

## Complexity, Uncertainty and Wonder: Physical Geography for Grown-ups of All Ages

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1

## Geography is a fantastic subject!



It's a wonderful world...  
Geography is all about exploring it

2

## Starting Point

The world is more interesting than my newly-arrived undergraduates have been led to believe!

- The world is complicated, we don't understand all of it, and scientists often don't agree.
- Students don't appreciate that uncertainty and controversy are important and exciting.
- Widely-used A-level text books ignore recent science and simplify to the point of being wrong.

Do we really need a "junior" version?

3

## What I want to talk about

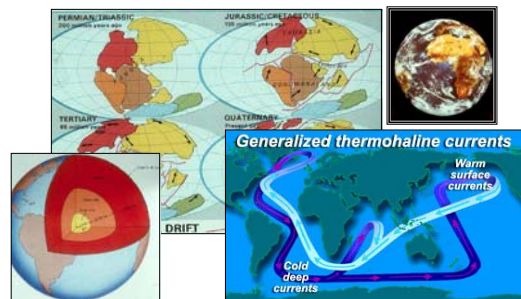
1. What I say to my 1<sup>st</sup> years about Geography being exciting, complicated and incomplete
2. The reasons why they seem so surprised: the origins of some of their misconceptions
3. Case study: Glaciers – some recent research that isn't in the text books

and what *you* will be doing...

4

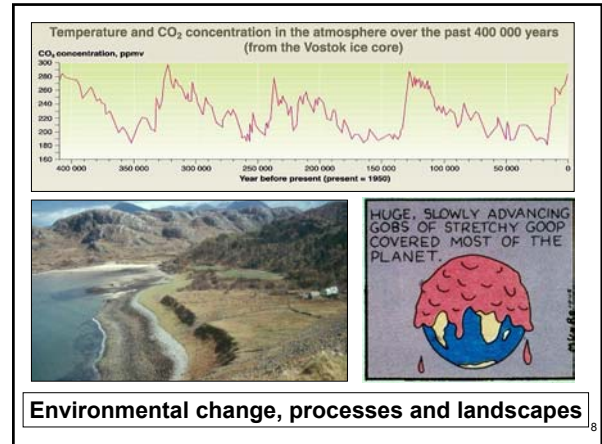
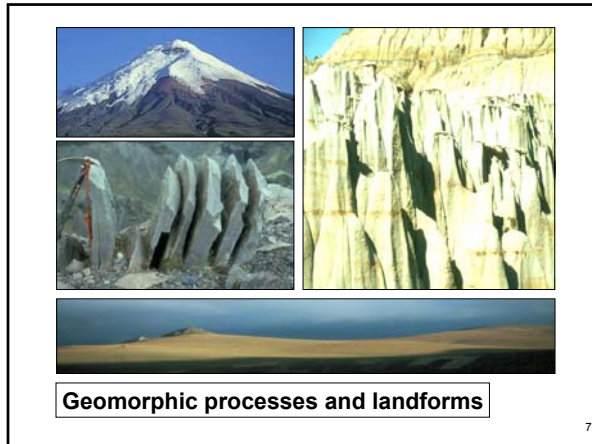
Is the world essentially a very complicated place or a pretty simple place?

## Part 1: What I say to my new explorers



Global aspects of physical geography

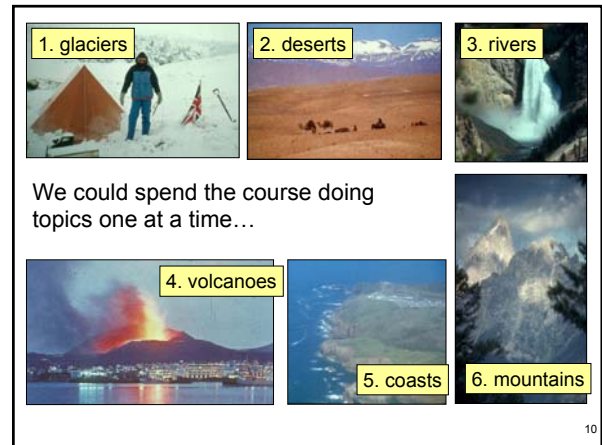
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**Our approach**

- not focusing on isolated “topics”
- not presenting you with “facts”
- recognising uncertainty and controversy

9



...but they work according to the same “rules”, so we don’t need to.

