeable layer

➔ dead plant remains kept saturated by:

(i) body of water, e.g. edge of lake, rainwater puddle
basin or hollow (any scale)
minerotrophic, topogenous



Source: Charman (2002)

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(i) body of water, e.g. edge of lake, rainwater puddle
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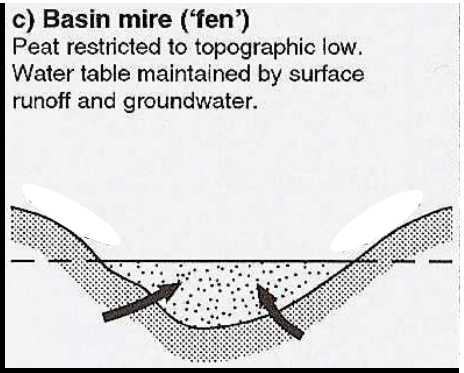
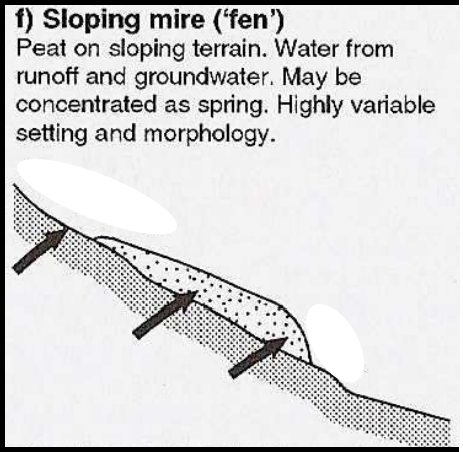
minerotrophic, topogenous

(ii) groundwater exiting bedrock as spring or seepage
basin or gentle slope
minerotrophic, topogenous or soligenous





Source of these and following diagrams: Charman (2002)

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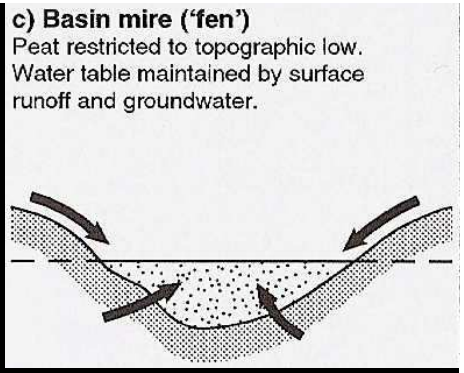
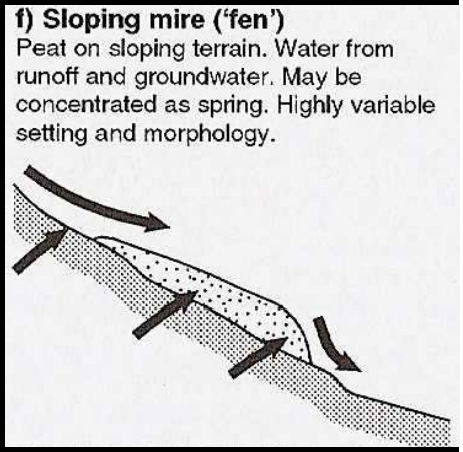
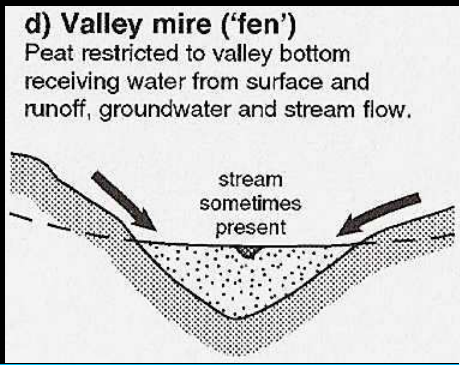
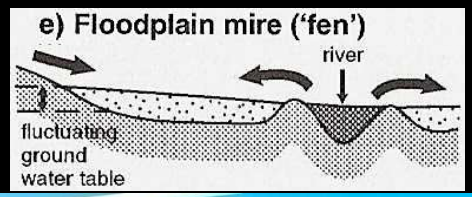
minerotrophic, topogenous or soligenous

(iii) diffuse flow over ground surface (any water origin)
gentle slope or valley floor
minerotrophic, soligenous









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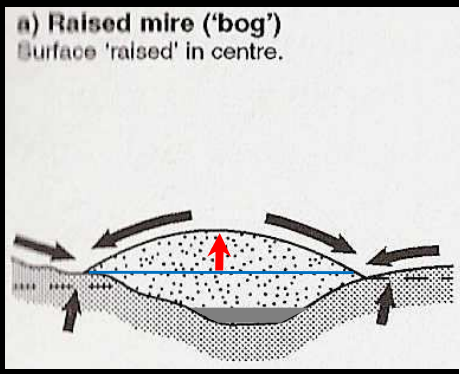
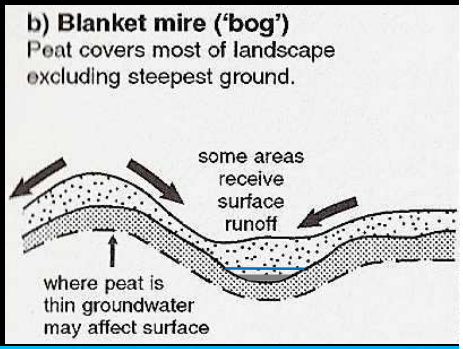
minerotrophic, topogenous or soligenous

(iii) diffuse flow over ground surface (any water origin)
gentle slope or valley floor
minerotrophic, soligenous

(iv) precipitation (i.e. rainwater + snowmelt only)
any land surface up to 20–30°
ombrotrophic





3. ORIGINS AND TYPES OF PEATLANDS

valley mire (fen)

Photo: A P Dykes

Wingecarribee Swamp, Australia

valley mire (fen)

Photo: A P Dykes

Tambille Valley, Peru

floodplain mire (fen)? ➔➔ raised bog

Photo: A P Dykes **Tuam (1909 bog burst)**

raised bog

Photo: A P Dykes **Dunmore (1873 bog burst)**

fen? ➔➔ raised bog or blanket bog (?)

