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Thank you.

IBRU

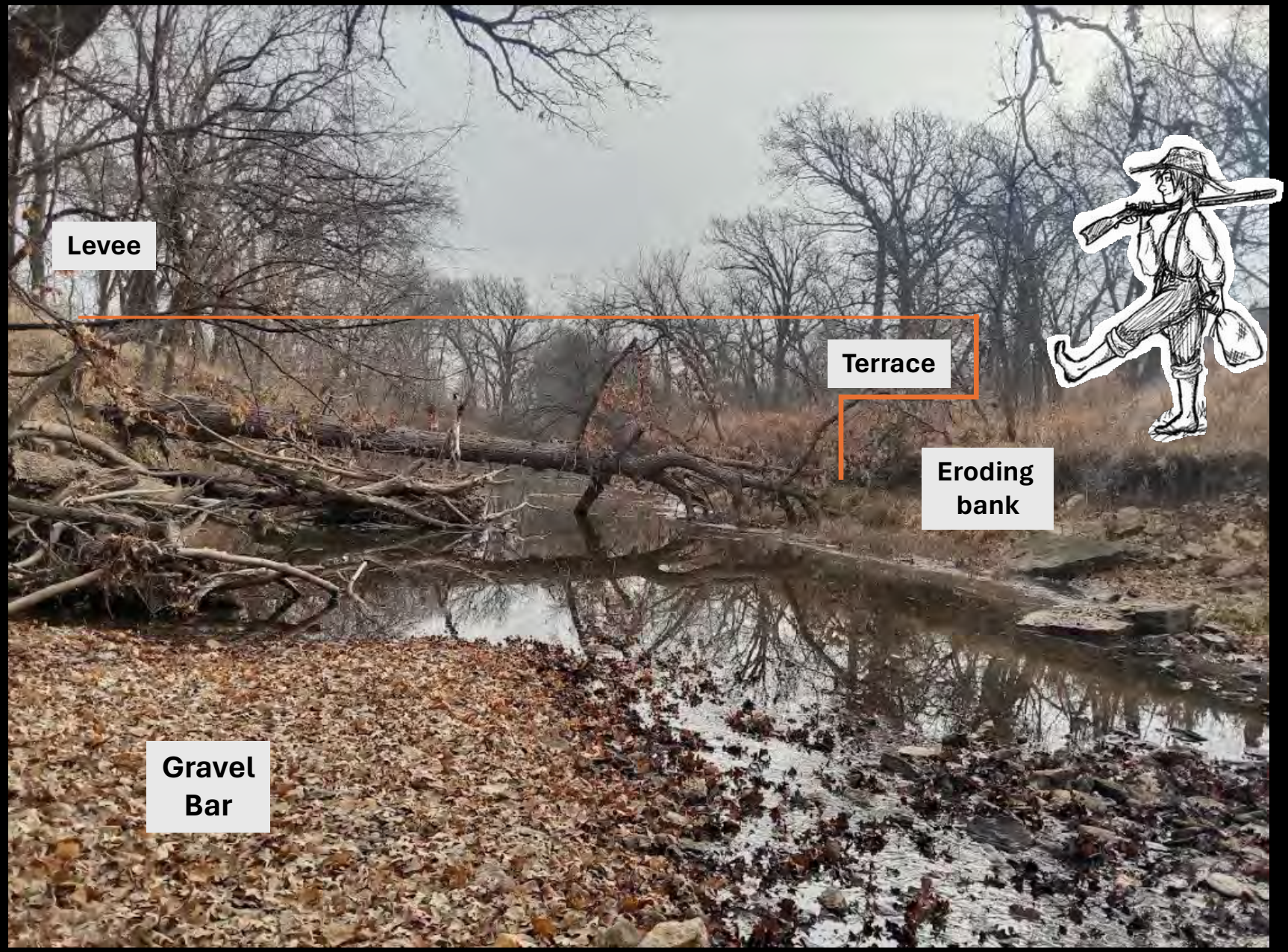
Durham University

Rivers and Complexity

Alan D. Ziegler
Maejo University

I grew up on the river

