



# U3A Geology

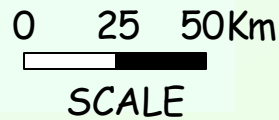
The Chanelled Scablands,

Washington State, USA

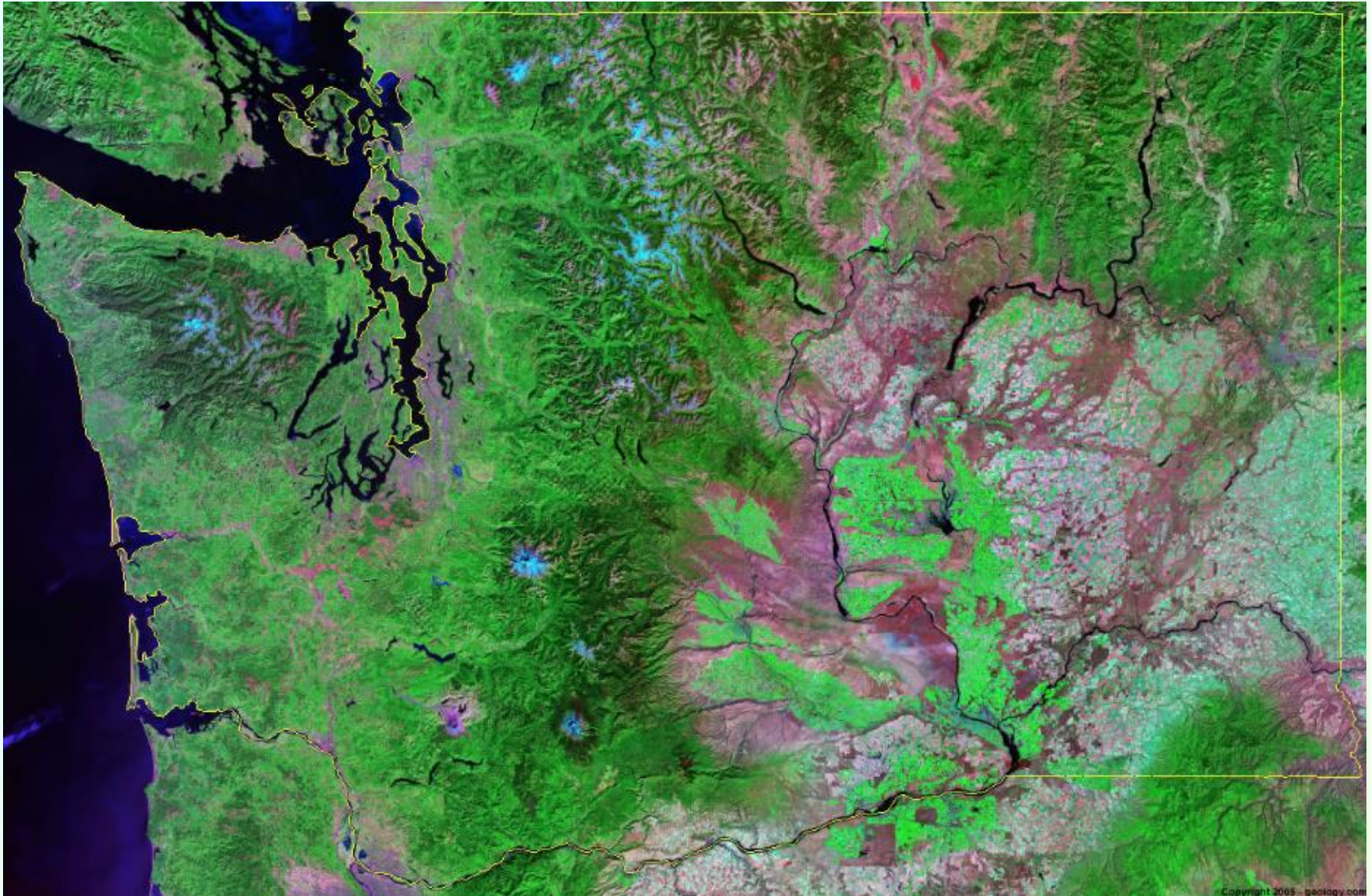
# Introduction

- Channeled Scablands → 4000km<sup>2</sup> region of uniquely sculptured terrain in the Columbia River Plateau region of east Washington State
- the area is underlain by thick flows of Columbia River Basalt
- region characterised by anastomosing channels, flat-topped basalt hills and very few trees
- the landscape is the result of massive flood erosion in the late part of the last ice age

# Scablands locality



# Landsat image, Washington State



# Landsat image of the Scablands



# Prelude to talk

- The story of the interpretation of the geology of the Scablands and decades of controversy that followed → great story
- there are many examples through history of scientists pilloried because their philosophies did not conform with accepted beliefs of the time
- this talk looks at another of these scientists considered a maverick because his interpretations were considered geological heresy