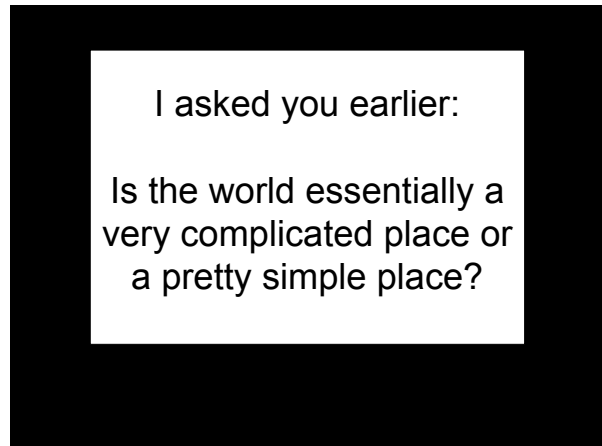
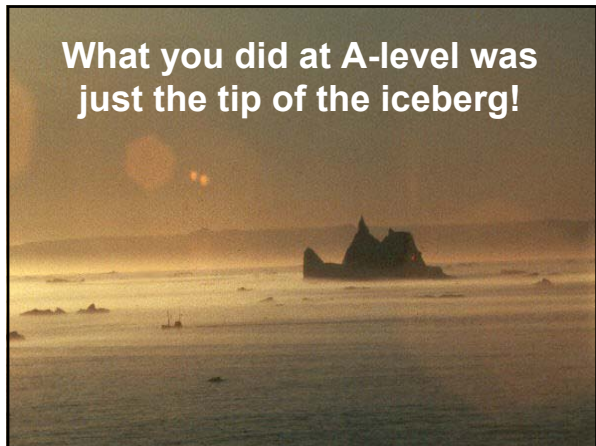
We can understand *any* landscape, if we understand those *basic principles*. That’s our mission

11

**Everything is connected in a complex system**

Glaciers, climate, sea-level, tectonics, geomorphology, ocean currents...

12



**Part 2: Why the explorers sometimes seem a bit lost**

**Glaciers and Glacial Landscapes**

Examples of the problems students can face as they approach the bridge over the gap between school and university

15

Glaciers illustrate connections between parts of the global system at different scales...

OCR Geography A-level (2007): Module 2680 The Physical Environment  
*"As an introduction to this module the global hydrological cycle should be studied as a generalised, closed system."*

16

Glacier science: exciting. Rapid progress + new discoveries.

17

Teaching Glaciers: problematic. Conflicting sources.

18

Fundamental problems in teaching  
Physical Geography:

- keeping up with new discoveries
- choosing reliable teaching resources
- knowing what to tell students

**Especially when popular textbooks and websites such as the BBC are perpetuating out-of-date or incorrect information...**

19



“...a significant minority of candidates appeared to have no relevant knowledge and understanding concerning drumlins...”

Some simply stated that the glaciers somehow became tired, unable to carry on in lowland areas and dumped their load.”

*AQA Examiners' Report (GCE Geography A, 2005)*

20



An explanation of DRUMLINS from the A-level textbook that most of my incoming 1<sup>st</sup>-year Univ students used at A-level (a book described by one teacher's web site as “as good as it gets”):

“The most widely accepted view is that they were formed when the ice became overloaded with material and so the competence of the glacier was reduced. The reduced competence may have been due to the melting of the glacier or to changes in velocity...”

**WRONG** This isn't how glacial deposition works

21



<http://www.geography-site.co.uk/>

“There is still some debate about how drumlins are formed, but the most widely accepted idea is that they were formed when the ice became overloaded with sediment. When the competence of the glacier was reduced, material was deposited, in the same way that a river overloaded with sediment deposits the excess material.”