I grew up on the river

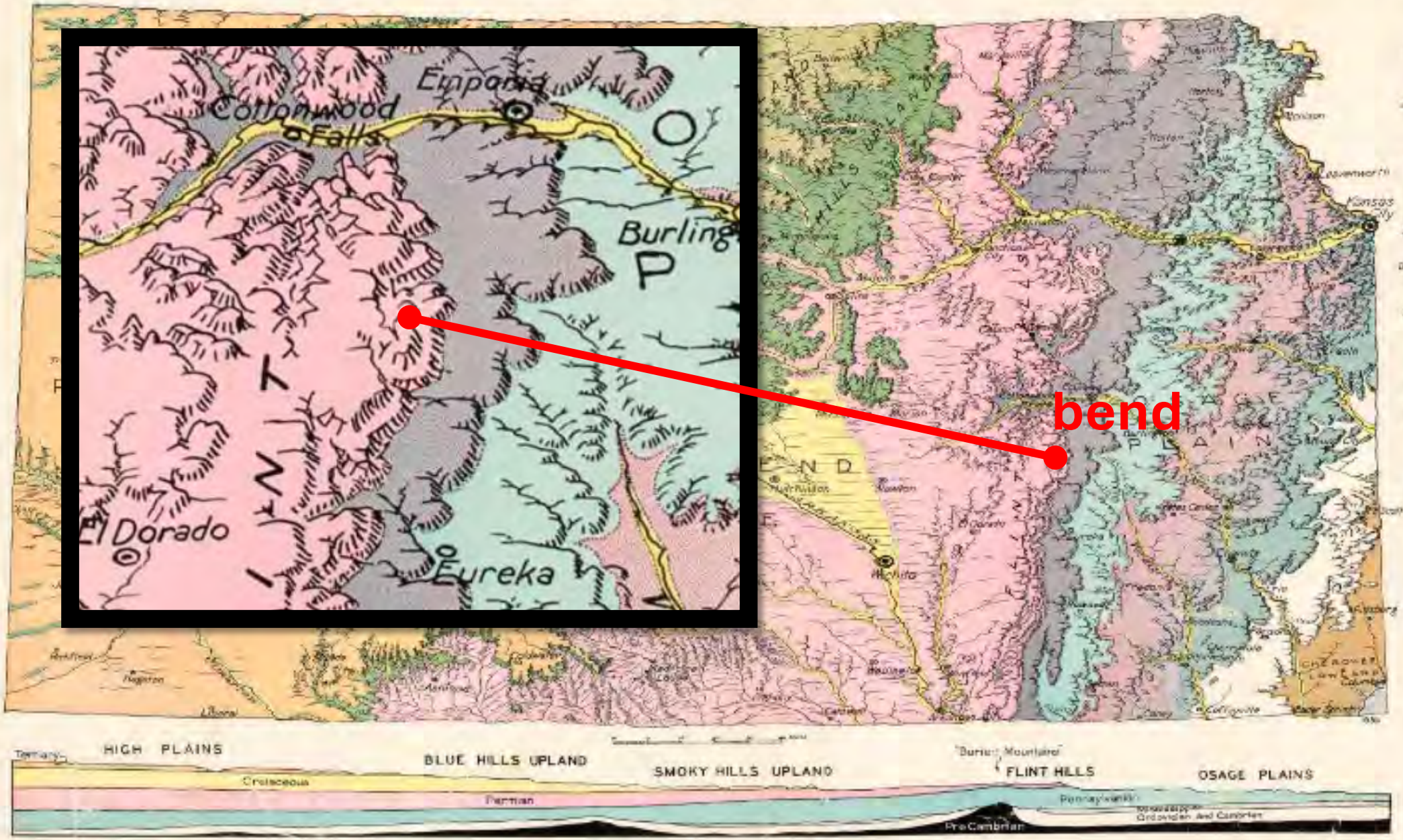


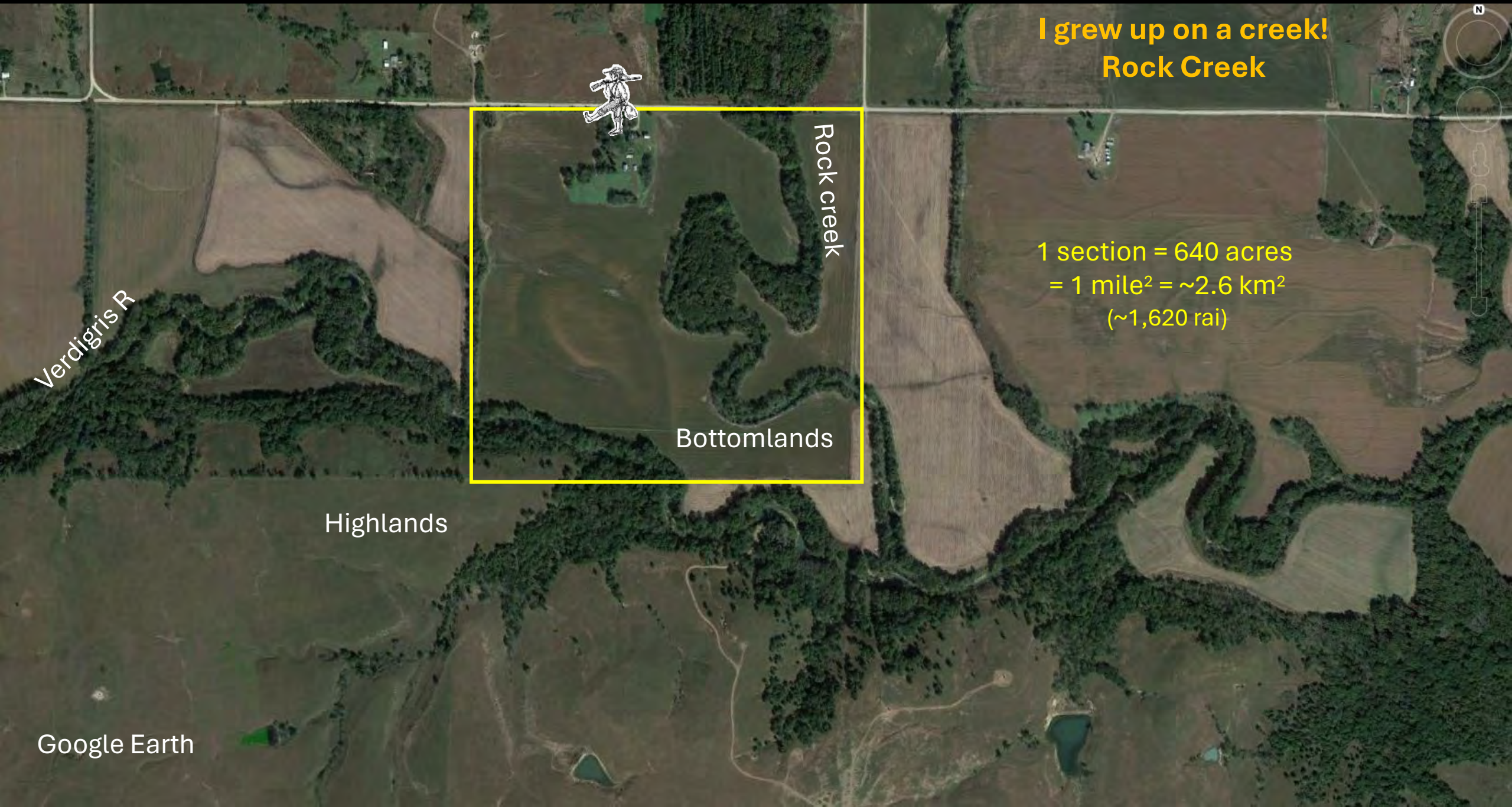
Verdigris River, Kansas, USA


Verdigris River System
bend
North Branch
South Branch
Madison
Kansas
Google Earth

GEOLOGIC MAP OF KANSAS

By RAYMOND C. MOORE




I grew up on a creek!
Rock Creek
Rock creek
Bottomlands
Highlands
Verdigris R
1 section = 640 acres
= 1 mile² = ~2.6 km²
(~1,620 rai)
Google Earth