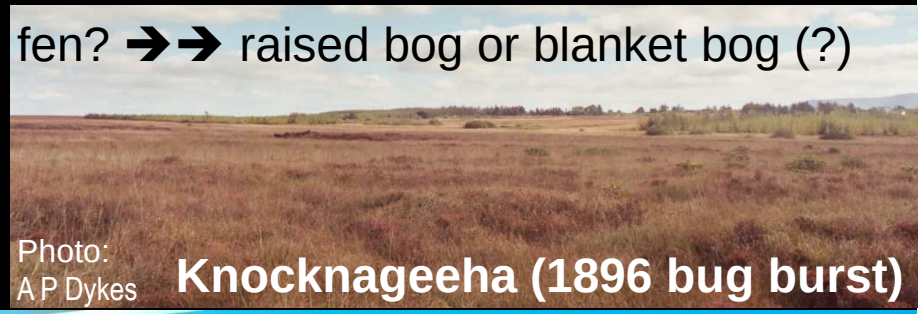


Photo: A P Dykes **Knocknageeha (1896 bug burst)**

3. ORIGINS AND TYPES OF PEATLANDS

blanket bogs

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4. DEVELOPMENT OF BLANKET BOG (AND RAISED BOG)

➔ general conditions necessary for blanket bog formation:

(i) at least 1000 mm annual rainfall
(ii) at least 160 wet days per year (i.e. >1 mm rain)
(iii) mean temperature <15°C for the *warmest* month
(iv) relatively small seasonal temperature variations

(Lindsay *et al*., 1988)

(v) effectively impermeable surface


Photo: A P Dykes


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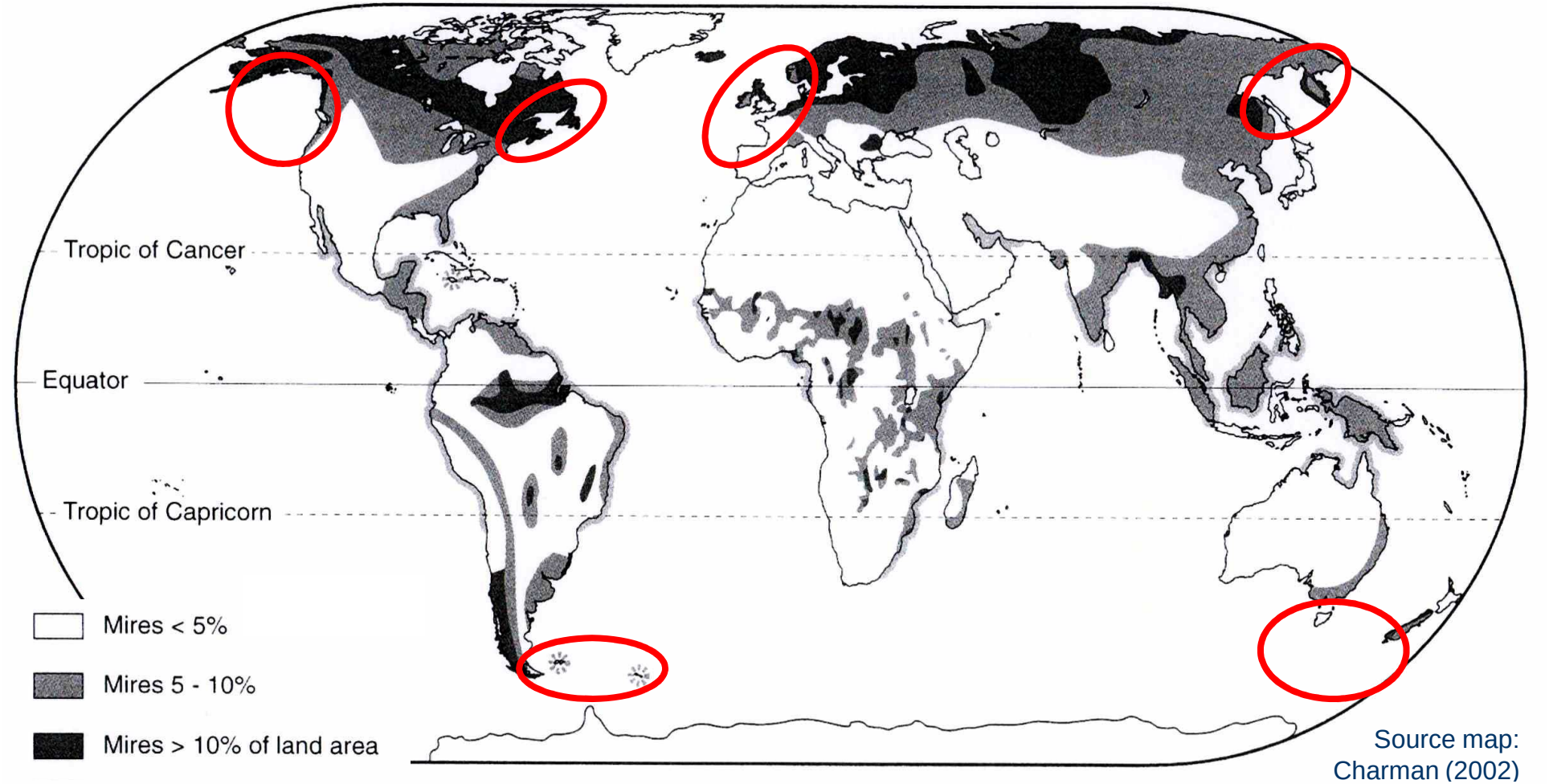
Photo: A P Dykes

4. DEVELOPMENT OF BLANKET BOG

➔ approximate distributions of blanket bogs outlined in red:



Source map:
Charman (2002)

4. DEVELOPMENT OF BLANKET BOG

➔ *Sphagnum* mosses grow first in the wettest sites e.g.

Photo: http://www.scotland.gov.uk/Resource/Img/25954/0013320.jpg

creating an initial thin layer of peat ...