# Catastrophism v uniformitarianism

- In the late 18<sup>th</sup> century, people were thinking seriously about the age of the Earth. Two philosophies prevailed regarding the formation of crustal rocks
- the first (catastrophism) proposed that rocks composing the Earth's crust, formed by a number of short term, global, catastrophic events such as the Noachian flood → young Earth
- the second (originated by James Hutton) called uniformitarianism proposed that geological processes operate very slowly and the Earth was much older than was thought at that time
- these two opposing views were debated over much of the first half of the 19<sup>th</sup> century

# J Harlen Bretz (1882-1981)



- Worked as school teacher in Seattle and Michigan (1908-11)
- graduated with BSc in Biology (Albion College, Michigan)
- completed PhD in Glacial Geology (University of Chicago)
- Geology lecturer (University of Washington, University of Chicago)
- in 1922 began field studies in Columbia River plateau region
- the next 7 years he conducted field studies on the intensely eroded landscape that he named the Channelled Scablands



# Generalised stratigraphy of Cenozoic rocks in the Pasco Basin (after Lindsay and Gaylord 1990)

<b>Quaternary</b>	Holocene	Holocene surficial deposits
	Pleistocene	unconformity Hanford Formation
		unconformity Palouse Loess
		unconformity Ellensburg Formation
<b>Tertiary</b>	Pliocene	unconformity
		Ringold Formation
	Miocene	unconformity Columbia River Basalt Group

Glacial flood deposits

Loess (wind blown)

Volcanic ash,  
lahar deposits

Fluvial sediments

Flood basalts

# Scablands stratigraphy

- Scabland region underlain by thick sequence of basalt lava flows up to 2km thick (6 - 14.5myr old)
- unconformably overlying the basalts are fluvial silts and sands
- during arid glacial periods sand and silt loess formed a large area of rolling, grass covered hills → Palouse Hills
- flood erosion stripped off most of the loess, dissected the underlying basalt forming steep-sided coulees
- the Hansford formation comprises coarse gravels and sands deposited by glacial floods