Mississippi River Basin

★ Verdigris River

4th largest catchment in the world

3.2 million km²

1/3 USA area

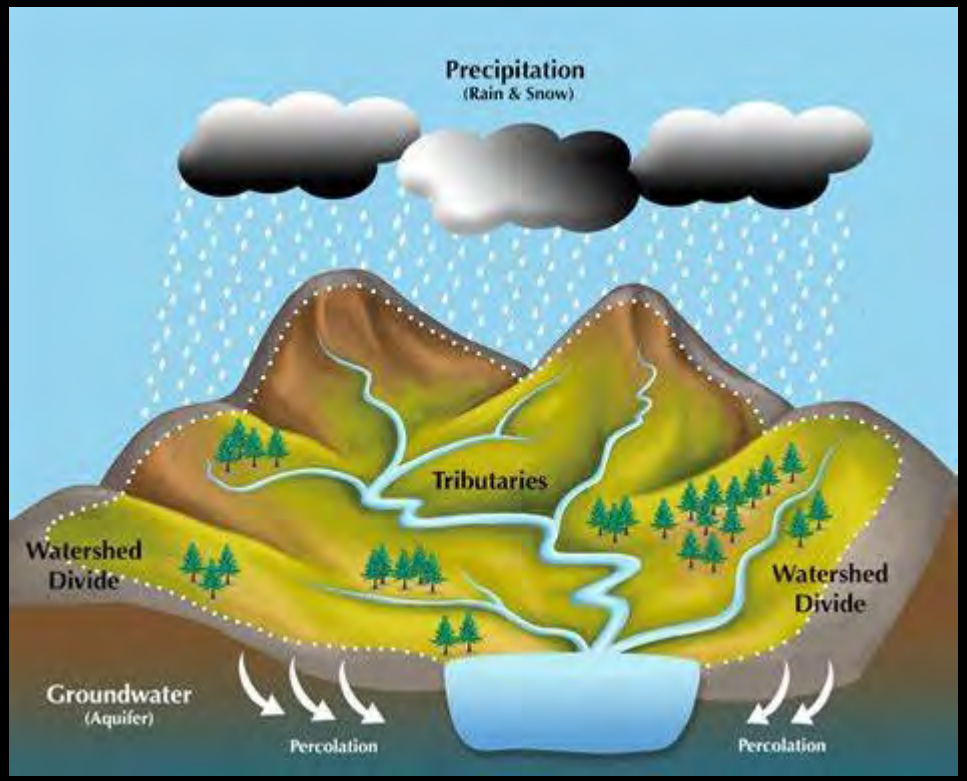
From a management perspective, a catchment or watershed is a sensible way to divide territory.