Photo: A P Dykes

Photo: A P Dykes

Photo: A P Dykes

4. DEVELOPMENT OF BLANKET BOG

➔ events in early stages may give rise to inherent structural weaknesses in or near base of peat profile, e.g.

fire – charcoal layer – discontinuity

erosion event? – (inwash of mineral)
create smooth surface – discontinuity


Photo: A P Dykes


Photo: A P Dykes

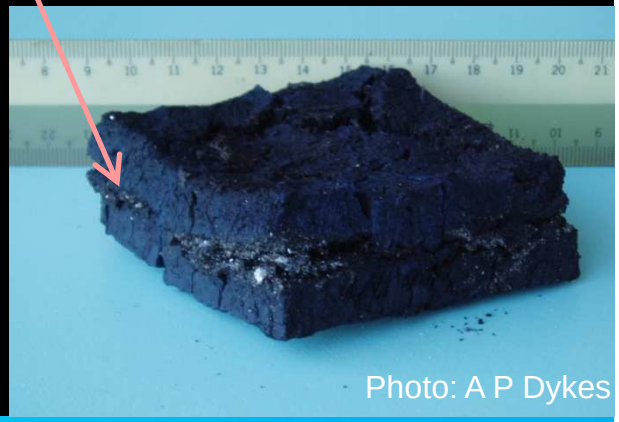


Photo: A P Dykes

4. DEVELOPMENT OF BLANKET BOG

➔ other structural features result from constituent vegetation

different plant ➔ different peat characteristics

e.g. *Sphagnum* moss – homogeneous material
dominantly vertical flow

Eriophorum (cotton grass) – strongly fibrous peat
typically horizontal flow

contrasts diminish with increasing humification
BUT
may give rise to macropores and eventually pipes

4. DEVELOPMENT OF BLANKET BOG

➔ most Irish blanket bogs dominated by *Sphagnum*

BUT ...

they are highly variable with (in particular) more woody layers commonly found towards the base

4. DEVELOPMENT OF BLANKET BOG

➔ most Irish blanket bogs dominated by *Sphagnum*

Photo: A P Dykes

lowest 0.7 m
of peat profile

Photo: A P Dykes

BUT ...

they are highly variable with (in particular) more woody layers commonly found towards the base

4. DEVELOPMENT OF BLANKET BOG

➔ most Irish blanket bogs around 6000–8000 years old

average accumulation rates ~0.5 (range 0.1–1.2) mm y^{-1}

➔ extreme drought conditions cause surface desiccation

cracks may be infilled and buried but persist as structures

Photo: A P Dykes

4. DEVELOPMENT OF BLANKET BOG

➔ when peat is deep enough, two layers *may* be identified:

acrotelm = layer within which the water table fluctuates
i.e. occasionally aerated zone

catotelm = permanently saturated, anaerobic zone

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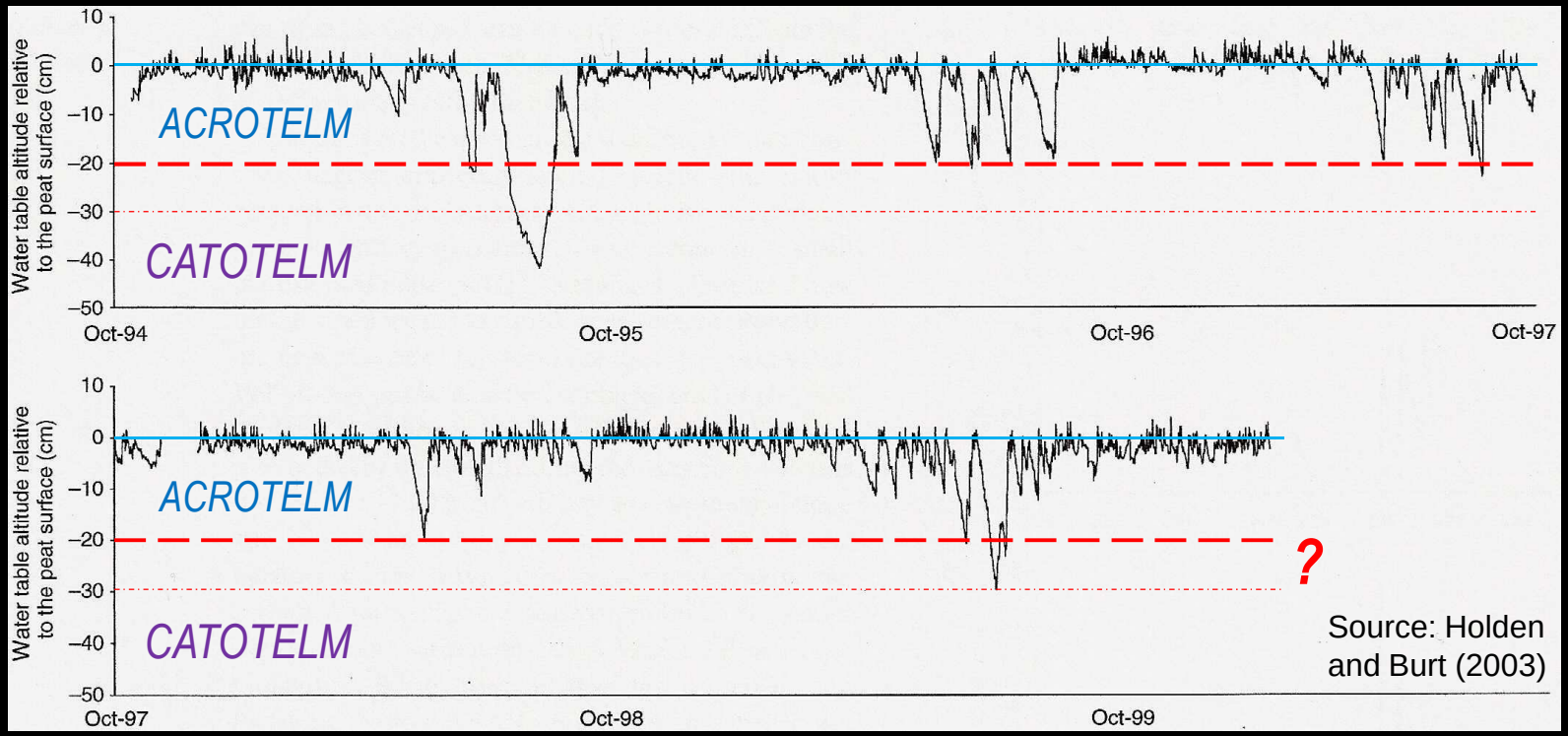