**WRONG** Did they get this from that text book?

22



<http://www.bbc.co.uk/schools/>

“Lodgement till:

This is sometimes referred to as **Ground Moraine**. It is the Material that is deposited under ice while the ice is moving. This action is almost like smearing and occurs when the weight of material becomes too great to carry on by the glacier. Features created by this deposition include **Drumlins**”

**WRONG** They've been reading that text book again!

23

The origin of drumlins

- Hypothesis 1: Deposition by ice
- Hypothesis 2: Erosion by ice
- Hypothesis 3: Deformation by ice
- Hypothesis 4: Erosion by subglacial megafloods

“The strongly polarized debate about the origin of drumlins exemplifies the problem when speculation is relatively unconstrained by definitive evidence...”



**Prof. Geoffrey Boulton, University of Edinburgh**  
*In Knight, P.G. (2006) Glacier Science and Environmental Change (Blackwell).*

24

### The controversial "subglacial megafood" hypothesis



"Enormous floods from beneath the Pleistocene Ice Sheets may have formed drumlins, one of the most enigmatic landforms on Earth.

Prof. John Shaw, University of Alberta.  
<http://www.engineering.ualberta.ca/civil/shaw.cfm>

"...most Quaternary scientists give little or no credence to the megafood interpretation, and it conflicts with an overwhelming body of modern research"



Dr David Evans, University of Durham.  
 Benn, D. and Evans, D.J.A. (2006) in Knight P.G. (ed.) *Glacier Science and Environmental Change* (Blackwell)

25

### "Glacier motion

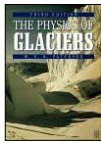
Ice may move through one of these three processes:

1. Plastic Flowage: Ice has plastic qualities and may flow en-masse like a viscous liquid
2. Basal Slip: The process through which ice slips and slides over the underlying rock.
3. Internal Shearing: Movement similar to rock faulting involving differential sliding along planes."

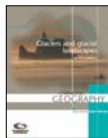
**WRONG** (at least in part, and very incomplete)

26

1. Plastic flowage
2. Basal slip
3. Internal shearing



1. Internal deformation of ice
2. Sliding of ice across substrate
3. Deformation of substrate



"Until the 1970s, sliding and internal deformation were the only mechanisms that scientists recognised. The idea that deforming beds contribute to glacier motion has been one of the most important ideas in recent decades."

27

### Ice Erosion

•This involves three processes:

1. Plucking: Parts of the underlying rock are frozen into the base of the ice and pulled away.
2. Glacial Abrasion: The grinding process where stones frozen in the ice scrape and scratch against the underlying rock.
3. Sapping: The breaking of rocks by the alternate freezing and thawing of the ice at the bottom or sides of the mass.

**WRONG**

28

## Both a problem and an opportunity

New research:

puts "errors" into old textbooks

*but*

helps to make the subject more exciting to learn and to teach

Dynamic, Relevant, Cutting edge, Topical, Interdisciplinary, Complex linked system, Global and local scale interactions...

29

EXAMPLE

### Climate-independent glacier fluctuations



BBC: "Glacier retreat is a sure sign of global warming."

**WRONG**

**EXAMPLE**

**1. Changing basal friction:**

1. Accumulation and thickening

2. Basal deformation, acceleration, advance, thinning...

3. Less basal deformation, slowing, retreat.

31

**EXAMPLE**

**2. Floating glacier margins:**

W. Greenland

NB: Ice-shelf "collapse"

W. Greenland

32

**EXAMPLE**

**3. Ice-divide migration**

STAGE 3

STAGE 2

STAGE 1

PRECIPITATION

FIGURE 7  
A MODEL OF ICECAP DEVELOPMENT

Pictures by Andrew Dugmore

**The world is even more interesting than the text books tell us!**

- The basal ice layer
- Ice streams
- Deformable beds
- Surging glaciers
- Megafloods
- Jökulhlaups
- Glaciers flowing up-hill
- Glaciers controlling climate etc...

34

**Ways forward...**

- bridging texts  
eg The GA's "Changing Geography" series
- school/university interaction  
eg visits/workshops/correspondence
- teacher-researcher co-authorship  
eg web-sites, text books, etc

35

**I asked you earlier:**

**Is the world essentially a very complicated place or a pretty simple place?**

**Part 3:  
Not everything is in the text books**



37

**The bottom of the  
Greenland ice sheet**



38

**Basal ice**



39

**Basal ice:**

ice that has been affected by processes operating at the bed, and consequently has physical and chemical characteristics different from the (englacial facies) ice above.