# Columbia River basalt (Trinidad)



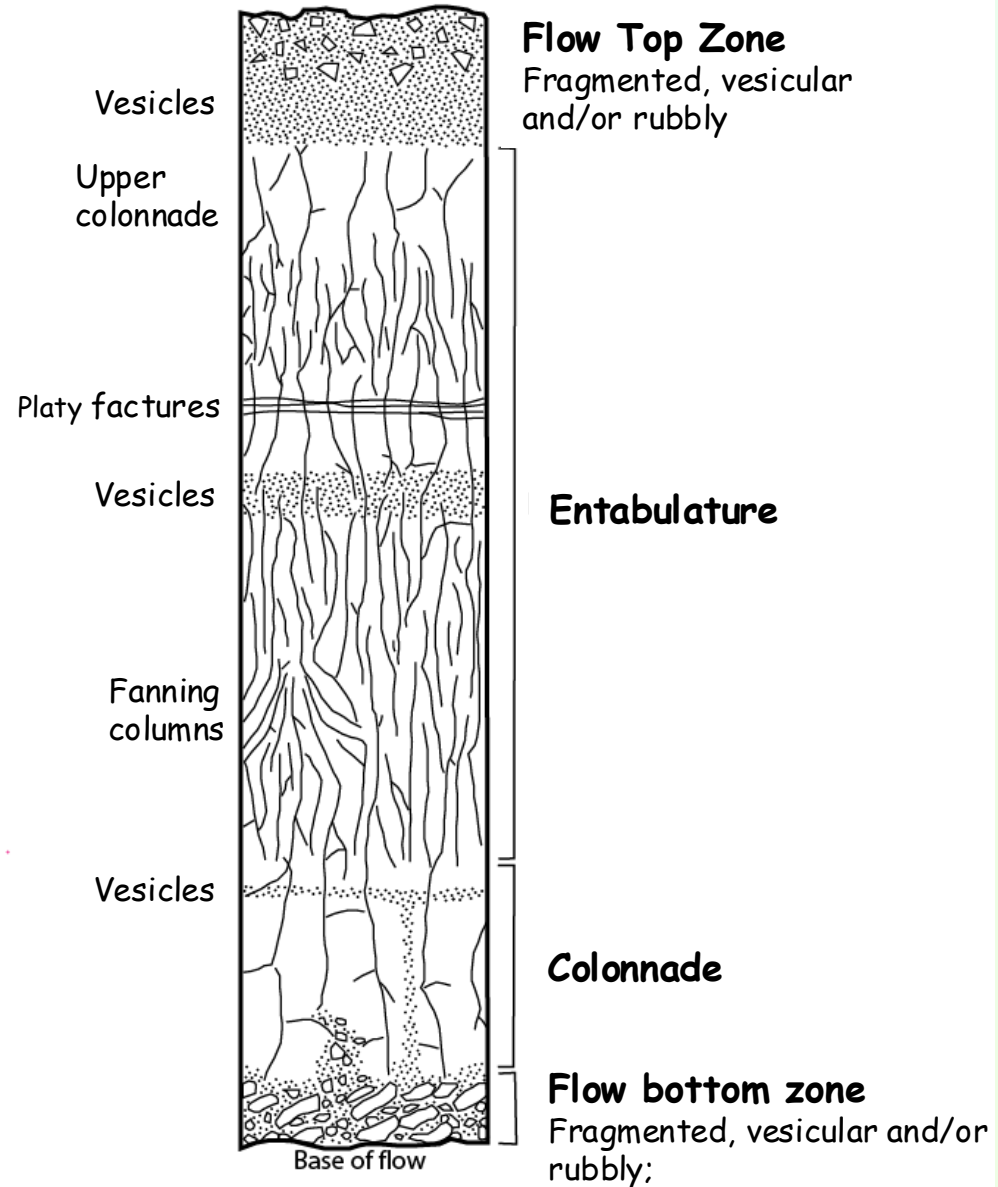
# Stratigraphy - Palouse loess



# Basalt erosion

- Remarkable feature of the scablands → deep erosion of basalt
- due to structure of basalt and immense energy of floodwaters
- lava flows show internal zonation
- colonnade → columnar basalt at base of flow → slow cooling
- entablature → overlying colonnade → faster cooling → greater density of fractures than the colonnade
- increased number of vertical and horizontal fractures → cooling contraction

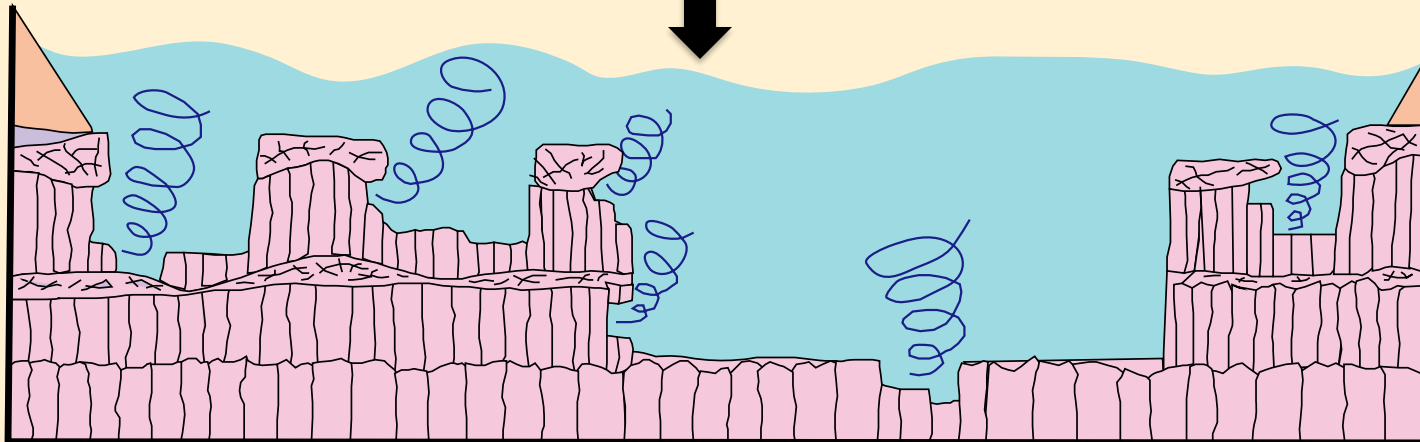
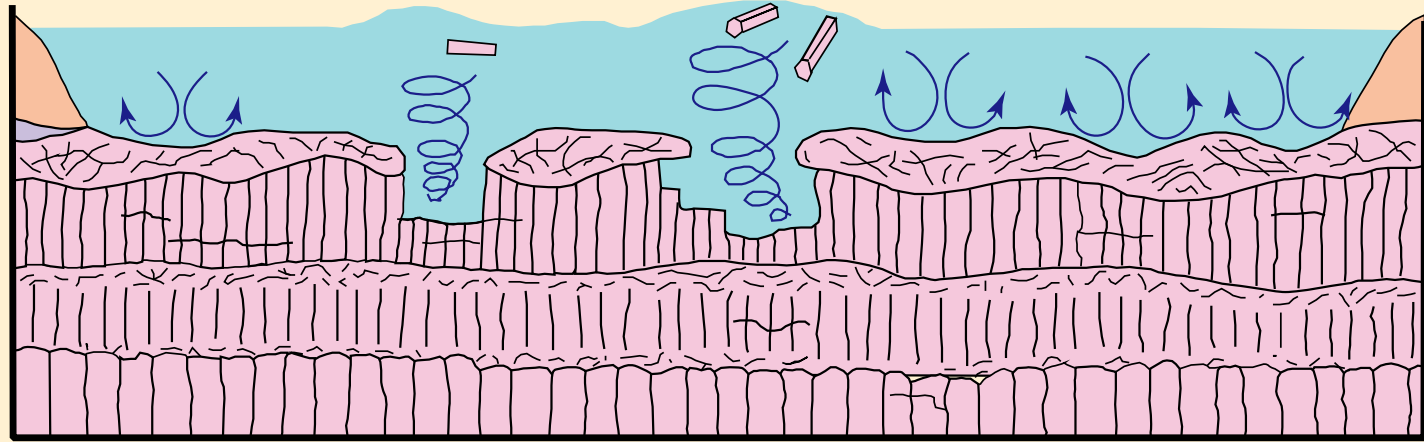
# Basalt zonation (Bjornstad 2008)