acrotelm = layer within which the water table fluctuates
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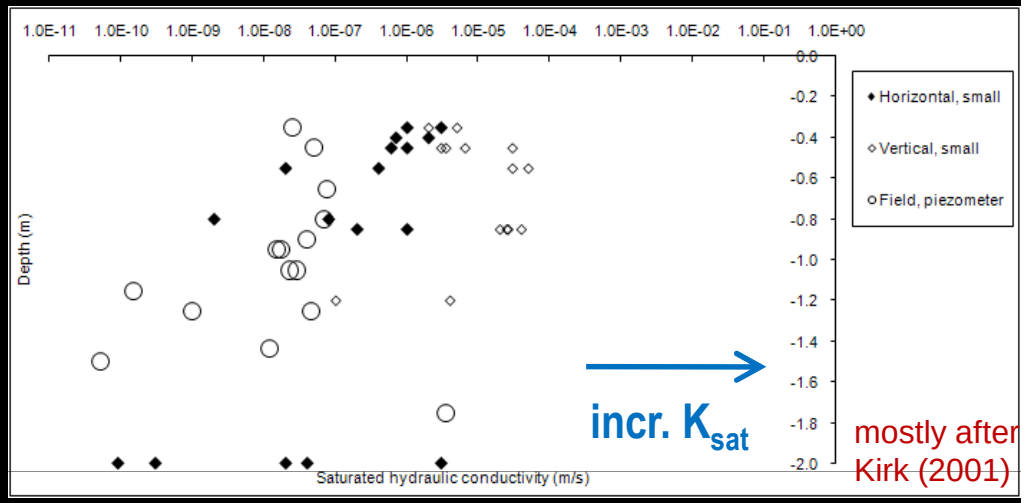
5. PEAT PROPERTIES

➔ highly variable – inappropriate to generalise?

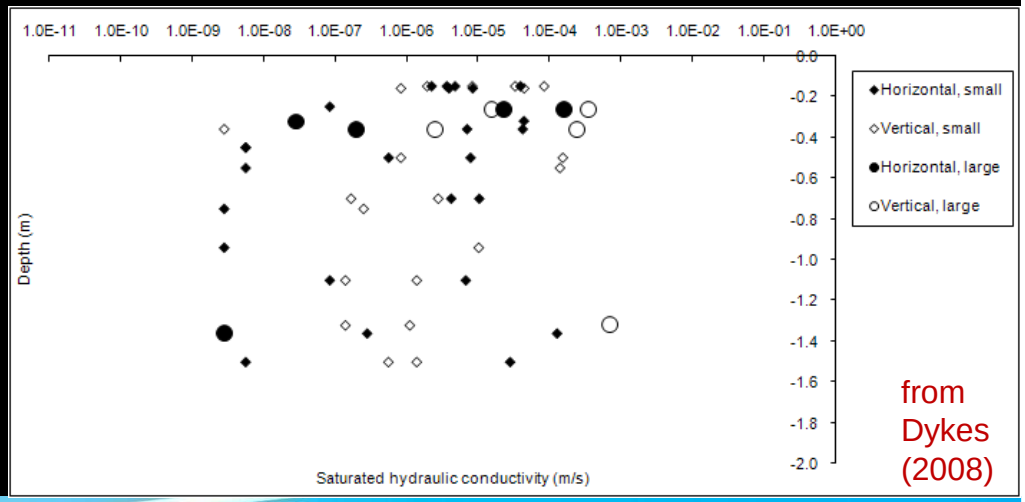
e.g. Saturated hydraulic conductivity, K_{sat}

Cuilcagh Mountain,
Co. Fermanagh/Cavan



mostly after Kirk (2001)

Dooncarton Mountain,
Co. Mayo

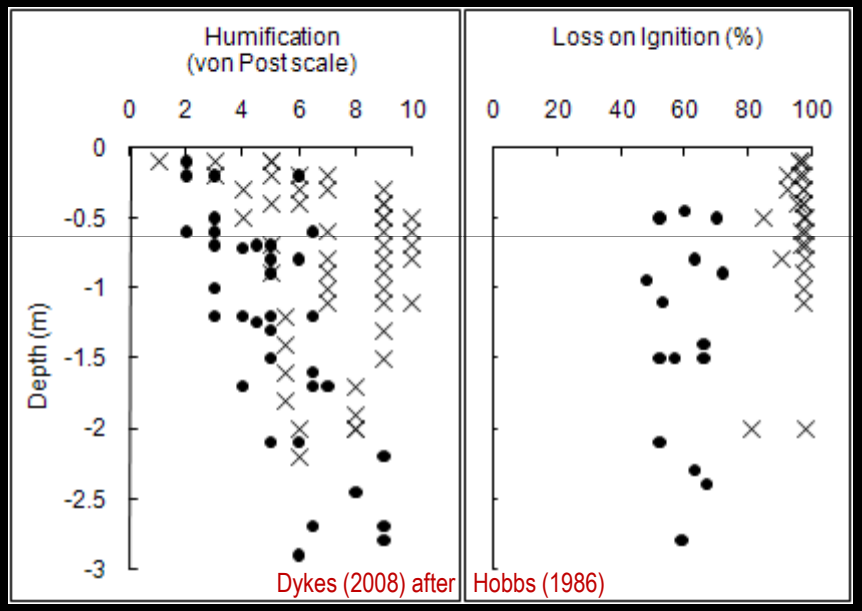


from Dykes (2008)

5. PEAT PROPERTIES

➔ some patterns discernible across different peat deposits

➔ main reference is Hobbs (1986) but few relevant data:



✕ = data from adjacent to Irish upland blanket bog failures

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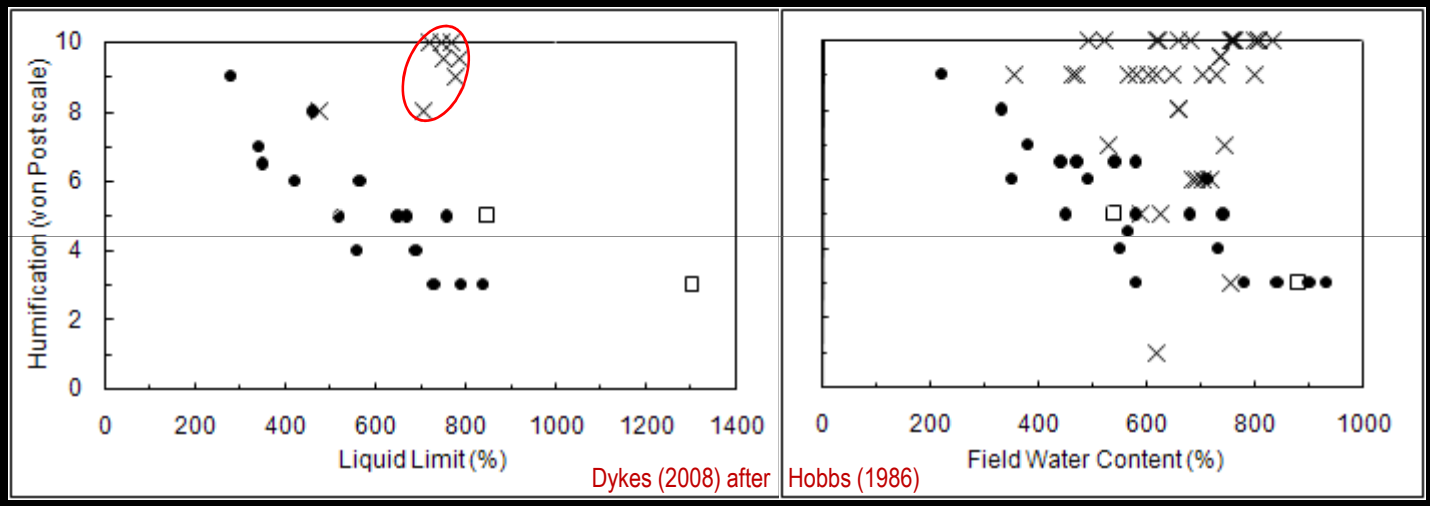

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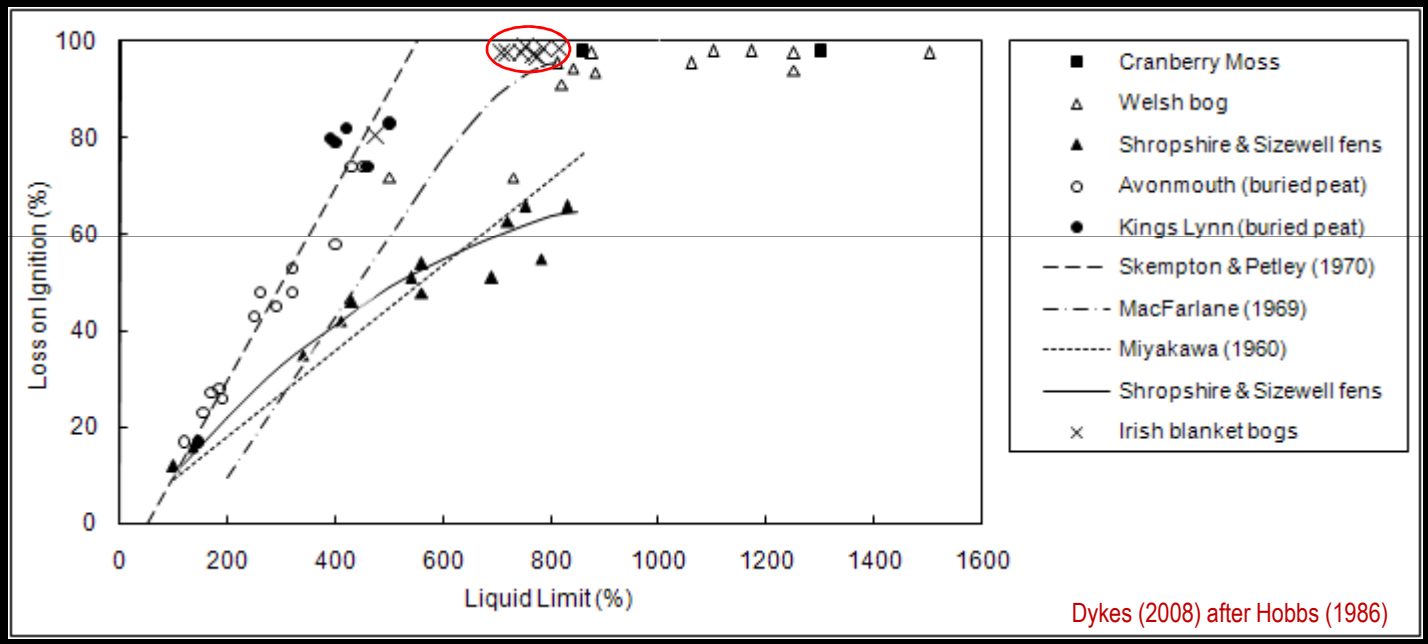


Dykes (2008) after Hobbs (1986)

✕ = data from adjacent to Irish upland blanket bog failures

5. PEAT PROPERTIES

➔ summary for ombrotrophic blanket peat in Ireland:

‘water held together by bits of decomposing plant matter’

organic matter content	>95%

‘peat has less solids in it than milk’ (Charman, 2002)

humification rarely <H_6	‘H_{10} with fibres’ is common
volumetric water content	>90%
mass fraction water content highly variable	typically 500–1000%
saturated unit weight > water	typically ~10 kN m^{-3}

field-wet (unsaturated) unit weight ***may*** be slightly < water

5. PEAT PROPERTIES

➔ geotechnical properties?

shear strength??

how???

