

# Introduction to Geomorphology



## Goals of Today's Lecture

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1. To introduce you to the course organization.
2. To provide you with an idea of what we will discuss in this class.
3. Review of material you need to know as background to this course



## Geomorphologist

School of Environmental Science  
& Department of Geography

B.Sc. University of Guelph

M.Sc. University of Southern California

Ph.D. University of British Columbia

Post-Doc University of California, Berkeley

I am a geomorphologist who works on 3 inter-related problems: 1) the physics of flooding, 2) sediment export from mountain ranges and the physics of bedrock river incision.

We do field work in big rivers & canyons. We also do controlled laboratory experiments to test hypotheses in the River Dynamics Laboratory.

I have active projects in the Fraser Canyon, the Southern Andes Mountains and, of course, my lab at SFU.

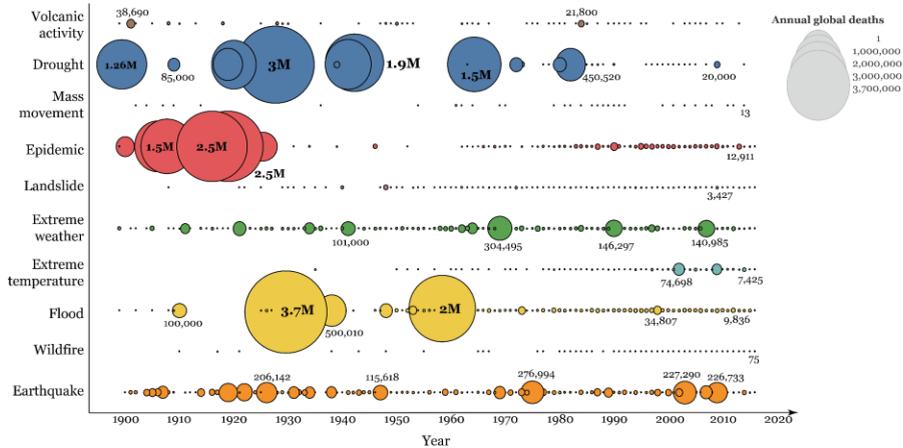


**Floodplains are  
floodplains  
because they  
flood.**

## Floods are bad...

### Global deaths from natural disasters, by type (1900-2016)

Global annual deaths from natural catastrophes, differentiated by disaster type from 1900 to 2016. The size of the bubble represents the total death count per year.



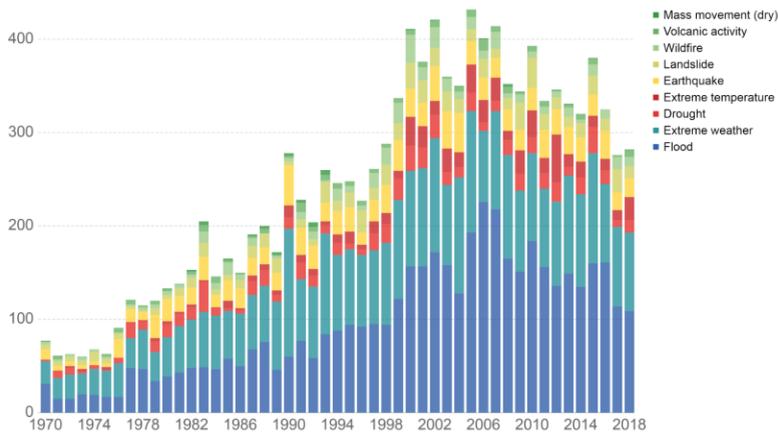
Data source: EMDAT (2017); OFDA/CRED International Disaster Database, Université catholique de Louvain - Brussels - Belgium. The data visualization is available at OurWorldInData.org. There you find research and more visualizations on this topic.

<https://ourworldindata.org/natural-disasters>  
Licensed under CC-BY-SA by the authors Hannah Ritchie and Max Roser.

## ...they happen a lot...

### Global reported natural disasters by type

The annual reported number of natural disasters, categorised by type. This includes both weather and non-weather related disasters.

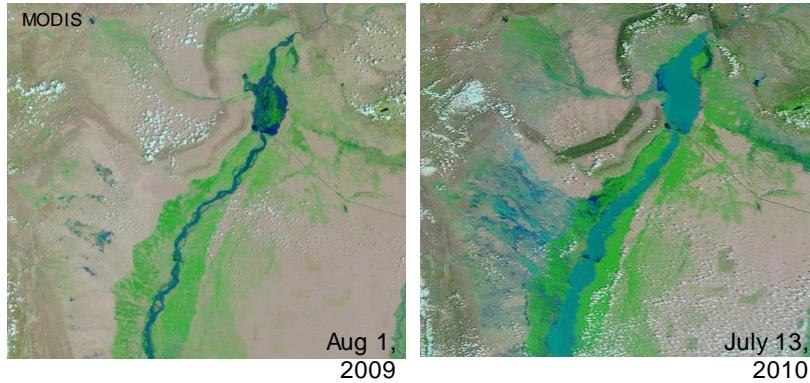


Source: EMDAT (2017); OFDA/CRED International Disaster Database, Université catholique de Louvain - Brussels - Belgium  
OurWorldInData.org/natural-disasters • CC BY

<https://ourworldindata.org/natural-disasters>

..they cost a lot.

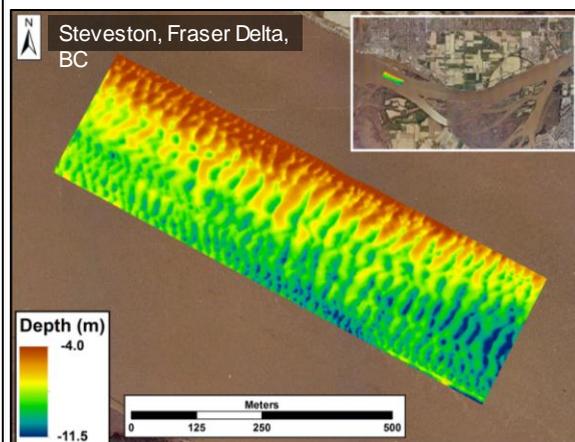
2010 Indus River Flood in Pakistan: >6 million displaced, >1,500 deaths **Economic impact US\$43 billion.**



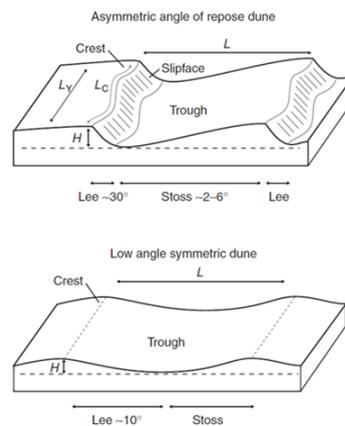
Canada in 2017: Insured costs \$590 million, uninsured costs borne by governments ~\$750 million = **\$1.34 billion.**

## Flood Research in SFU River Dynamics Lab

**Water levels are modulated by roughness on river beds, but we don't know how it coevolves with flow.**



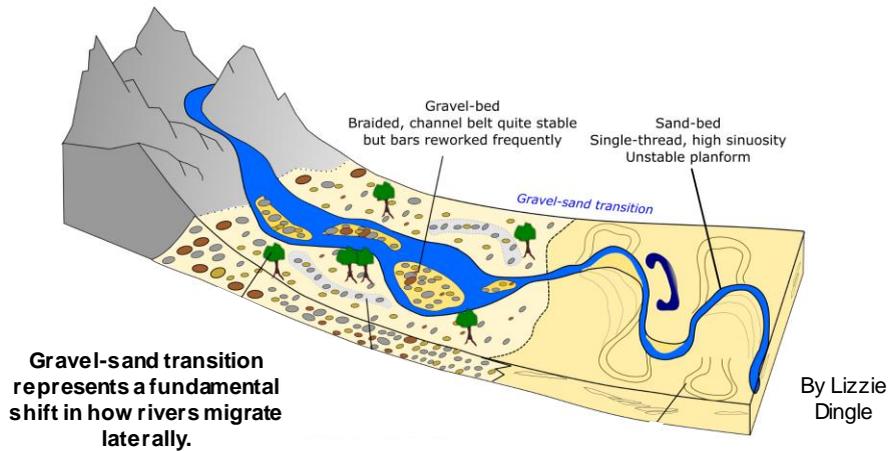
Hendershot et al., *Sedimentology*, 2016