# Columnar basalt, Grand Coulee



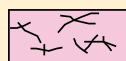
# Basalt erosion (after Bjornstad 2008)



Palouse  
Loess



Ringold  
Formation



Basalt  
entablature



Basalt  
colonnade



Kolk



Longitudinal  
vortices



# Scabland erosion features

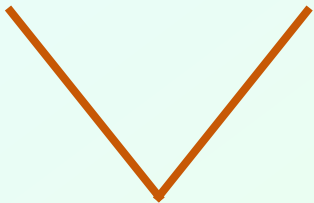
The Scablands contains a variety of features consistent with having been formed by floodwater erosion and deposition

## Erosional features

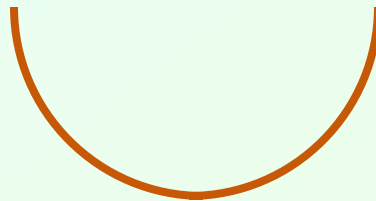
- channels and coulees
- potholes and plunge pools
- mesas and buttes
- pinnacles and pillars
- cataracts and cascades
- streamlined sedimentary hills

# Coulees

- Orthogonal shaped valleys with flat floors and vertical walls
- the Scablands is characterised by a network of anastamosing channels and coulees that are orthogonal in cross-section
- most modern day coulees contain either no streams or (rarely) underfit streams



River valley



Glacial valley



Coulee

# Channels and coulees - Drumheller channels



# Landforms - orthogonal channels (Palouse Canyon)



# Landforms - hanging coulee Drumheller channels

Hanging coulee → abandoned spillway over low divide



# Landforms - mesas and buttes

- Mesas and buttes are flat-topped hills
- form where flood-waters have eroded weak layers and undercut more resistant layers causing them to collapse leaving behind vertical walls
- difference between mesas and buttes → mesas much wider than tall → buttes are narrower
- tops of mesas and buttes are flat → overlying sediment stripped off exposing more resistant basalt entablature

# Landforms -Buttes and mesas



Mesa, Drumheller channels



Butte, Crab Creek coulee

# Landforms - pillars (the Twin Sisters)





# Cataract - Dry Falls

- In places where floods race across bedrock, floods create a series of cascades or cataracts often in descending step fashion
- cataracts formed through rapid erosion with up to 15km recession



# Cascades - Staircase rapids



# Landforms - cataracts and plunge pools

Plunge pools → deep round basins formed where swirling flood-waters dropped 50m or more over cataract cliffs



Palouse falls

# Landforms - pothole (Drumheller Channels)

Fast moving flood-waters produced kolks that bored and scoured deep potholes in the basalt



Pothole, Potholes  
coulee

# Landforms - streamlined Palouse hills

- Streamlined hills formed where flood-waters eroded sediments overlying basalt
- hills have teardrop shape → oriented parallel to flow direction