Western “half” purchased from France in 1803 for $7/km²

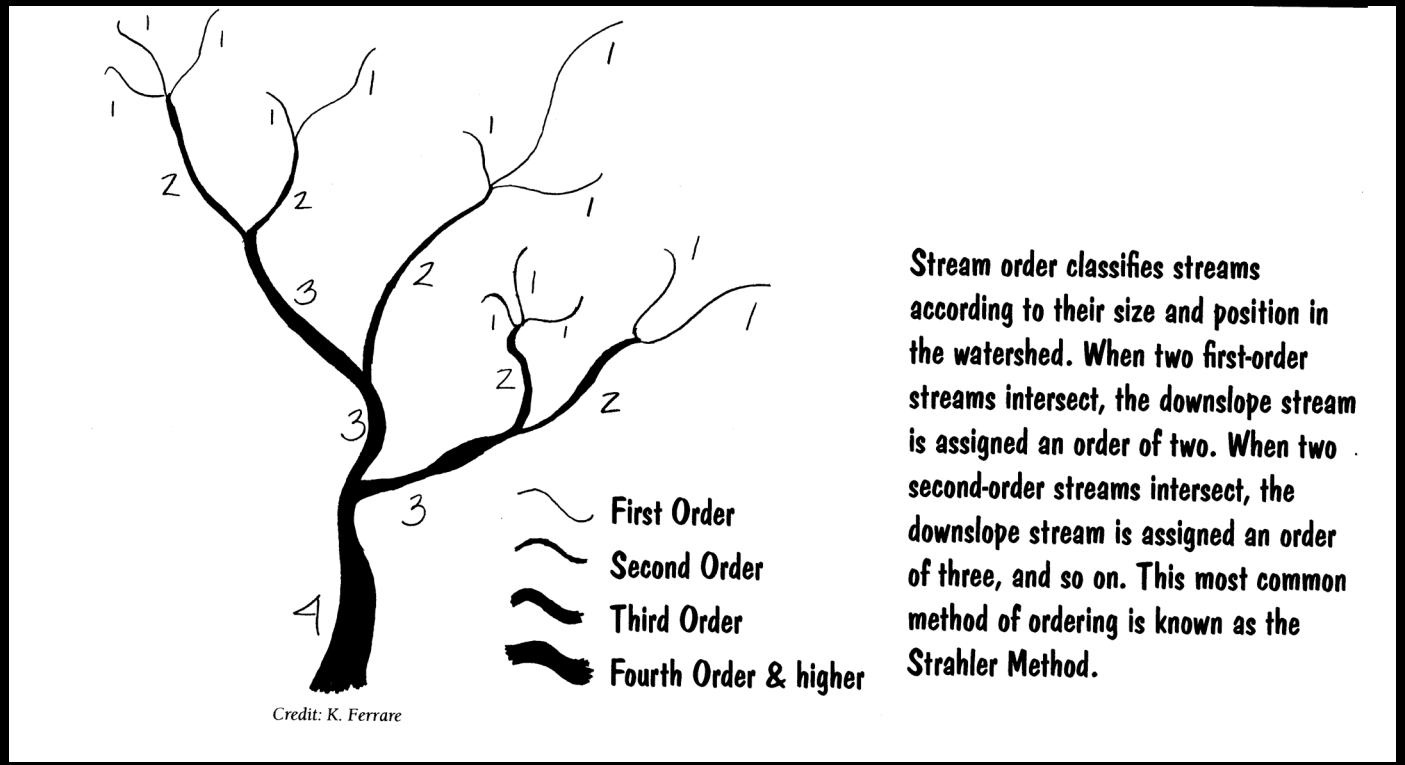
WHAT IS A WATERSHED?

Also known as a “catchment”, which is divided into sub-catchments (micro-catchments). The stream system fallows an ordering. The streams and divides form natural, observable boundaries.

Basins > {Catchment, Watershed} > sub-catchments > Micro-catchments (no hard rules on terminology)