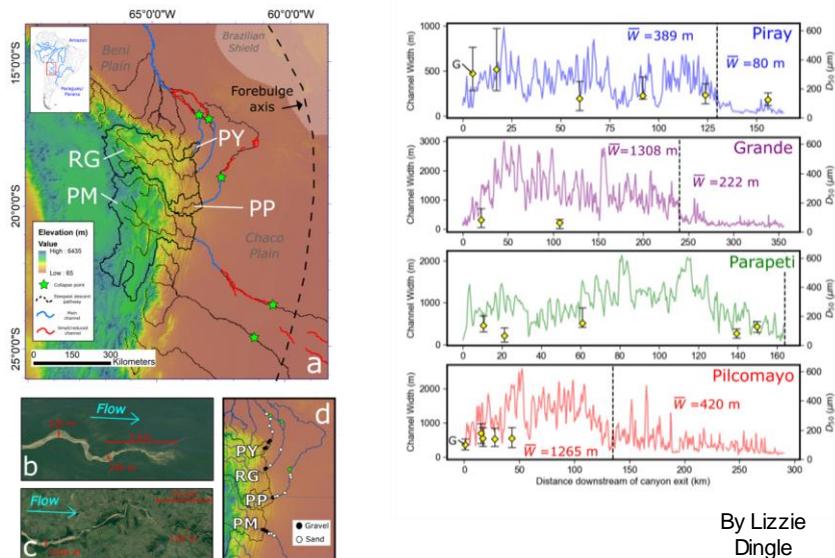
Venditti, *Treatise*, 2013

## Sediment Export from Mountain Ranges

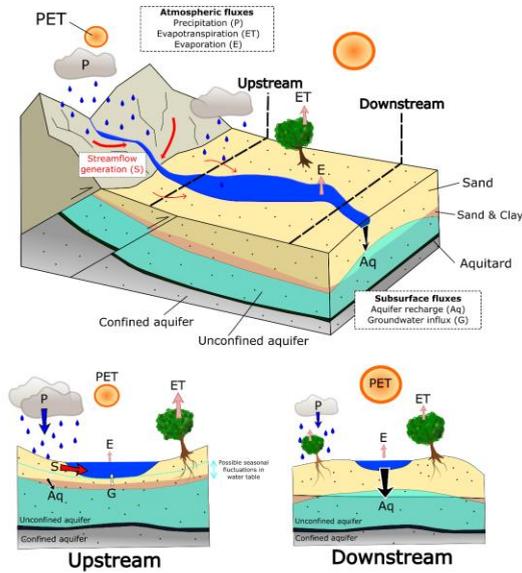
### Global mapping of gravel-sand transitions



## Disappearing rivers in Bolivia



## Disappearing rivers in Bolivia



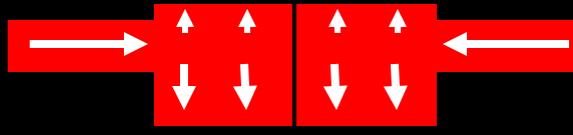
## Incision of Bedrock Canyons

### When continents collide...

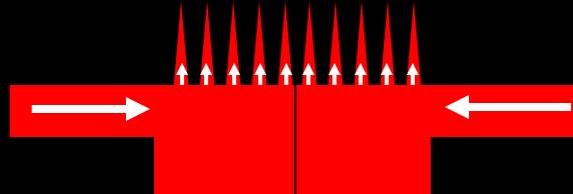
Classical view: uplift is controlled by mantle convection cells



Two colliding continents will force a thickening of the crust and building of a mountain root



Incision of bedrock channels will allow buoyant forces to lift the landscape surface

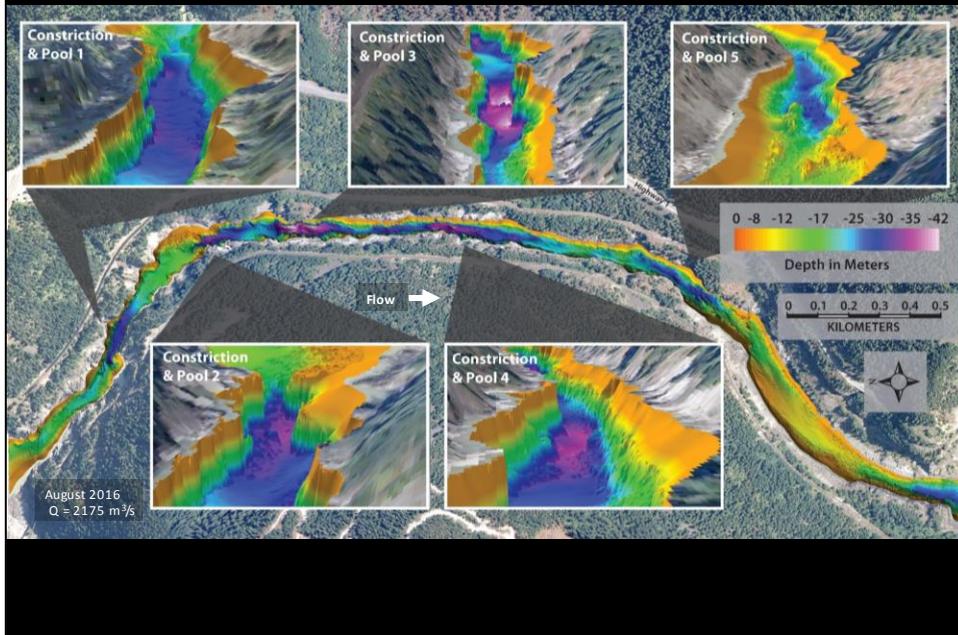


Flow Structure in a Bedrock Canyon

## Black Canyon



## Results: Morphology of Black Canyon



**Global News** BC News & Radio Programs

**Major rock slide in Fraser River sparks fears of blocking migrating salmon**

By Sean Boynton and Jordan Armstrong Global News

Global News Hour at 6  
Rocksides in Fraser River raises salmon concerns

ROCK SLIDE  
Significant slide in Fraser may hinder salmon passage.

**NATIONAL POST**

**Rock slide in Fraser River, B.C., may hinder salmon passage**

TORONTO WEATHER **13°C**

**Monday** 18°C  
**Tuesday** 22°C  
**Wednesday** 23°C  
**Thursday** 25°C

**THE CANADIAN PRESS**

**Rock slide in Fraser River, B.C., may hinder salmon passage**

VANCOUVER — The Department of Fisheries and Oceans says it is aware of a "significant" rock slide that occurred on the Fraser River in British Columbia, which could possibly hinder the passage of returning salmon.

Remember Tom Hancock says the slide happened Tuesday morning north of the Big Bar Ferry causing a disturbance in the river.

In a statement, the fisheries department says it is aware that the slide occurred in a narrow portion of the Fraser River.

The department says it has conducted an aerial survey of the site.

It says it will be sending another crew of engineers and habitat specialists into the remote area on Wednesday to determine the extent of the blockage.

It says it will be working with the province and local First Nations on next steps. (CBC)

BELLYER (THE)

**VANCOUVER SUN**

**Fisheries working on solutions as rock slide in Fraser River hinders salmon passage**

A "significant" rock slide that occurred in the Fraser River in B.C.'s Interior could hinder the passage of returning salmon.

THE CANADIAN PRESS Updated: June 28, 2019

The federal and British Columbia governments are working with local First Nations, communities and stakeholders to co-ordinate the response to a "significant" rock slide in the Fraser River.

### FRENCH BAR CANYON

Bedrock Entrance	558577m E	5675000m N	421.4 Rkm
Bedrock Exit	559205m E	5674068m N	419.5 Rkm

CANYON DEPTHS		CANYON VELOCITIES	
Variable	Depths	Variable	Velocity
d <sub>bet</sub> (m)	3.68	Mean 600 kHz (m/s)	n/a
d <sub>ave</sub> (m)	11.67	Mean 1200 kHz (m/s)	n/a
d <sub>mid</sub> (m)	3.02	Mean M9 (m/s)	1.70
d <sub>max</sub> (m)	28.60	Q / (d w) (m/s)	0.68

Measurement date is Sept 18, 2009; Discharge Q = 985 m<sup>3</sup>/s

CHANNEL WIDTH			
Variable	u/s Alluvial	Canyon	d/s Alluvial
Area (m <sup>2</sup> )	209301	269618	158206
Length (m)	1250.00	1860.33	800.00
Width (m)	167.44	144.93	197.76
Mean Depth, d (m)	6.34	10.00	5.35
w/d	26.39	14.50	36.98
W/d <sub>ave</sub>		5.07	

POOL DATA			
Variable	Pool 1	Pool 2	Pool 3
S <sub>bet</sub>	-0.0566	-0.149	--
S <sub>bet</sub>	0.0966	0.0803	--
d <sub>max,p</sub> (m)	24.30	28.60	--
Z <sub>bet</sub> (m)	21.56	19.00	--
Z <sub>ave</sub> (m)	13.94	20.36	--
W <sub>ave</sub> (m)	183.32	99.91	--
W <sub>c</sub> (m)	62.84	38.79	--
W <sub>ave</sub> (m)	119.91	77.98	--
% const	65.7	61.2	--