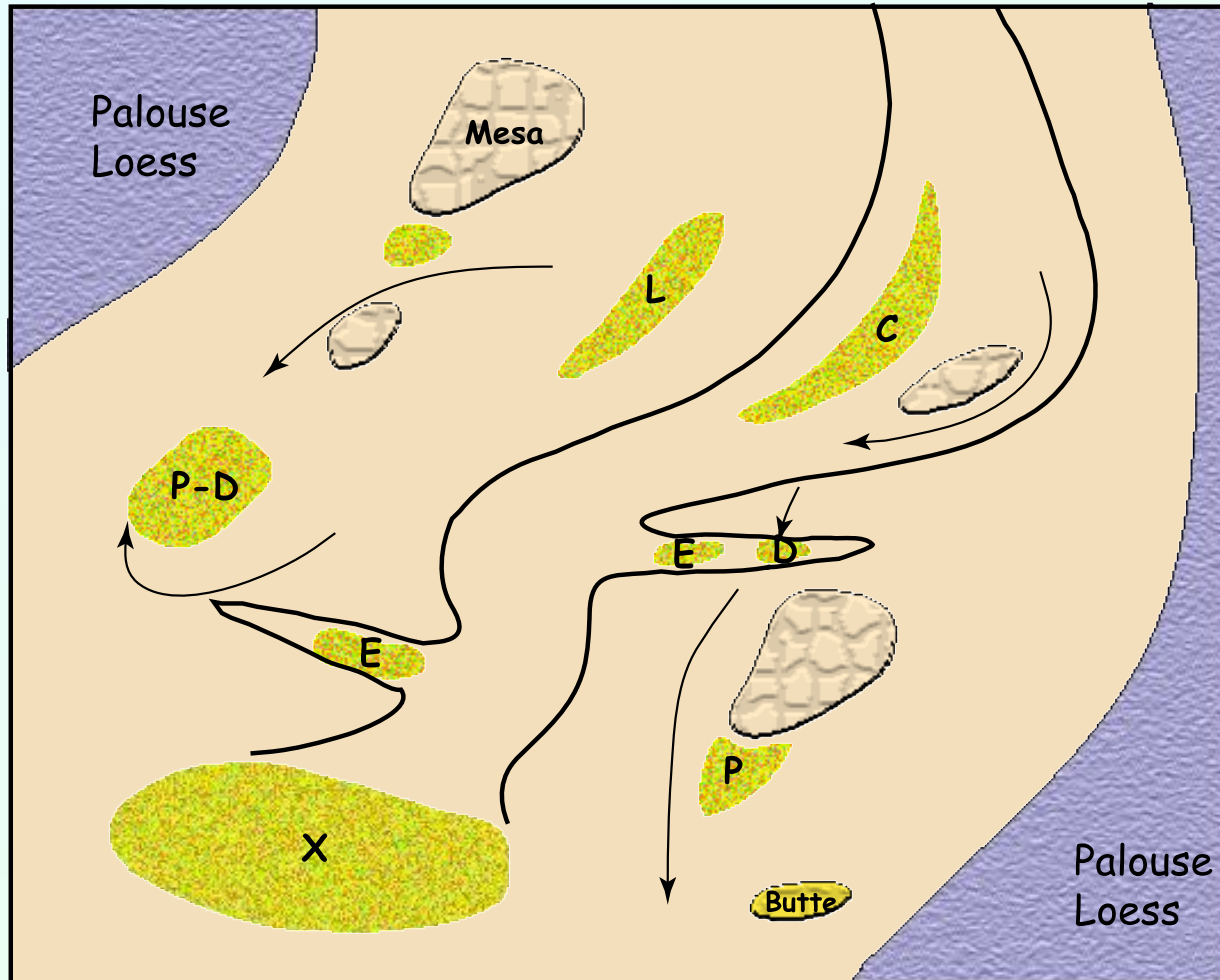
# Scabland depositional features

Distinctive depositional features are observed throughout the scablands

- giant flood bars
- giant current ripples
- slackwater rhythmites
- ice erratics and bergmounds

# Giant flood bars (after Bjornstad 2008)

Bars are elevated area of sediment (sand and gravel) deposited by rivers or floodwaters



-  Flood bars
- E = Eddy
- C = Crescent
- P = Pendant
- L = Longitudinal
- X = Expansion
- D = Delta
-  Scabland

# Crescent Creek bar





# Depositional features - bar gravels (Beverly bar)



# Exotic pebble (gneiss) in Beverly bar gravels



# Giant current ripples

- Occur on the surface of many flood bars
- up to 15m high, wavelength up to 200m
- not recognised until identified on aerial photographs



Giant current ripples, Camas Prairie, Montana

# Giant ripples along banks of the Snake River



# Depositional features - slackwater rhythmites (Hanford Formation)

Slackwater rhythmites → interbedded, graded silt and sand laid down in back-flooded valleys where energy of flood-waters is greatly diminished



Laminated rhythmites containing fine to moderate rippling

# Ice rafted erratic (Frenchman Hills)



# Bergmounds

**Bergmounds** → groups of boulders deposited by grounded icebergs



# Bretz's geological interpretations

## First paper (early 1923)

- Described Scabland features
- concluded that the landscape was sculptured by glacial flood waters
- no comment on magnitude of floods nor time frame

## Second paper (late 1923)

- Proposed that erosion was due to a gigantic, cataclysmic glacial flood (>300m deep)
- flood waters followed courses of pre-existing streams
- volume of water exceeded capacity of valleys
- erosion occurred over a very short period of time (weeks)



# Bretz's conclusions and evidence

Bretz recognised that:

- An enormous amount of rapidly moving water was necessary
- all channels, coulees and divide crossings had to be contemporaneously active