5. PEAT PROPERTIES

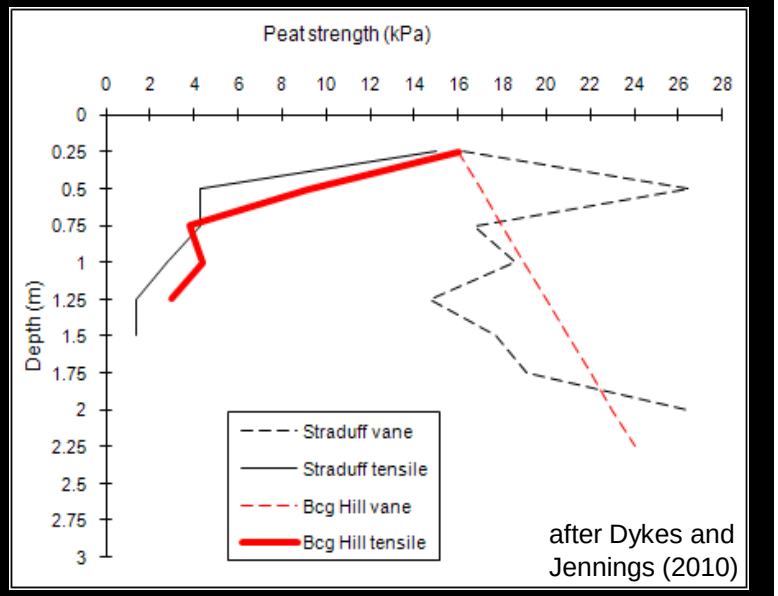
➔ geotechnical properties?

shear strength??

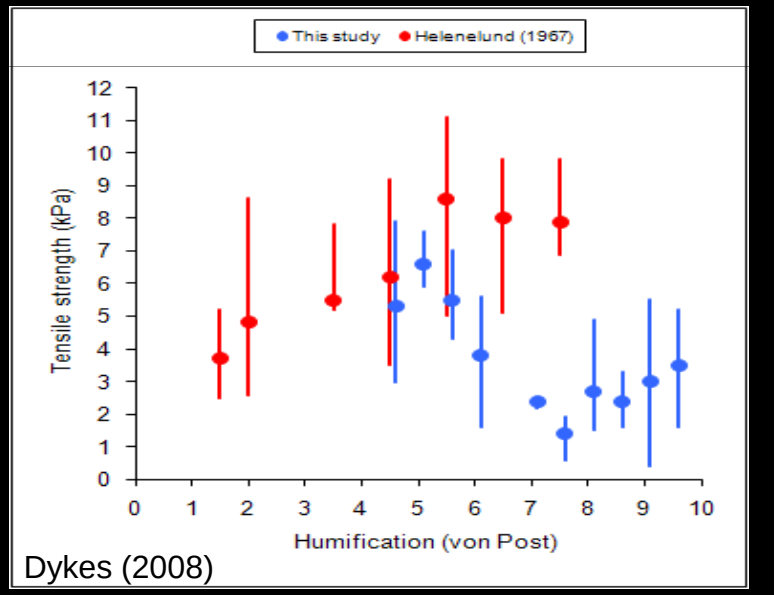
how???

tensile strength of small laboratory samples to give approximation of c_u

lower catotelm of Irish blanket bogs ≤ 4 kPa



after Dykes and Jennings (2010)



Dykes (2008)

5. PEAT PROPERTIES

➔ Irish blanket bog failures analysed using SLOPE/W (fully-specified failure surfaces)

in all cases: $c_u < 2$ kPa

➔ implications for stability analysis ...

Bogflow ID	Analysis details	undrained cohesion (kPa) for FS = 1.0
GDN-63	southwest side, full length northeast side, full length	**1.2** **1.1**
CCA-79		**1.5**
SDF-84		**0.9**
TNN-85		**1.3**
CNA-86	 steeper lower ⅓ only	**0.8** **1.1**
SBO-88		**1.7**
SRS-90s		**1.7**
SDF-90		**1.6**
SAR-98		**1.5**
MHA-00s		**0.7**
Bog slide ID	*Source: A P Dykes (unpublished)*	
MCY-45	 individual steeper segments only	**1.6** **1.9**
SBO-73		**1.9**
ECM-86		**1.9**
BCF-88	 steeper head zone (top 40 m only)	**0.9** **1.6**
SRH-91a		**1.9**
SRH-91b		**1.8**
ECM-92	 steeper head zone (top 45 m only)	**1.0** **1.4**
CTR-93		**1.3**
ECM-97	 steeper upper ½ only	**1.0** **1.6**
ECM-98	 steeper upper ½ only	**0.7** **1.0**

5. PEAT PROPERTIES

➔ peat mass properties (*sensu* ‘rock mass properties’)

e.g. pipes within (small and large) and/or below the peat


Photo: A P Dykes


Photo: A P Dykes


Photo: J Warburton


Photo: A P Dykes

5. PEAT PROPERTIES

➔ peat mass properties (*sensu* ‘rock mass properties’)

e.g. horizontal basal discontinuities – like slickensides

e.g. vertical discontinuities – (relict) desiccation cracks, peat extraction ‘tines’


Photo: A P Dykes


Photo: A P Dykes

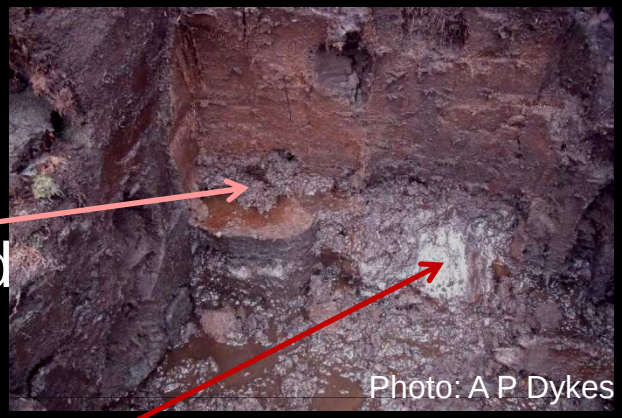

Photo: A P Dykes

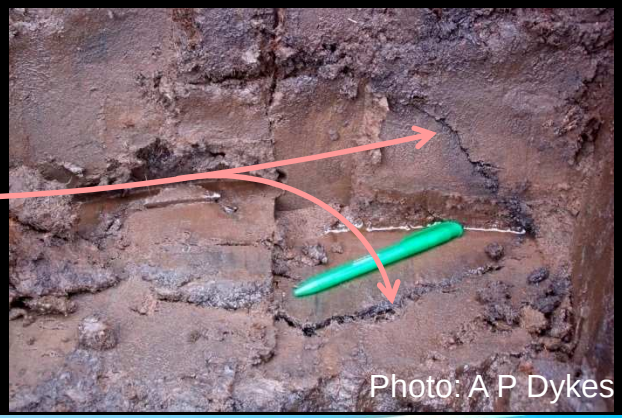
5. PEAT PROPERTIES

➔ peat mass properties (*sensu* ‘rock mass properties’)

e.g. ‘rotten’ peat

i.e. soft, grey slurry in confined bodies or as zero-strength discontinuities (planar surfaces or networks)