#### CANYON WIDTH

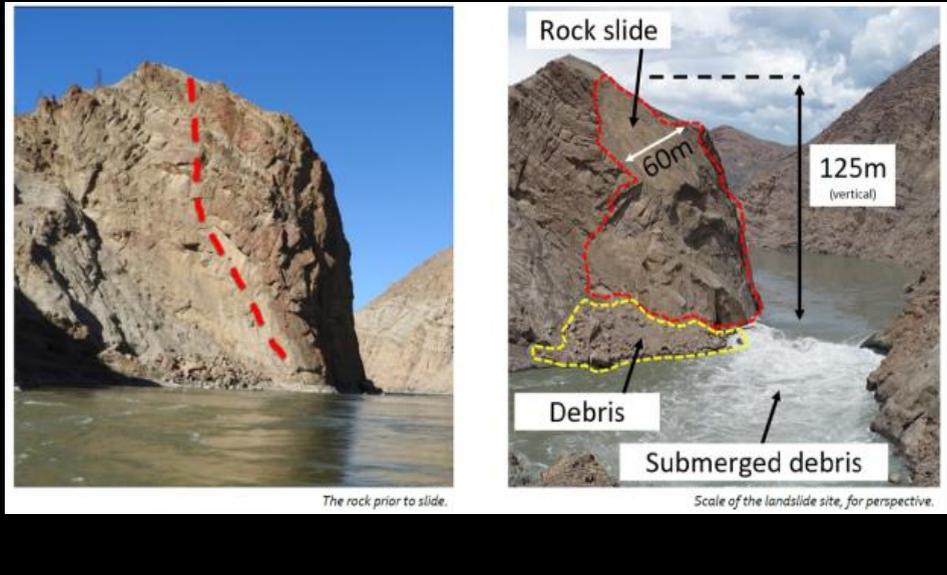
#### OVERVIEW

Imagery from Province of British Columbia, 31/12/2004. Accessed on Google Earth 25/07/2017

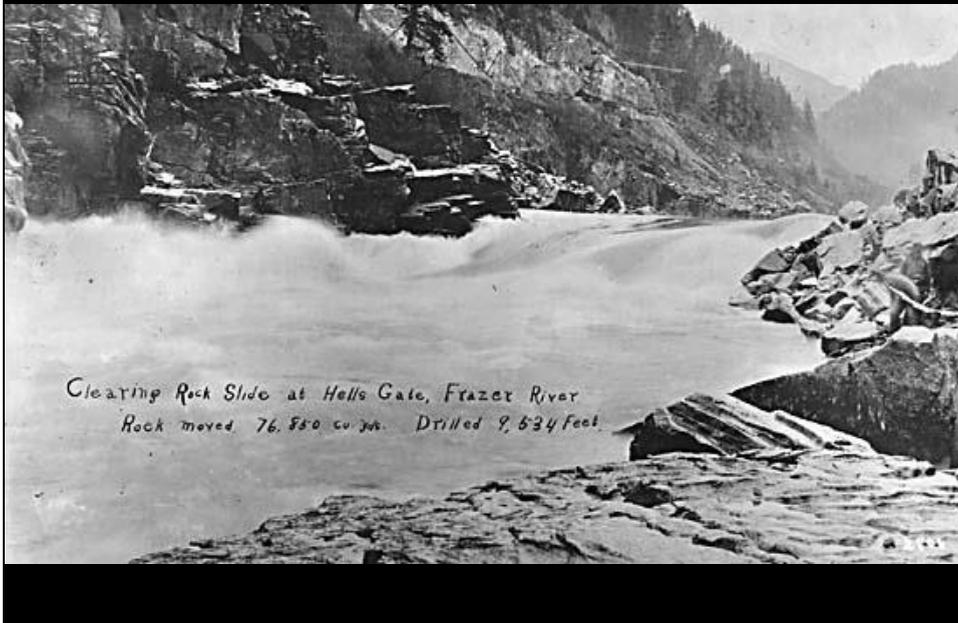
Legend  
▲ Width Measurement  
— Bedrock Entrance Boundaries  
— River Kilometers Upstream from Sand Heads

#### LOCAL WIDTHS

**What happened at French Bar Canyon?**  
**Plunging flow undercut the wall and it failed.**



### 1913 Hell's Gate Slide



### The deepest part of the Fraser Canyon was blasted to allow fish migration!



# Introduction to Geomorphology (GEOG 213)

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**Instructor:**

Dr. Jeremy G. Venditti  
Email: jeremy\_venditti@sfu.ca  
Office hour: Mon 11:30 - 12:20 (by  
Zoom)

**Teaching Assistant:**

Tingan Li  
Email: Tingan\_Li@sfu.ca  
Office hour: Wednesday 10:30 - 12:30

## The Course Format

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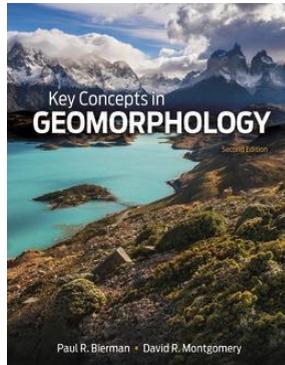
**Lectures:** Mon 12:30 - 14:20 in AQ 4150

**Labs:**

Mon 14:30 - 16:20	WMC 3251
Mon 16:30 - 18:20	AQ 5050
Tues 10:30 - 12:20	AQ 5038

# The Readings

## Required Texts



Bierman, P.R. and D.R. Montgomery (2020) *Key Concepts in Geomorphology, second edition*, MacMillan Learning

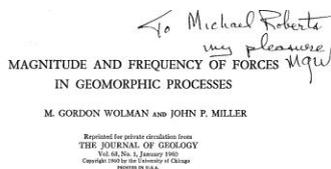
[https://www.macmillanlearning.com/college/ca/product/Key-Concepts-in-Geomorphology/p/1319059805?select\\_ed\\_tab=About](https://www.macmillanlearning.com/college/ca/product/Key-Concepts-in-Geomorphology/p/1319059805?select_ed_tab=About).

**You may also use the first edition of the textbook if you can find it used.**

Note there is a whole series of case studies that accompany the book here: <http://serc.carleton.edu/vignettes/index.html>

# The Readings

## Required Scholarly Articles (4):



### Disequilibrium of Holocene sediment yield in glaciated British Columbia

Michael Church & Olav Slaymaker

## Suggested further readings:

*Important works that expand on topics covered in class*

REVIEW ARTICLE

### Late Cenozoic uplift of mountain ranges and global climate change: chicken or egg?

Peter Molnar & Philip England

The high altitudes of most mountain ranges have commonly been ascribed to late Cenozoic uplift, without reference to when crustal thickening and other tectonic processes occurred. Deep incision and recent denudation of these mountain ranges, abundant late Cenozoic coarse sediment near them, and paleobotanical evidence for warmer climates, where high mountain climates today are relatively cold, have traditionally been interpreted as evidence for recent uplift. An alternative cause of these phenomena is late Cenozoic global climate change: towards lower temperatures, increased alpine glaciation, a stormier climate, and perturbations to humidity, vegetative cover and precipitation.

### The search for a topographic signature of life

William E. Dietrich<sup>1</sup> & J. Taylor Perron<sup>2</sup>

Landscapes are shaped by the uplift, deformation and breakdown of bedrock and the erosion, transport and deposition of sediment. Life is important in all of these processes. Over short timescales, the impact of life is quite apparent: rock weathering, soil formation and erosion, slope stability and river dynamics are directly influenced by biotic processes that mediate chemical reactions, dilate soil, disrupt the ground surface and add strength with a weave of roots. Over geologic time, biotic effects are less obvious but equally important: biota affect climate, and climatic conditions dictate the mechanisms and rates of erosion that control topographic evolution. Apart from the obvious influence of humans, does the resulting landscape bear an unmistakable stamp of life? The influence of life on topography is a topic that has remained largely unexplored. Erosion laws that explicitly include biotic effects are needed to explore how intrinsically small-scale biotic processes can influence the form of entire landscapes, and to determine whether these processes create a distinctive topography.

## The website

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Readings and lecture materials can be found at my website:

**<http://www.sfu.ca/~jvenditt/>**

Links to the website will be posted in Canvas, but the documents will not in Canvas.

## The Laboratories

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Labs begin on September 20 & 21.

There are 6 laboratory exercises/assignments.

See syllabus for 'Tentative Lecture and Laboratory Exercise Schedule' for due dates and return dates.

Late labs will be penalized 1 grade per day.

Links to the lab exercises will appear in Canvas prior to the laboratory assignment. You are to submit your assignment to the TA using Canvas.

You may contact myself or the TA regarding lab exercise content, but the TA is better suited to deal with specific questions.

## The Field Trip

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There will be a **mandatory** field trip to complement topics covered in lectures and labs. The field trip consists of a series of videos recorded along the banks of the Fraser River. You can watch them at your leisure.