40

**Importance of the basal ice layer:**

A record of processes and environments at the inaccessible glacier bed.

Controls flow properties of base of glacier, affecting how glacier moves (eg friction).

Geomorphically very active – interface between ice and bed, agent of erosion, source of sediment for deposition.

41

**A problem and a new hypothesis**

Thick basal ice in some temperate settings: problematic

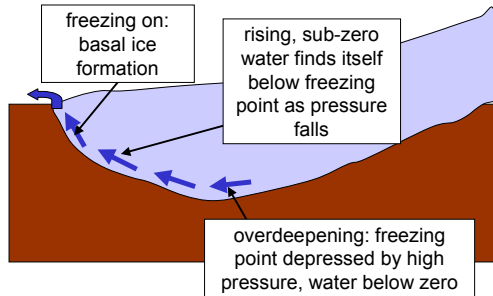
**Subglacial glaciohydraulic supercooling...**  
a way of freezing ice to the base of temperate glaciers?



(<http://www.geosociety.org>)

42

## Glaciohydraulic supercooling



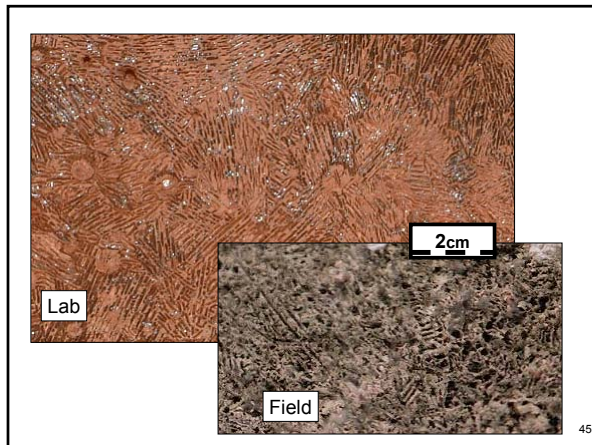
43

## Producing "supercooled" ice in the lab



Two Methods: pressure and turbulence.

44



45

## Field observations



"supercooling" site: Roberts et al. (2002) and Spedding and Evans (2001).

46

## Controversy

"...glaciohydraulic supercooling is the primary mechanism creating the stratified facies of the basal zone"  
(Lawson et al. *J. Glaciol.* 1998)

"...referees urged us to accept that glaciohydraulic supercooling accounts for the extensive layers of basal ice. We believe that such certainty is premature."  
(Spedding and Evans *Sedimentary Geology*, 2001)

"...further research is required to test its true significance"  
(Cook et al., *Prog. in Phys. Geog.* 2006)

47

## Basal ice sequences close to supercooled water outlets



Unique "supercooling" basal ice facies with distinctive "herringbone" texture

48

Basal ice sequences far from  
supercooled water outlets



"Normal" (non-supercooling) basal ice facies

49

**SOME basal ice is created by....**

**SOME drumlins are created by...**

**It DEPENDS on...**

50

## Conclusions

Complexity, uncertainty  
and wonder.

Physical Geography for  
grown-ups of all ages.

1.

- The world is very complicated. But that is exciting, important, and need not be overwhelming.
- The world is also very simple. We can find underlying themes and principles that provide us with a clear framework for understanding.
- To oversimplify the world is to do it, and our young explorers, a serious disservice.

52

2.

- Glaciers provide valuable theme linking local/global, present/past, human/physical.
- Rapidly moving research frontier makes it exciting for students to learn but hard for textbooks and teachers to keep up.
- Opportunities for resources that "bridge the gap", and for collaboration between Schools and Universities... how can we help?

53

3.

- Geography isn't *finished* yet: we are discovering new things all the time.
- Our challenge, as guides, is to find ways of helping the explorers to see more.
- We should help them to be excited by uncertainty and controversy in the subject, not ignorant of it and ready to be scared by it.
- Physical Geography is a subject for grown ups, whatever their age.

54