## Evidence for cataclysmic flooding:

- (1) Occurrence of high level divide crossings
- (2) Deposition of high level gravel bars
- (3) Dry cataracts in the middle of coulees
- (4) Giant potholes and plunge pools
- (5) Gigantic boulders deposited along major channels

# Palouse Canyon

- Palouse Canyon is a coulee formed by the floodwaters
- prior to the Scabland floods, there was a ridge between the Palouse and Snake rivers with both flowing into the Columbia River
- floodwaters flowing rapidly southward, crossed the ridge and formed a waterfall at the Snake River
- floodwaters eroded backwards forming a coulee called the Palouse Canyon resulting in the capture of the Palouse River by the Snake River

# Palouse canyon



# Palouse River Capture

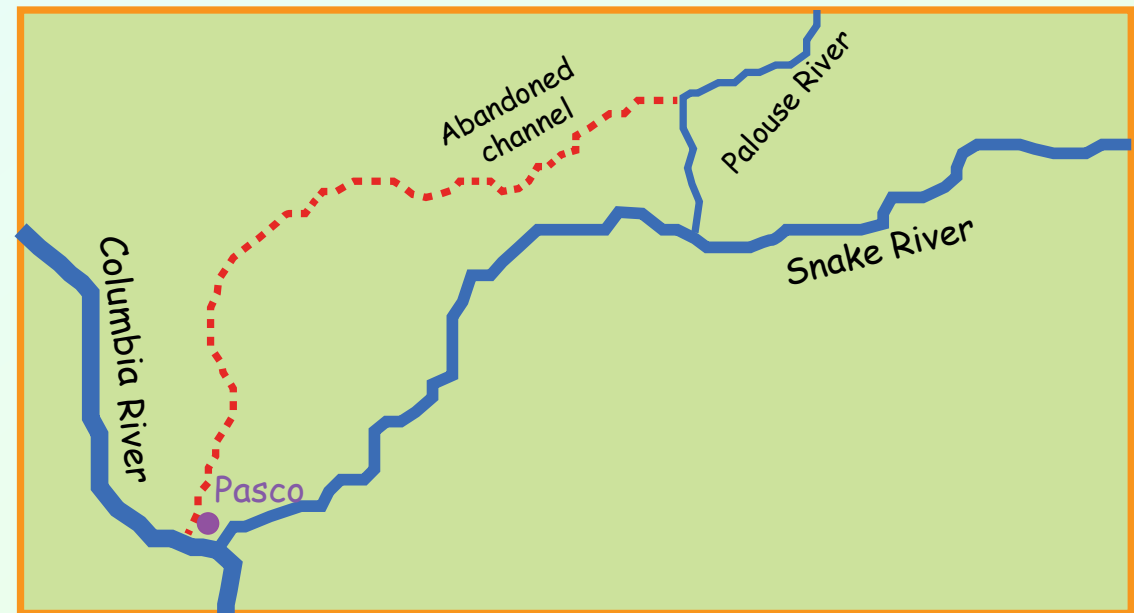
- Bretz concluded that new channels were carved out where divides were crossed e.g. Palouse Canyon
- Palouse River diverted by stream capture (stream piracy)
- current Palouse River now flows down coulee (Palouse Canyon) eroded by floodwaters
- present day it flows into Snake River, prior to flood → flowed into Columbia River
- tectonic fractures in basalt aided floodwaters in carving out the Palouse Canyon

# Palouse river capture

Pre-flood course of Palouse River



Post-flood course of Palouse River

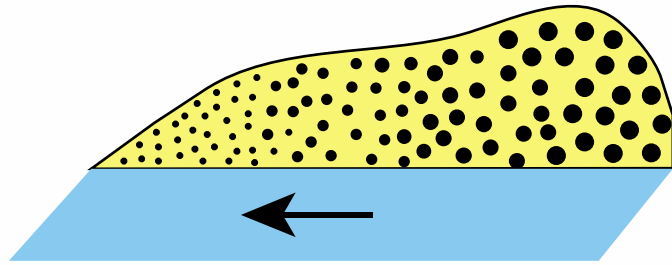


# Reversal in flow of Snake River

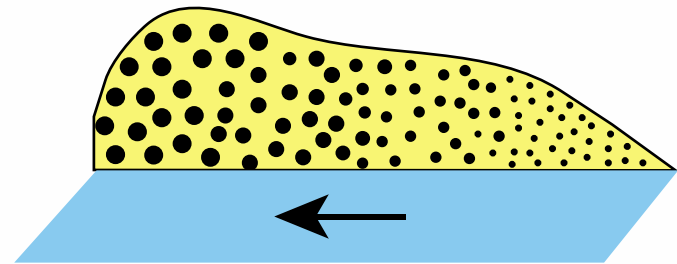
- The Snake River reversed its flow for a period of time due to floodwaters flowing down Palouse Canyon
- fast moving floodwaters rushed more >20km upstream and formed a delta bar 8km long and 30m thick