### **Virtual Fraser River Field Trip** **Videos to be released on Nov 1, 2020**

<https://www.youtube.com/channel/UC3kS6d197hebubFU0YqqfZw>

## The Grading

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Laboratory assignments	30%
Field Essay	20%
Mid-term examination	25%
Final examination	25%

### **Important dates**

1. MIDTERM: 12:30-14:20, Monday, Nov 1, 2020
2. FIELD ESSAY due: 12:30, Monday, Nov 29, 2020
3. FINAL EXAM: TBD by SFU scheduling in Mid-October

## Picture(s) of the week

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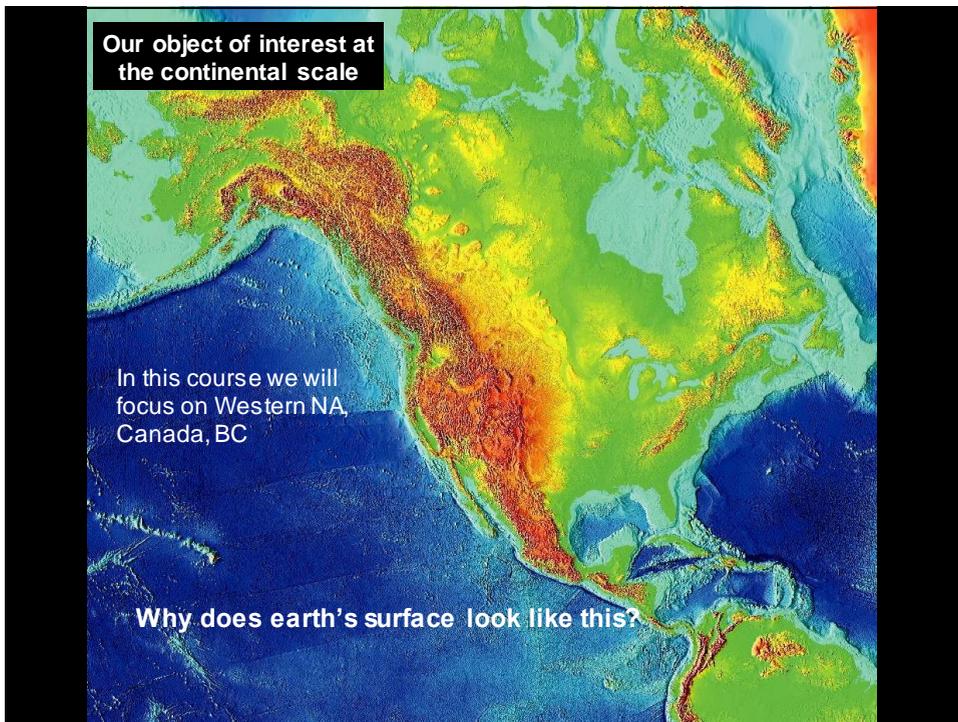
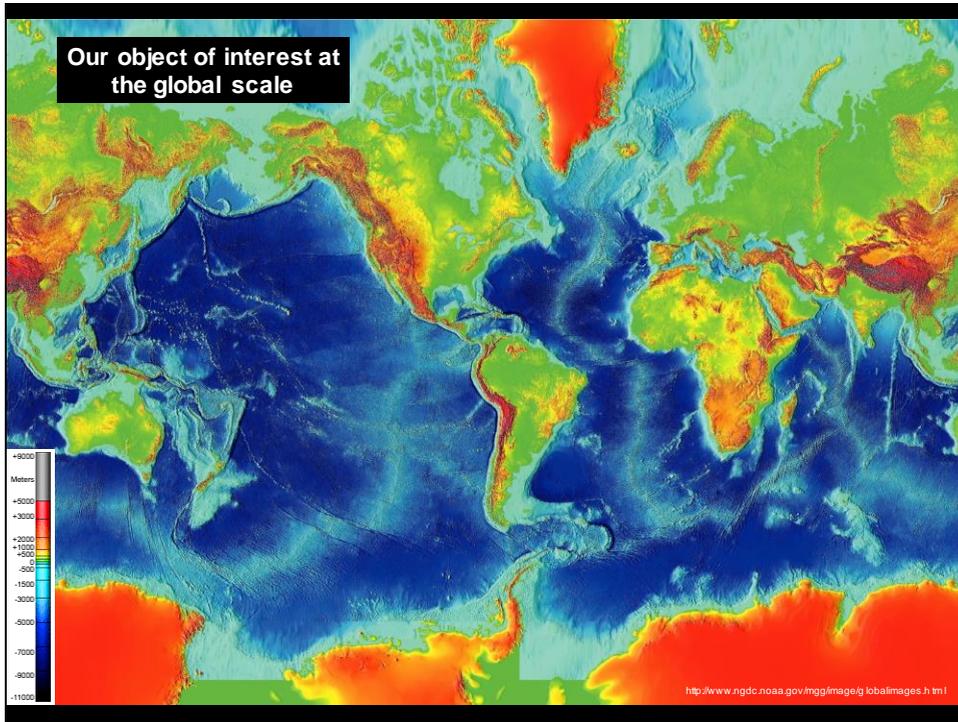
### What is picture of the week?

- Find a picture of a landscape that you took bring it to class and I'll explain how the landscape in your picture was formed.
- I'll do it on the fly without ever seeing the picture before, so it'll be hard for me.
- What kind of picture can it be? Any landscape picture...a vacation in the mountains, or on a beach...a picture from your backyard...a picture you took out of a plane window, whatever.
- Can it have people in it? Yes, I don't care and it won't be loaded online anywhere, so if you don't care, I don't care (make sure the people are clothed!)
- Can it be from the internet? **No!** Send something you took, from somewhere you went.

## The Course Content

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**Geomorphology** is the study of Earth's surface and the processes that form it. As such, it is a crucial component of solutions to a wide range of environmental problems and engineering designs. It has even become an important tool for understanding how far-off planets like Mars and Venus have evolved to their current state. This particular course is about Earth's landscape, its present form, and the processes responsible for its large-scale organization. **The goal is to provide students with an appreciation of how the landscape around them formed and its continued evolution** with particular focus on landscapes of British Columbia, Western North America, and Canada.



**Our object of interest at  
the local scale**



**Our object of interest at  
the local scale**





Our object of interest at the grain-scale

This scale controls what happens at the larger scales!

The top-left image shows a cross-section of a soil bank with a root system. The top-right image shows a large, rounded rock with distinct horizontal bedding. The bottom-left image shows a close-up of a sand dune with a person's foot for scale.

Flooding happens at the local scale

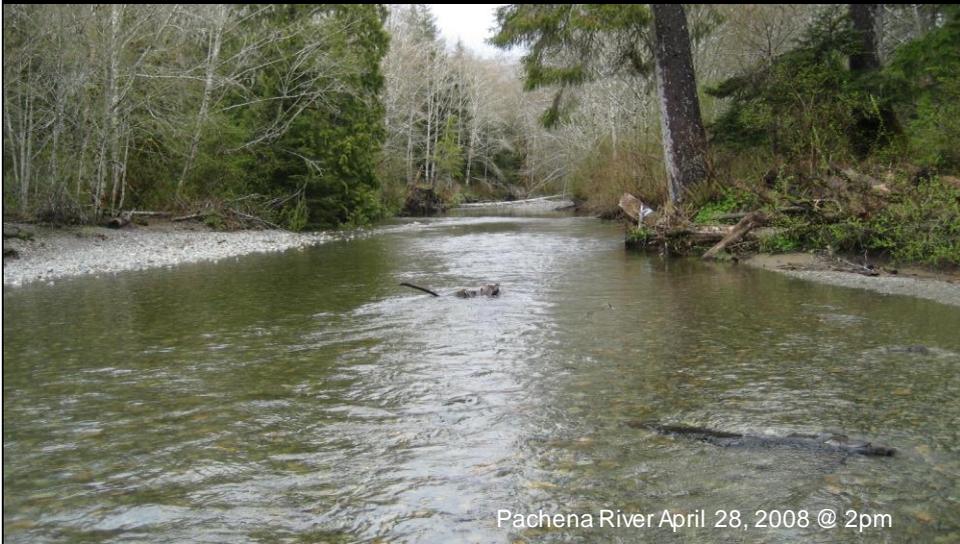


Pachena River at base flow April, 2008

The local scale is where the change is most obvious and relevant.

The photograph shows a river flowing through a forested area with a person standing in the water for scale.

**Flooding happens at the at local scale**



Pachena River April 28, 2008 @ 2pm

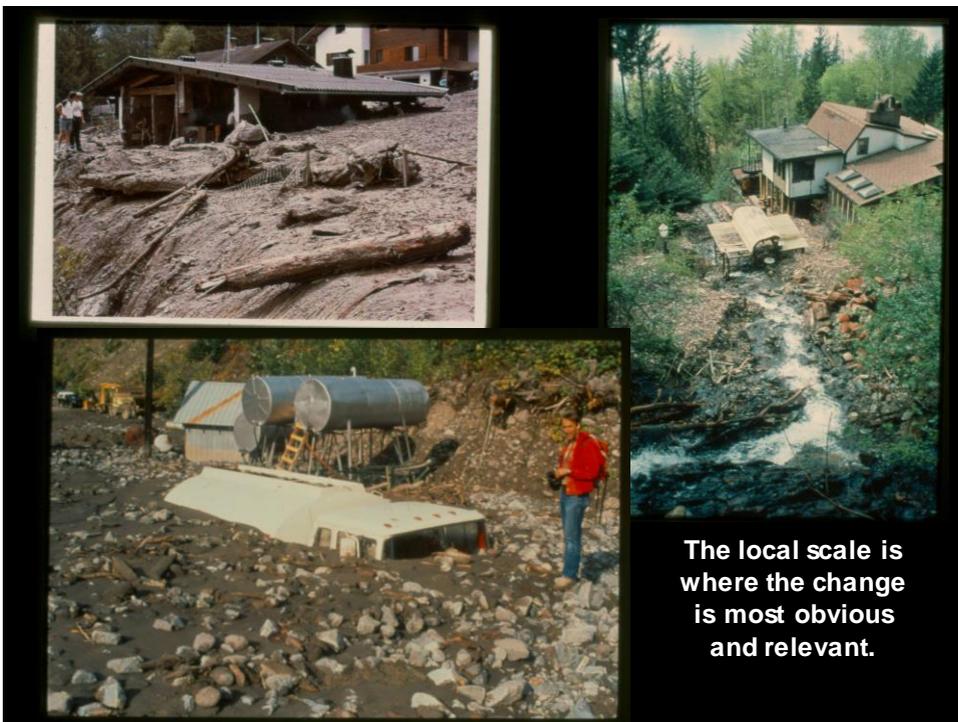
The local scale is where the change is most obvious and relevant.