1. Why are we interested?
2. What is peat?
3. Origins and types of peatlands
4. Accumulation and development of peat
5. Peat properties
6. Peatland instability

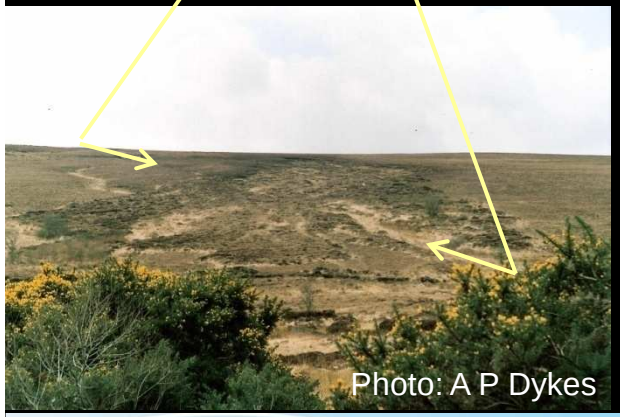
6. PEATLAND INSTABILITY

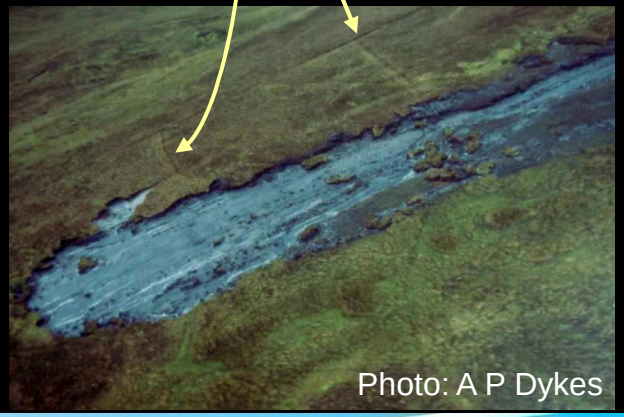
➔ ~50% of Irish peat failures have been associated with anthropogenic causal factors, e.g.

Townland boundary ditches

general drainage ditches

forestry ditches/plough furrows





6. PEATLAND INSTABILITY

➔ ~50% of Irish peat failures have been associated with anthropogenic causal factors, e.g.

peat cutting or mechanical extraction

eroded due to burning or overgrazing

loading by fill placement or heavy machinery

6. PEATLAND INSTABILITY

➔ ~50% of Irish peat failures therefore entirely natural ...

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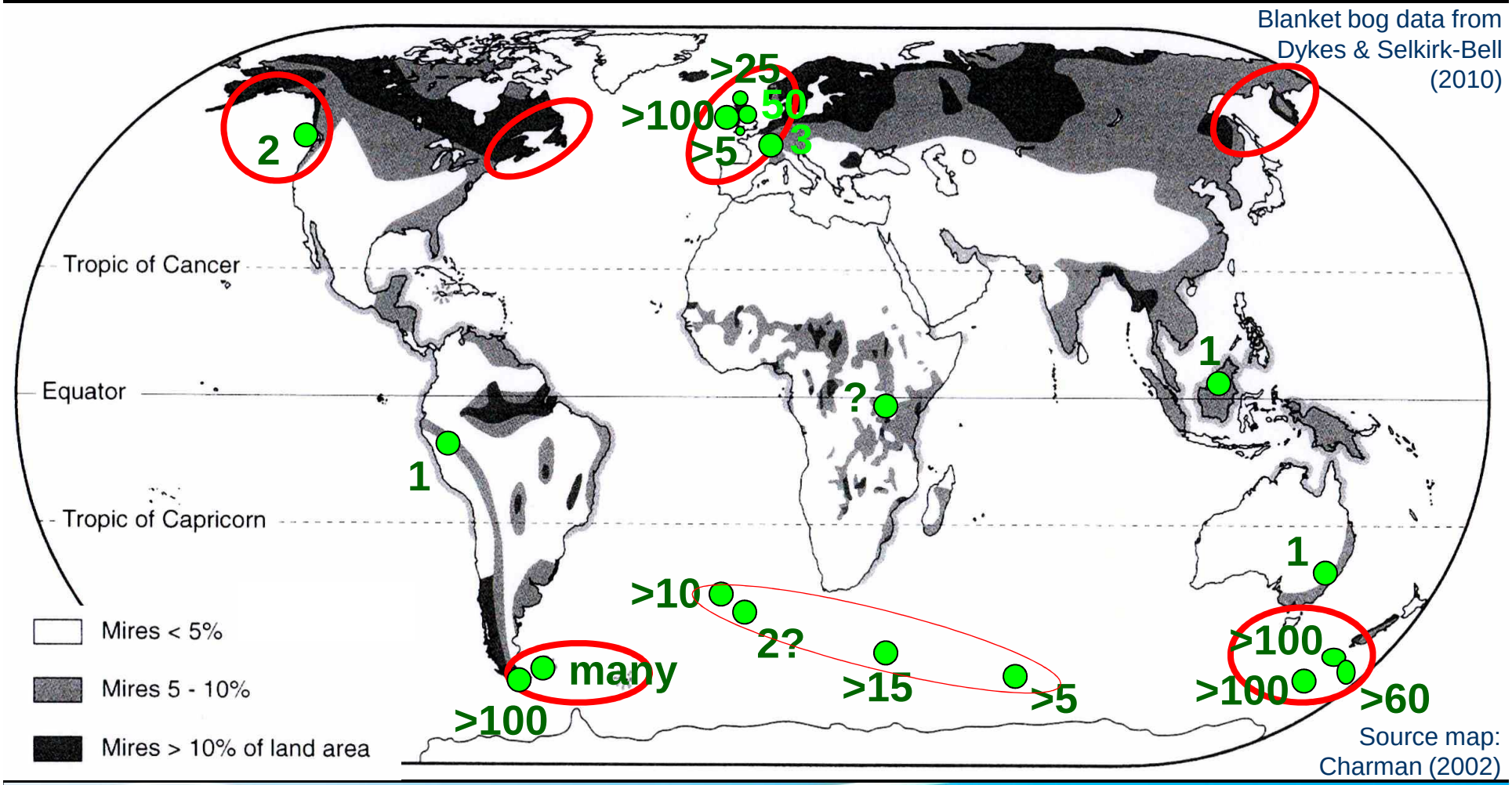
➔ ~50% of Irish peat failures therefore entirely natural ...