# Reversal in flow of Snake River

Glacial sediments found along banks of the Snake River  
>20km upstream from the Palouse River junction



Bar in Snake River  
downstream from  
Palouse River junction



Bar in Snake River  
upstream from  
Palouse River junction

# Wallula Gap

- Constricted flow of floodwaters into the Columbia River
- Scabland erosion on top of cliffs 300m above the Columbia River





# Lake Lewis

- Lake Lewis was a large transient lake (lasting only days to weeks) formed by the glacial floods
- the floods filled the Pasco and Quincy Basins for a short period due to the Wallula Gap constricting the outflow from the basin

# Waterflow into and out of Lake Lewis



# Horse Heaven Hills (shoreline of Lake Lewis)



# Criticism of Bretz

- 1927 presentation of his theory received with widespread derision
  - interpretations dismissed as preposterous, incompetent
  - implied catastrophism when gradualism was the accepted tenet
  - a problem was Bretz could not provide origin of flood waters
    - (1) Volcanic eruption under ice sheet (?)
    - (2) Rapid warming due to climate change (?)
- No evidence for either phenomena
- Joseph Pardee contributions (1925, 1940)
  - final recognition by some of his greatest protagonists (Gilluly, Flint)  
and universal recognition (Penrose medal)

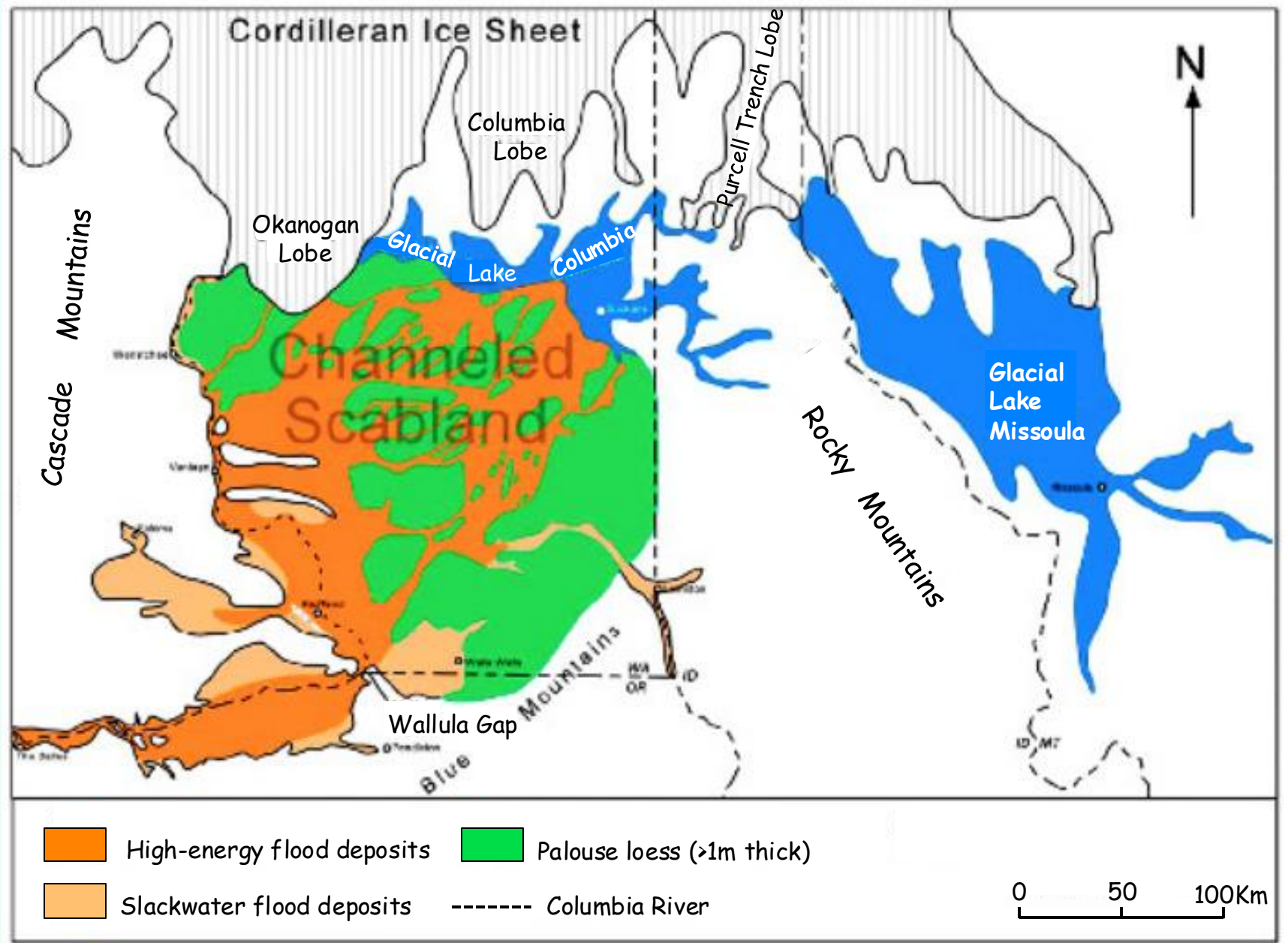
# Cordilleran ice sheet damming Lake Missoula