**Flooding happens at the at local scale**



Pachena River April 28, 2008 @ 4pm

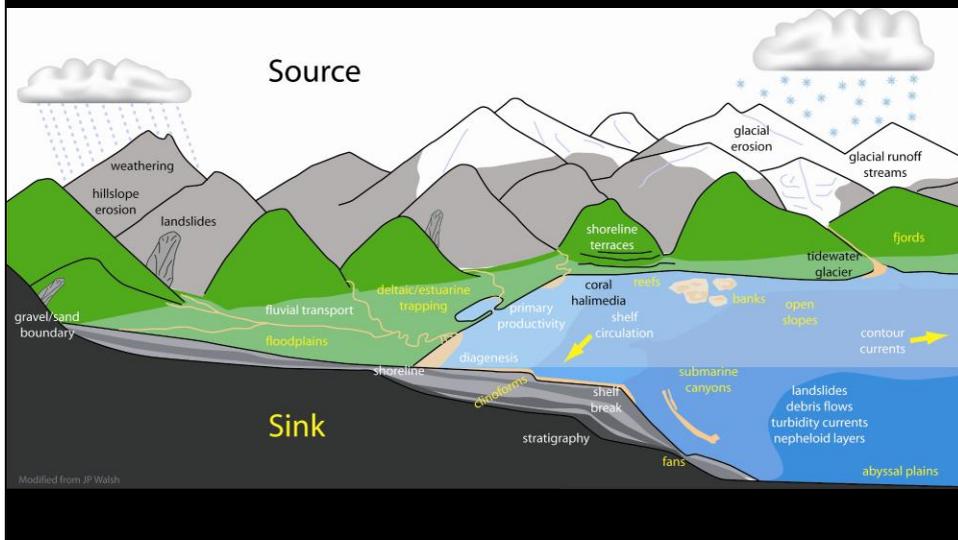
The local scale is where the change is most obvious and relevant.



## Questions we will answer in this course

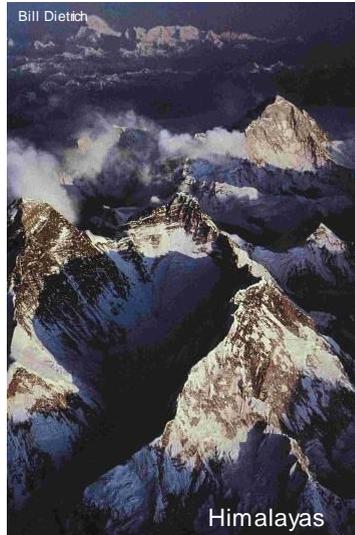


## 1. What is the fundamental basis of geomorphology?



## 2. What controls topographic relief?

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## 3. Where do landscape materials come from?

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#### 4. How do landscape materials get down from mountain tops to valley floors?

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#### 5. How do landscape materials get from valley floors to their ultimate sink (oceans or lakes)

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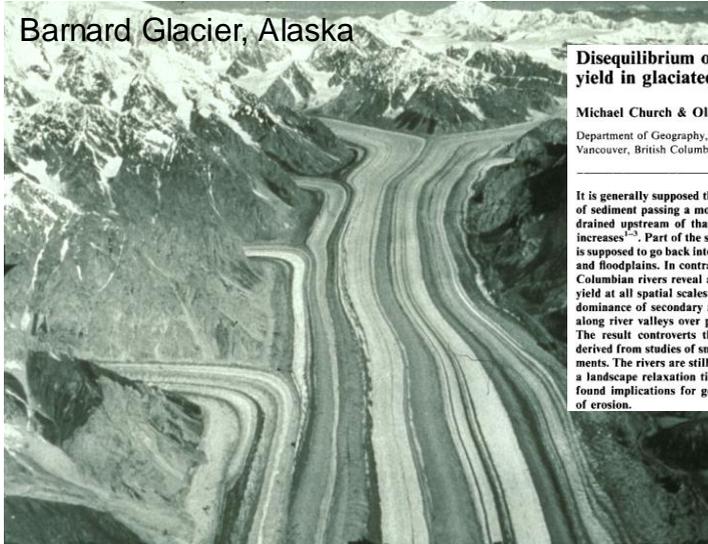


Lena Delta, Siberia



## 6. How do glaciers modulate landscape development?

Barnard Glacier, Alaska



### Disequilibrium of Holocene sediment yield in glaciated British Columbia

Michael Church & Olav Slaymaker

Department of Geography, University of British Columbia, Vancouver, British Columbia, Canada V6T 1W5

It is generally supposed that specific sediment yield—the quantity of sediment passing a monitored river cross-section per unit area drained upstream of that section—declines as the area drained increases<sup>1-3</sup>. Part of the sediment mobilized from the land surface is supposed to go back into storage at field edges, and on footslopes and floodplains. In contrast, we show here that data from British Columbian rivers reveal a pattern of increasing specific sediment yield at all spatial scales up to  $3 \times 10^4 \text{ km}^2$ . This results from the dominance of secondary remobilization of Quaternary sediments along river valleys over primary denudation of the land surface. The result controverts the conventional model which has been derived from studies of small, highly disturbed agricultural catchments. The rivers are still responding to the last glaciation, giving a landscape relaxation time greater than 10 kyr. This holds profound implications for geomorphological theory and for studies of erosion.

## 8. Has the emergence of life on this planet affected the large scale topographic organization of the earth?



### The search for a topographic signature of life

William E. Dietrich<sup>1</sup> & J. Taylor Perron<sup>1</sup>

Landscapes are shaped by the uplift, deformation and breakdown of bedrock and the erosion, transport and deposition of sediment. Life is important in all of these processes. Over short timescales, the impact of life is quite apparent: rock weathering, soil formation and erosion, slope stability and river dynamics are directly influenced by biotic processes that mediate chemical reactions, dilute soil, disrupt the ground surface and add strength with a weave of roots. Over geologic time, biotic effects are less obvious but equally important: biota affect climate, and climatic conditions dictate the mechanisms and rates of erosion that control topographic evolution. Apart from the obvious influence of humans, does the resulting landscape bear an unmistakable stamp of life? The influence of life on topography is a topic that has remained largely unexplored. Erosion laws that explicitly include biotic effects are needed to explore how intrinsically small-scale biotic processes can influence the form of entire landscapes, and to determine whether these processes create a distinctive topography.

# Why Study Geomorphology?

1. Earth's surface is our home!

<http://visibleearth.nasa.gov/>

# Why Study Geomorphology?

1. Earth's surface is our home!
2. All earth's organisms rely on physical characteristics of earth's surface as habitat.
3. Many transport processes (landslides, debris flows, floods, dust storms) are significant natural hazards



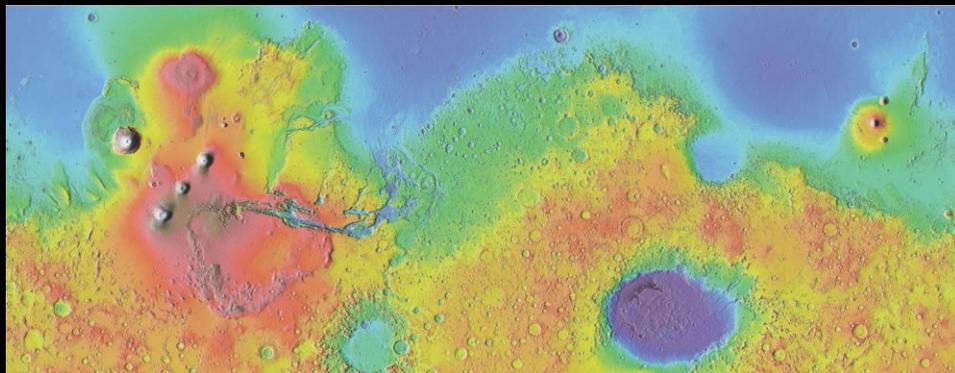
## Why Study Geomorphology?