6. PEATLAND INSTABILITY

➔ Slieve Bloom, 2009?


Photo: A P Dykes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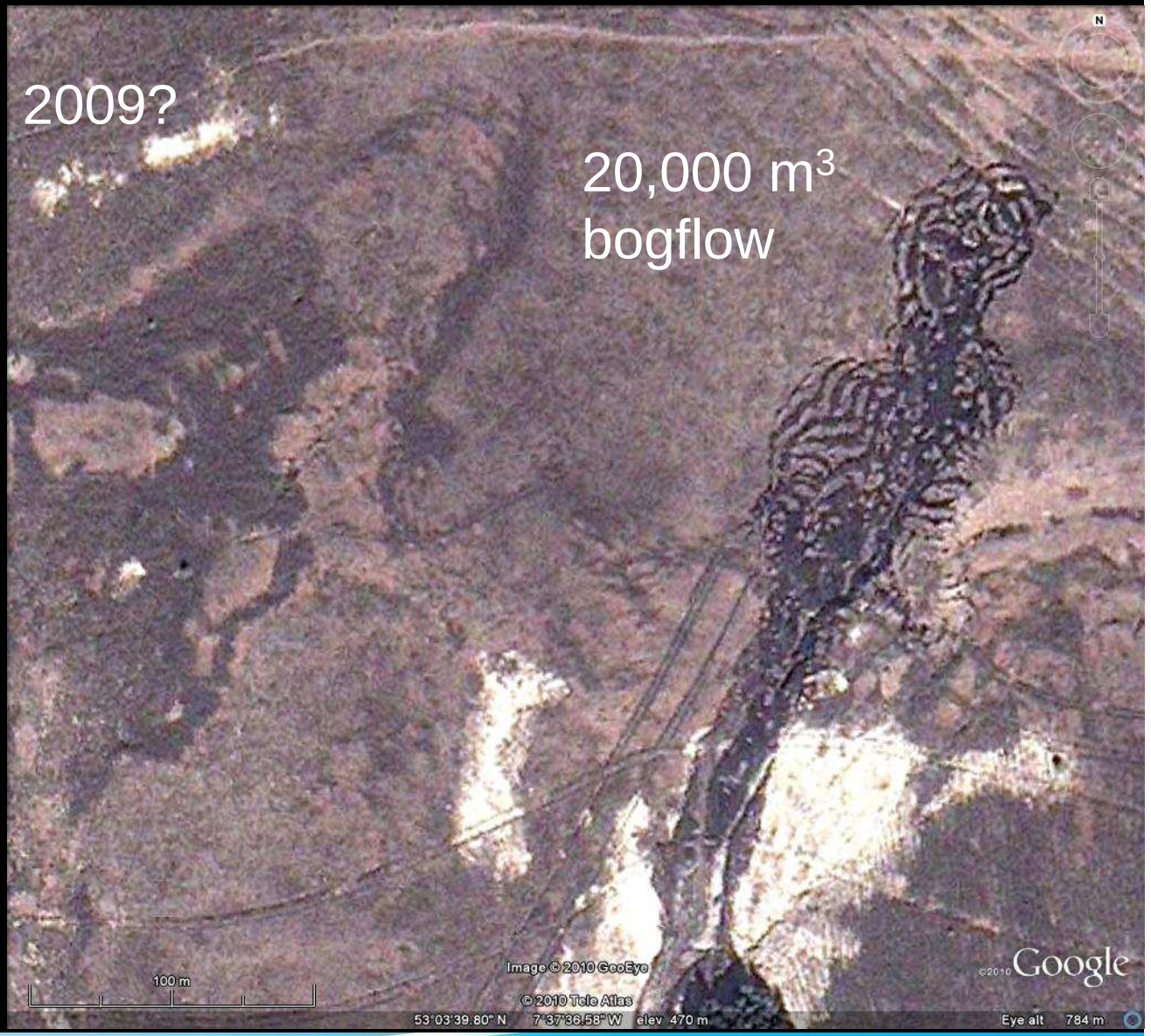

6. PEATLAND INSTABILITY

➔ two major challenges:

1. identify potential sites and consequences of future rainfall-triggered ‘natural’ peat failures (but taking account of any anthropogenic causal factors)

2. identify and quantify the risk of failure from upland developments such as windfarm construction or forestry activities

   (a) based on non-intrusive field data ➔ which, how?

   (b) obtain reliable estimates of peat strength

➔ research into all relevant aspects continues at Kingston

Kingston University London

CONCLUSIONS

1. Peat is an organic sediment that accumulates under wet conditions over thousands of years

2. It is a valuable environmental resource because it is a carbon sink and has a particular biodiversity ...

3. ... and can be destroyed in minutes by a JCB or a landslide

4. Geotechnical properties are difficult to determine and interpret → uncertain stability assessments

5. Peat stability is a difficult issue – hence this meeting!

Photo: A P Dykes

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Advancing geography and geographical learning

THE ROYAL SOCIETY
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bsg BRITISH SOCIETY for GEOMORPHOLOGY

Photo: A P Dykes

33,000 m^3 bog slide on Slieve Rushen, Co. Cavan (2009/10?)

Photo: A P Dykes

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