Lake Missoula formed through damming of Clark Fork River

- 10,000 Km<sup>2</sup> in area
- Up to 600metres deep
- Volume = 2000Km<sup>3</sup>
- Flow rate = 17,000,000m<sup>3</sup>/sec at 130km/hr

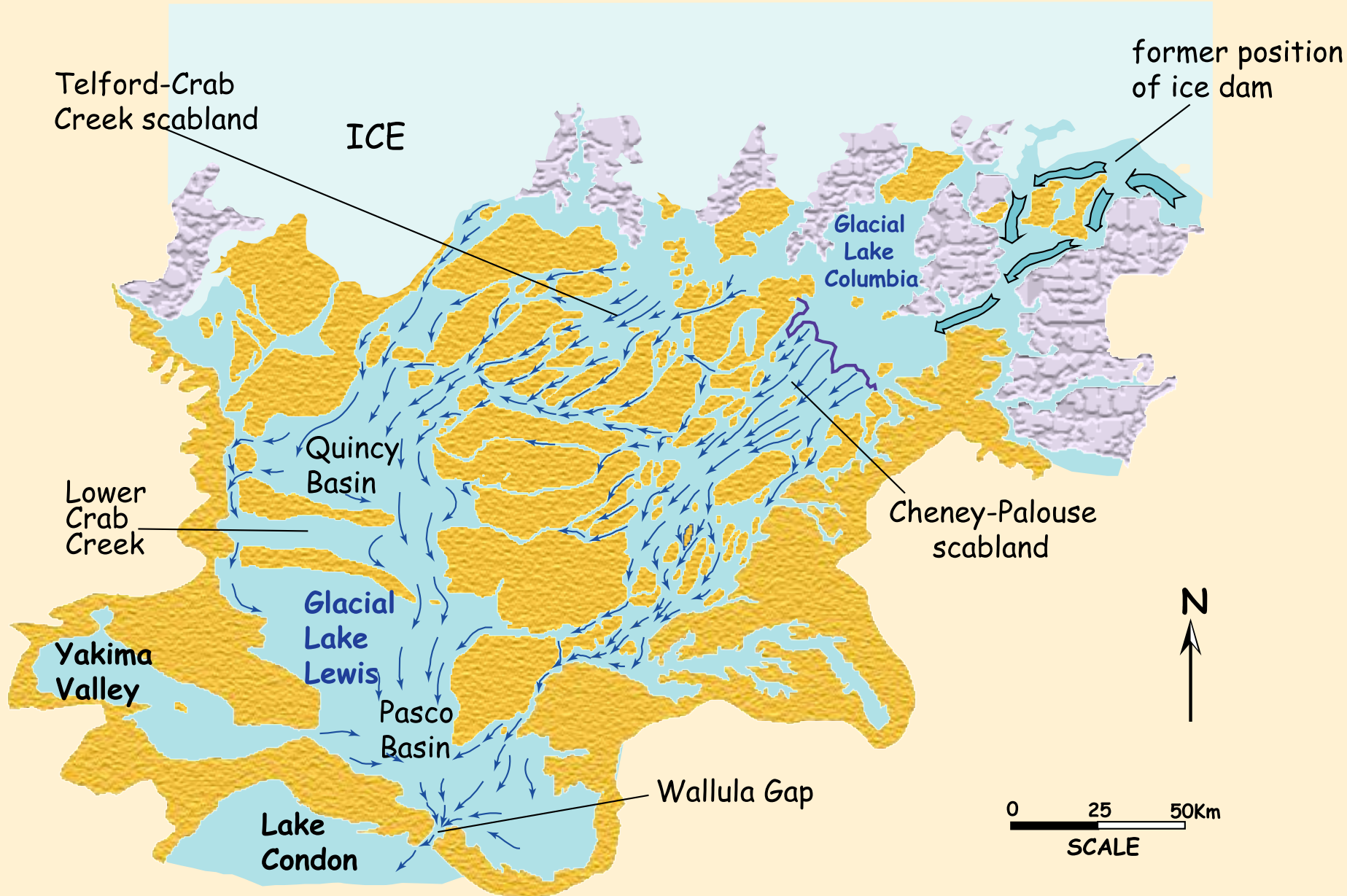
# Channeled Scablands



# Lake Missoula strandlines



# Pathway of flood waters from Lake Missoula (Alt 2001)





# Satellite false colour image of the Scablands