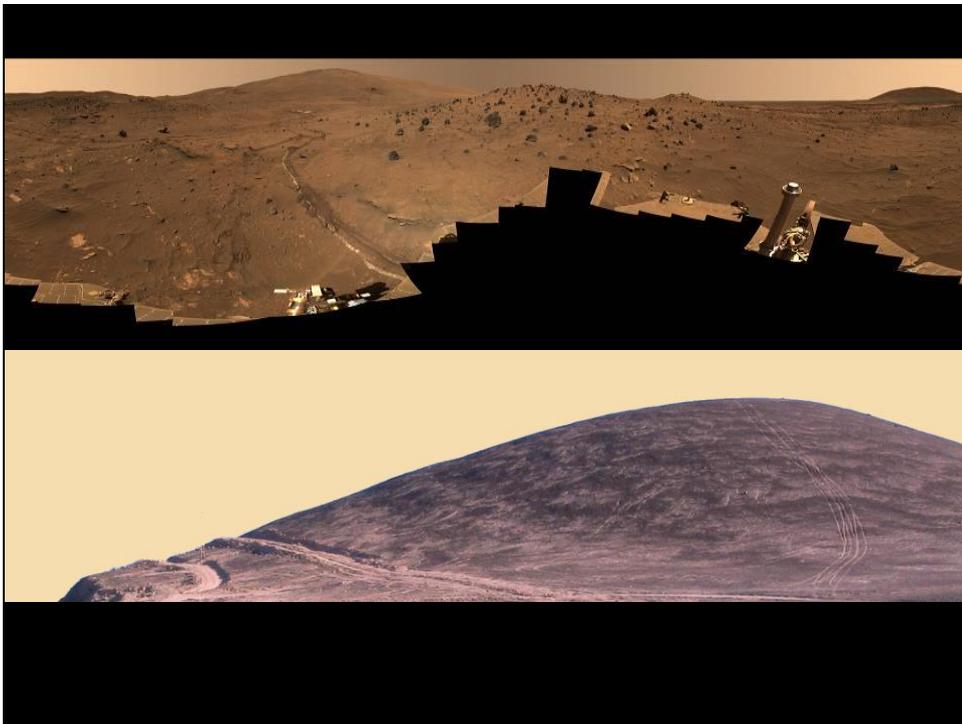
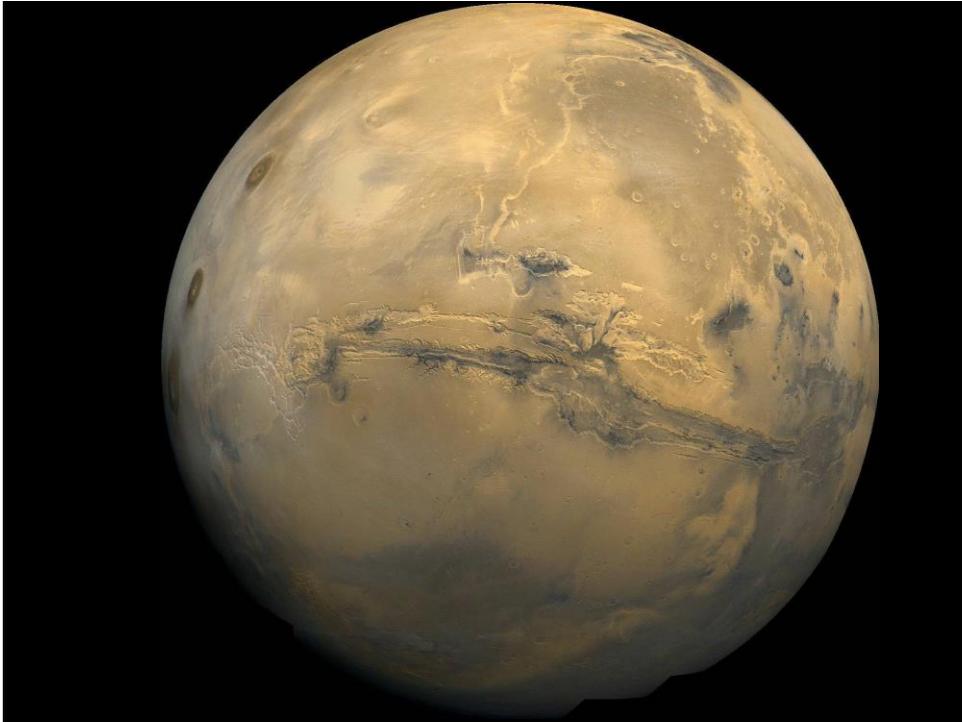
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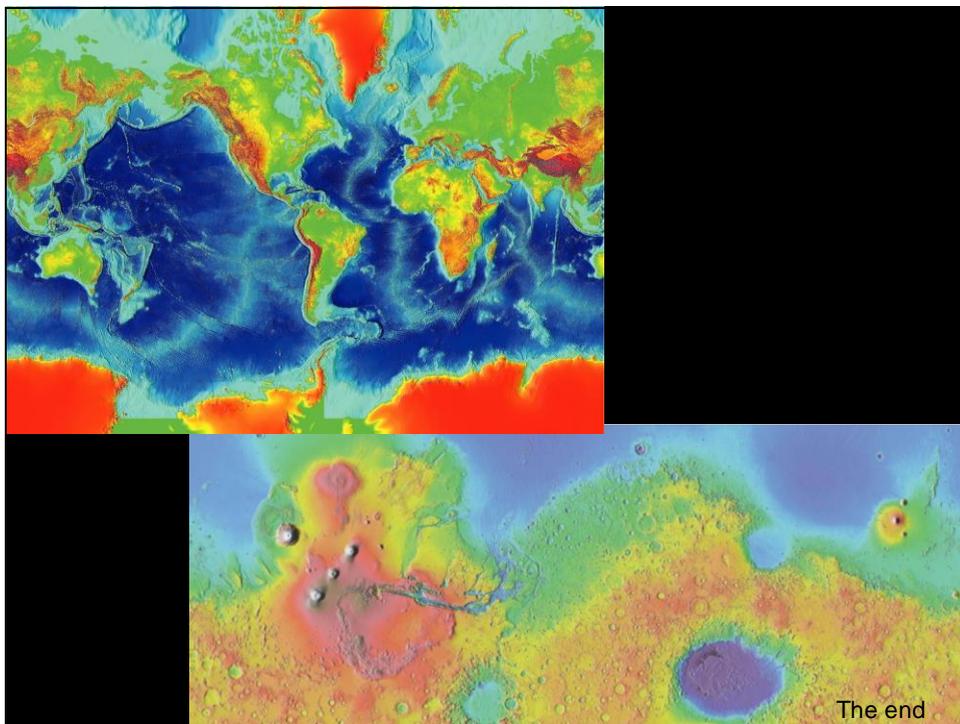
1. Earth's surface is our home
2. All earth's organisms rely (in varying degrees) on physical characteristics of earth's surface as its habitat.
3. Many transport processes (landslides, debris flows, floods, dust storms) are significant natural hazards



Where is this topography?







Picture(s) of the week

## Review of Geological Concepts

or things you should already know from GEOG 111 or EASC 101

### Reading Assignment:

You should review the material on the following slides. If you don't remember some of the material, review you GEOG 111 or EASC 101 textbooks and notes.

## Review of Geological Concepts

or things you should know from GEOG 111 or EASC 101

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### Rock Materials:

We need to understand the basics of rock materials because they contain information about how they were formed.

As such, rock materials allow us to estimate the overall history of a site and the rates of geomorphic processes (weathering rates, transport rates, transport distances).

Fortunately, knowledge of a **few basic minerals** is all that is needed to understand how most landscapes develop.

## Review of Geological Concepts

or things you should know from GEOG 111 or EASC 101

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### Rock Types:

- 1) Igneous: Form directly from the cooling of magma (e.g. basalt, granite).
- 2) Sedimentary: layers of this debris get compacted and cemented together (sandstone, mudstone, limestone, Halite).
- 3) Metamorphic: Rocks whose minerals have become unstable in their environment and are changed into something new (e.g. slate, schist, gneiss, and marble)

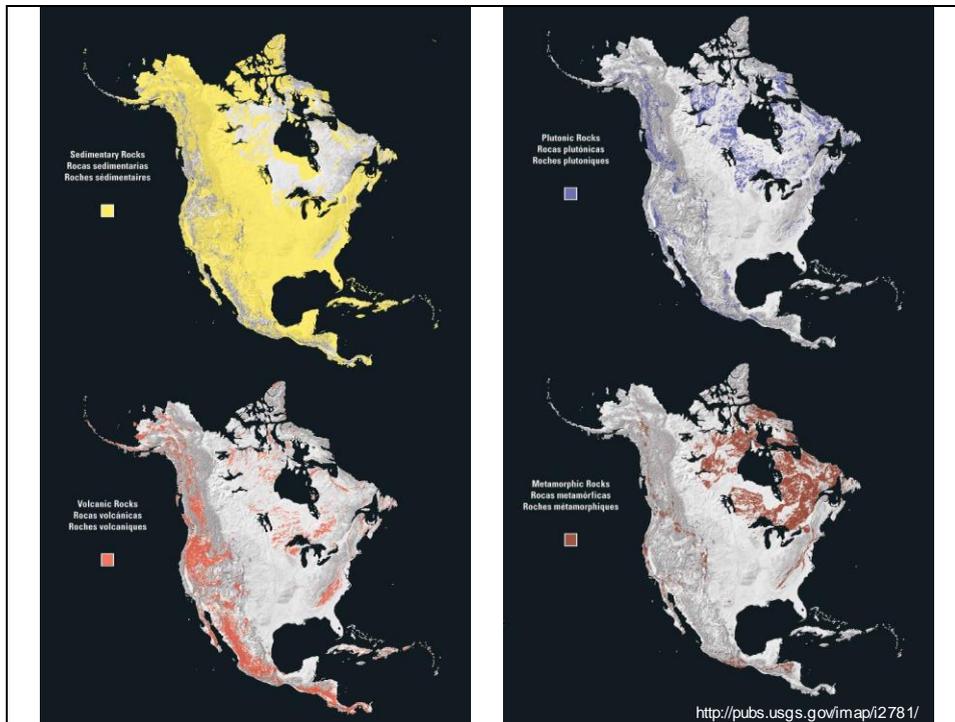


TABLE 1.8

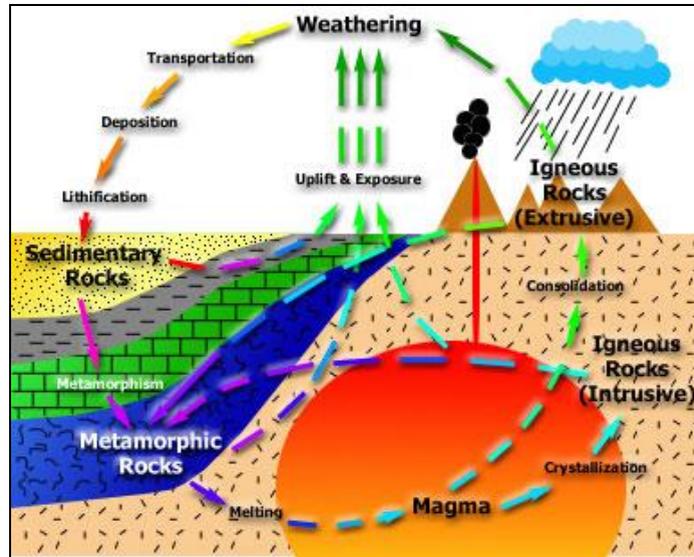
Rocks Exposed at the Surface of the  
North American Continent  
(expressed as % of area).

	Gilluly 1969	Blatt and Jones 1975
Sedimentary	61.5	52
Volcanic	8.2	11
Plutonic	3.8	6
Metamorphic	26.5	31

The portion of the lithosphere that is of greatest interest to us (i.e. the exposed surface) is largely sedimentary rock overlain by loose sediments.

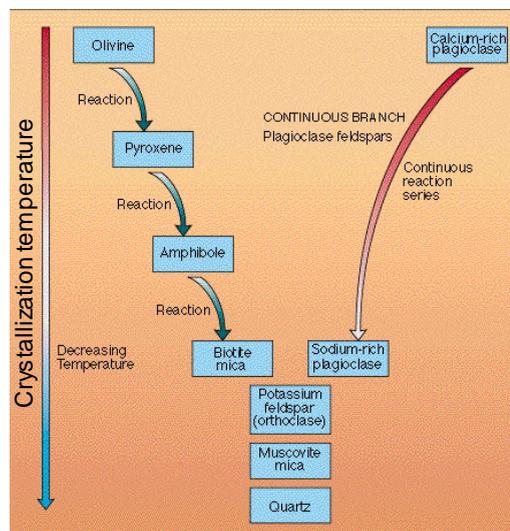
From Ritter, 2002

# The Rock Cycle



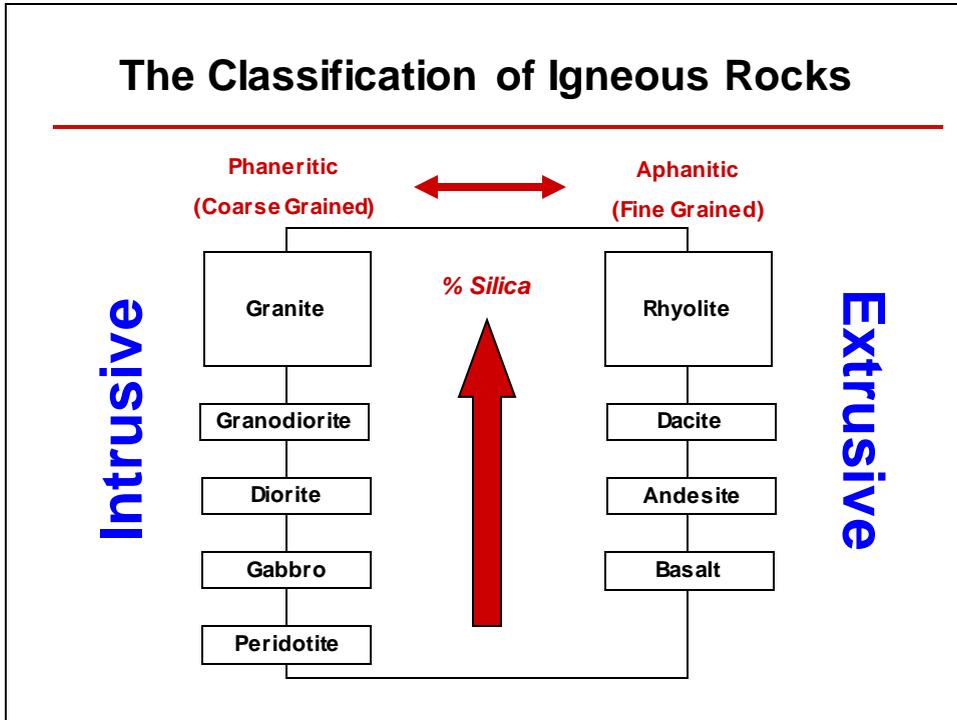
# Bowen's Reaction Series

**First to Crystallize**

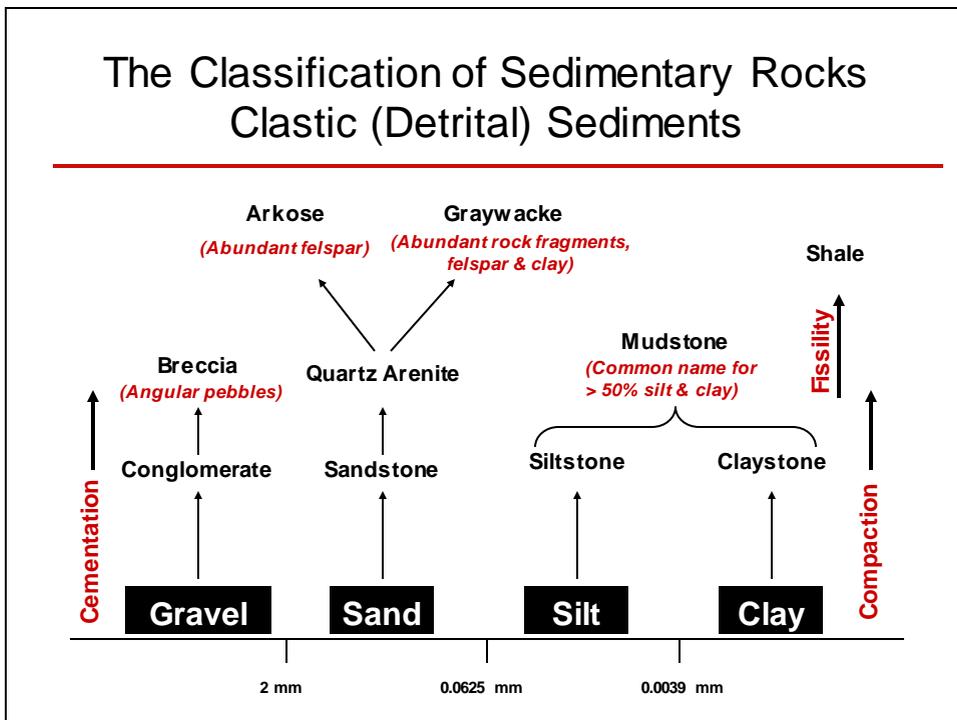


**Last to Crystallize**

## The Classification of Igneous Rocks



## The Classification of Sedimentary Rocks Clastic (Detrital) Sediments



## Nonclastic (Chemical) Sedimentary Rocks

### Inorganic

Limestone (calcite)

Dolomite

Halite

Gypsum

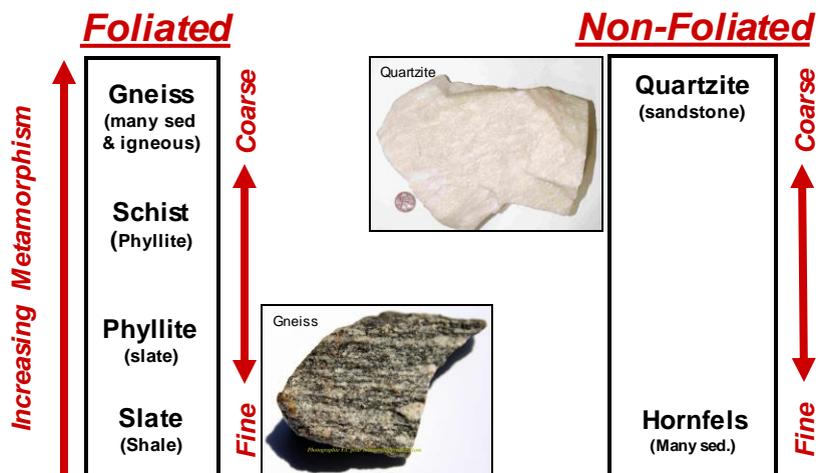
### Biochemical

Limestone (calcite)

Chert

Coal

## Classification of Metamorphic Rock



## Particle Size Classification

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	Millimeters (mm)	Microns ( $\mu\text{m}$ )
Boulders	$\geq 256$	
Cobbles	64 – 256	
Gravel (Pebble)	2 – 64	
Sand	0.064 – 2	64-2000
Silt	0.002-0.064	2-64
Clay	$\leq 0.002$	$\leq 2$

## Boulders (>256 mm)

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## Cobbles (64 - 256 mm)

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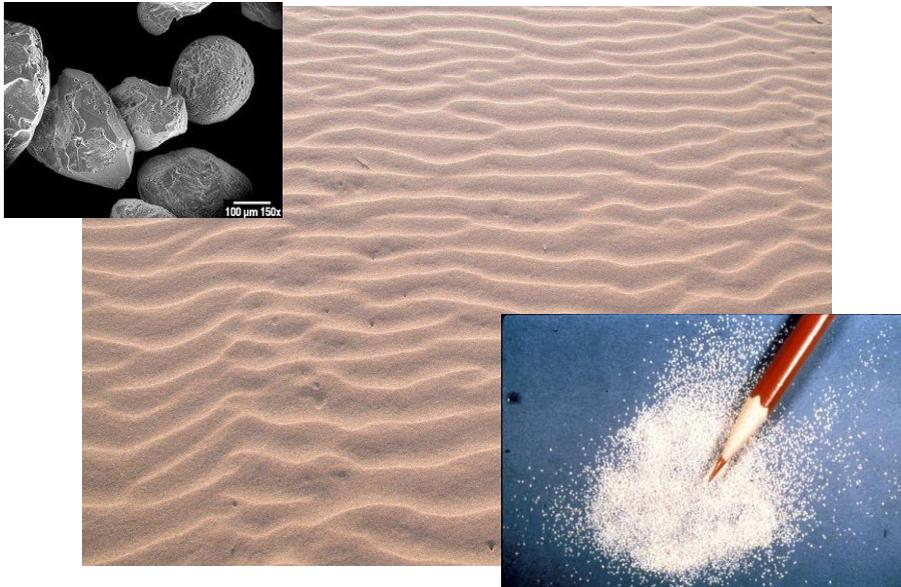
## Gravel (2 - 64mm)

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## Sand (0.064 - 2mm)

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## Silt (64 – 2 μm)

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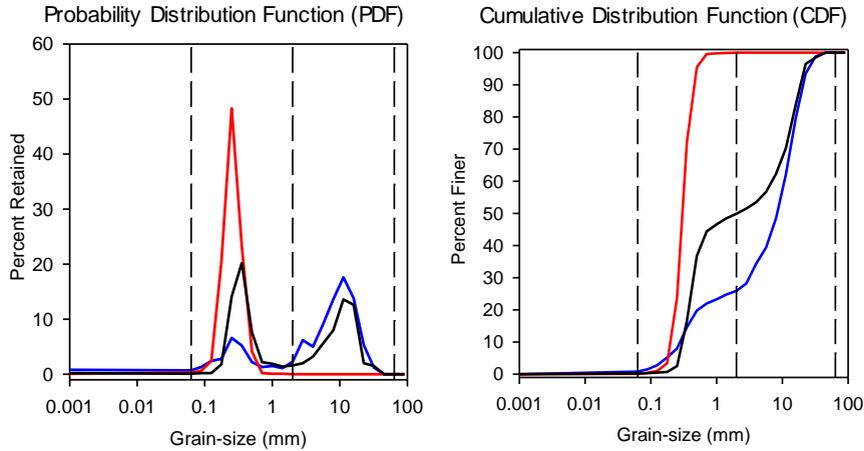
## Clay (<2mm)



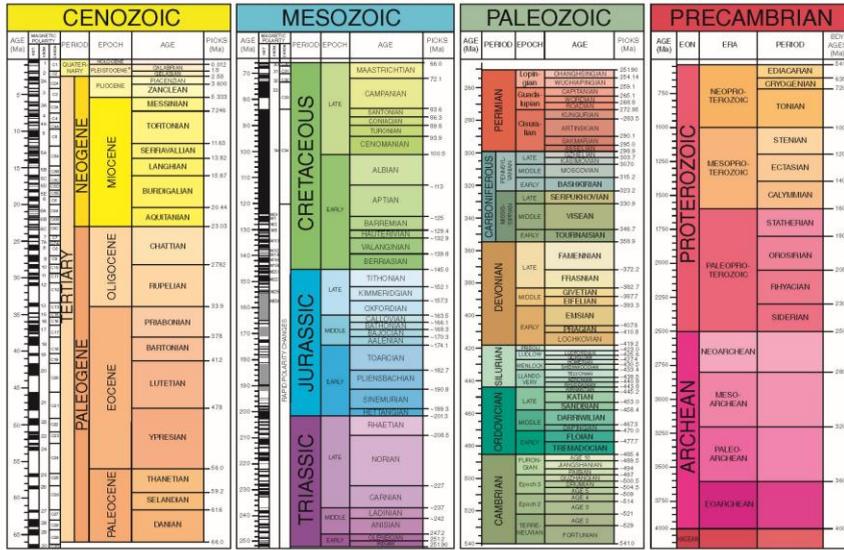
Class Name	Millimeters	Micrometers	Phi Values
Boulders	> 256		< -8
Cobbles	256 - 64		-8 to -6
Gravel	64 - 2		-6 to -1
Very coarse sand	2.0 - 1.0	2000 - 1000	-1 to 0
Coarse sand	1.0 - 0.50	1000 - 500	0 to +1
Medium sand	0.50 - 0.25	500 - 250	+1 to +2
Fine sand	0.25 - 0.125	250 - 125	+2 to +3
Very fine sand	0.125 - 0.062	125 - 62	+3 to +4
Coarse silt	0.062 - 0.031	62 - 31	+4 to +5
Medium silt	0.031 - 0.016	31 - 16	+5 to +6
Fine silt	0.016 - 0.008	16 - 8	+6 to +7
Very fine silt	0.008 - 0.004	8 - 4	+7 to +8
Coarse clay	0.004 - 0.0020	4 - 2	+8 to +9
Medium clay	0.0020 - 0.0010	2 - 1	+9 to +10
Fine clay	0.0010 - 0.00050	1 - 0.5	+10 to +11
Very fine clay	0.0005 - 0.00024	0.5 - 0.25	+11 to +12
Colloids	< 0.0024	< 0.24	> +12

*Table 3.1 Grain size scale American Geophysical Union*

# Grain-size distributions



## GSA GEOLOGIC TIME SCALE v. 5.0



Walker, J.D., Sisson, J.W., Browning, S.A., and Babcock, L.E., compilers, 2016, Geological Time Scale v. 5.0: Geological Society of America, <https://doi.org/10.1130/G585500>. G2016 The Geological Society of America.

\*The Precambrian is divided into four ages, but only two are shown here. What is shown as Cambrian is actually the age-Cambrian from 1910 to 791 Ma, Middle from 791 to 635 Ma, and Late from 635 to 541 Ma. The Cenozoic, Mesozoic, and Paleozoic are the five of the Phanerozoic Eon. Names of units and age boundaries usually follow the Gradstein et al. (2012), Gradstein et al. (2012), and Gradstein et al. (2012), updated compilation. Numerical age estimates and points of confidence usually follow the Gradstein et al. (2012), updated compilation. The numbered epochs and ages of the Cambrian are provisional. A "\*" before a numerical age estimate typically indicates an associated error of 0.4 to over 1.6 Ma. <https://doi.org/10.1130/G585500>.

Gradstein, F.M., Ogg, J.G., and Smith, A.G., 2012, International Chronostratigraphic Chart: *Geochronology*, 26, no. 2, p. 160-200. Updated 2017. <http://www.stratigraphy.org/publications/igcp-604-chronological-chart-2012/>.

Gradstein, F.M., Ogg, J.G., and Smith, A.G., 2012, The Geologic Time Scale 2012. Boston, USA, Elsevier. <https://doi.org/10.1016/B978-0-444-64402-0>.

Previous versions of the time scale and previously published papers about the time scale and its evolution are posted to <http://www.geological-society.org/time-scale/>.