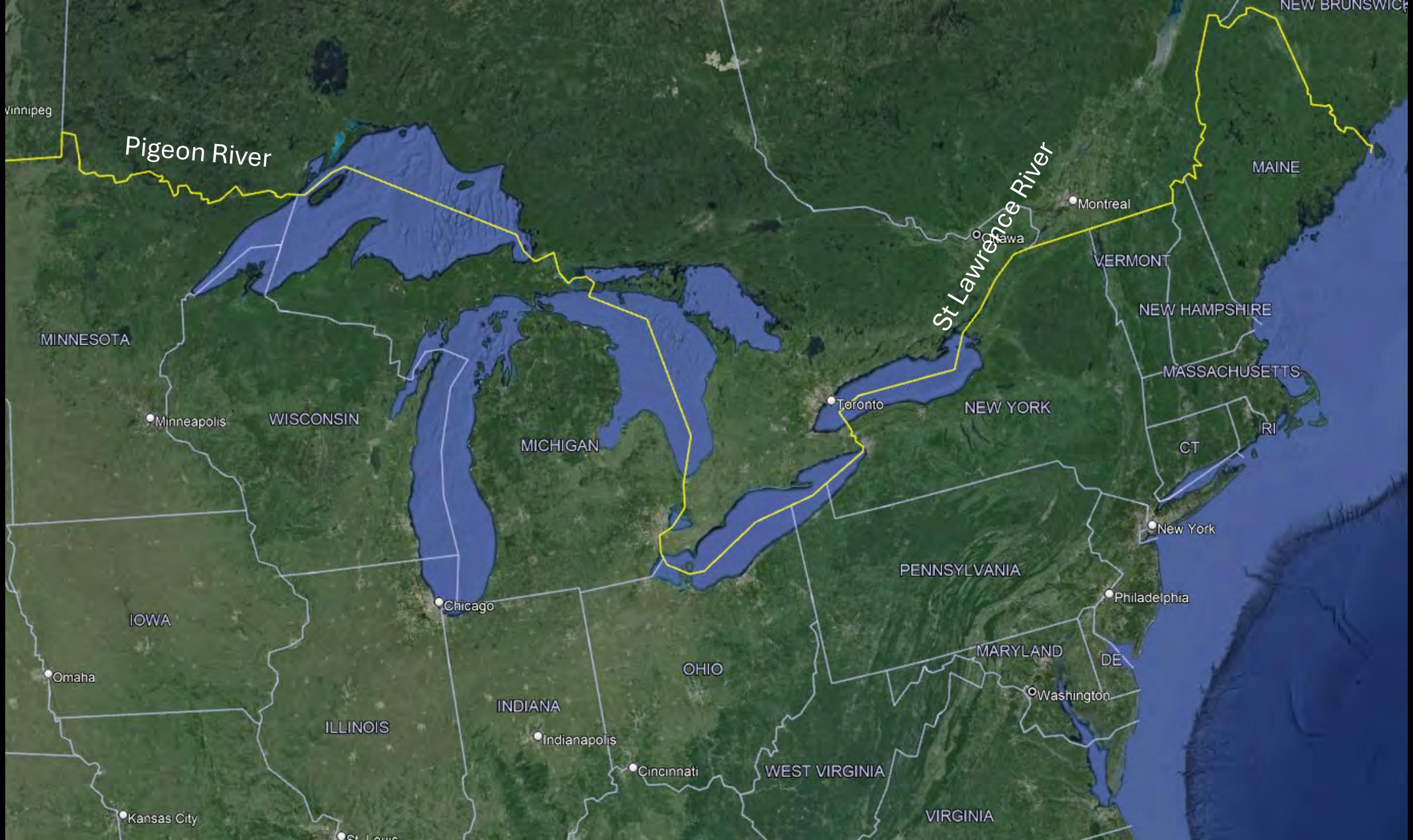


https://hudsonwatershed.org/what-is-a-watershed/



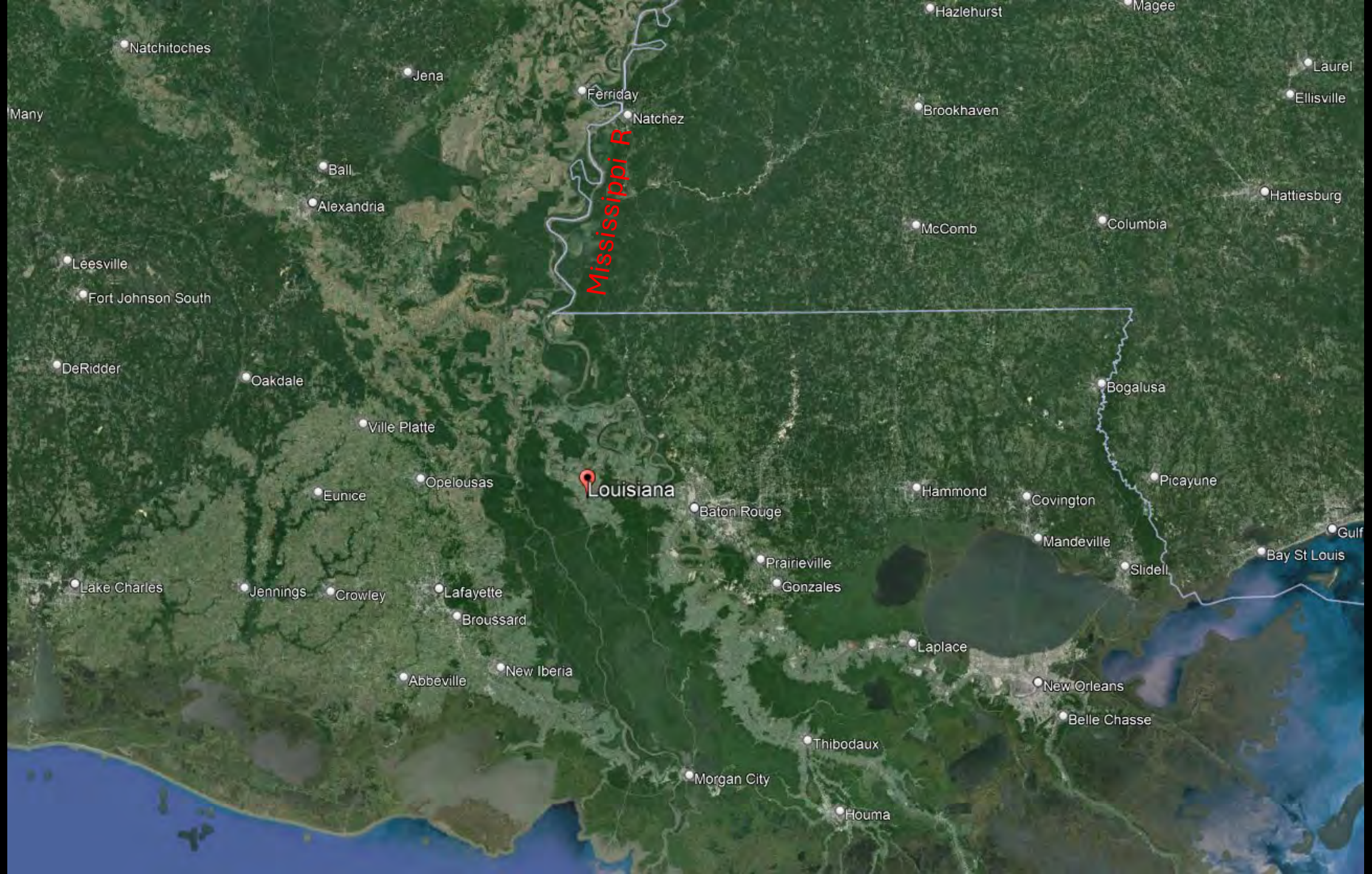
https://www.kuhl.com/borninthemountains/river-bagging-the-new-hampshire-73/

RIVER BORDERS IN NORTH AMERICA


Pigeon River
St Lawrence River
MINNESOTA
WISCONSIN
MICHIGAN
NEW YORK
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
RI
CT
PENNSYLVANIA
IOWA
ILLINOIS
INDIANA
OHIO
WEST VIRGINIA
VIRGINIA
MARYLAND
DE
Minneapolis
Chicago
Toronto
Montreal
New York
Philadelphia
Washington
Omaha
Indianapolis
Cincinnati
Kansas City


Canada
USA
St Lawrence River
Islands

RIVER BORDERS IN NORTH AMERICA


Hazlehurst
Magee
Natchitoches
Jena
Ferriday
Natchez
Laurel
Ellisville
Many
Brookhaven
Mississippi R
Ball
Alexandria
Hattiesburg
McComb
Columbia
Leesville
Fort Johnson South
DeRidder
Oakdale
Bogalusa
Ville Platte
Louisiana
Opelousas
Eunice
Hammond
Covington
Picayune
Baton Rouge
Gulf
Mandeville
Bay St Louis
Prairieville
Slidell
Gonzales
Lake Charles
Jennings
Crowley
Lafayette
Broussard
Laplace
New Iberia
Abbeville
New Orleans
Belle Chasse
Thibodaux
Morgan City
Houma


Natchitoches
Jena
Ferriday
Natchez
Many
Brookhaven
Laurel
Ellisville
Ball
Alexandria
Hattiesburg
McComb
Columbia
Leesville
Fort Johnson South
IGNORE THE MESS, USE THIS BOUNDARY
Mississippi River
Delta Complexes
Natural Levee Deposit
N
Teche
Atchafalaya
Wax Lake
Lafourche
Maringouin
Plaquemines-
Modern
St. Bernard
0
20
40


Border in a
Mangrove Delta...
Where?

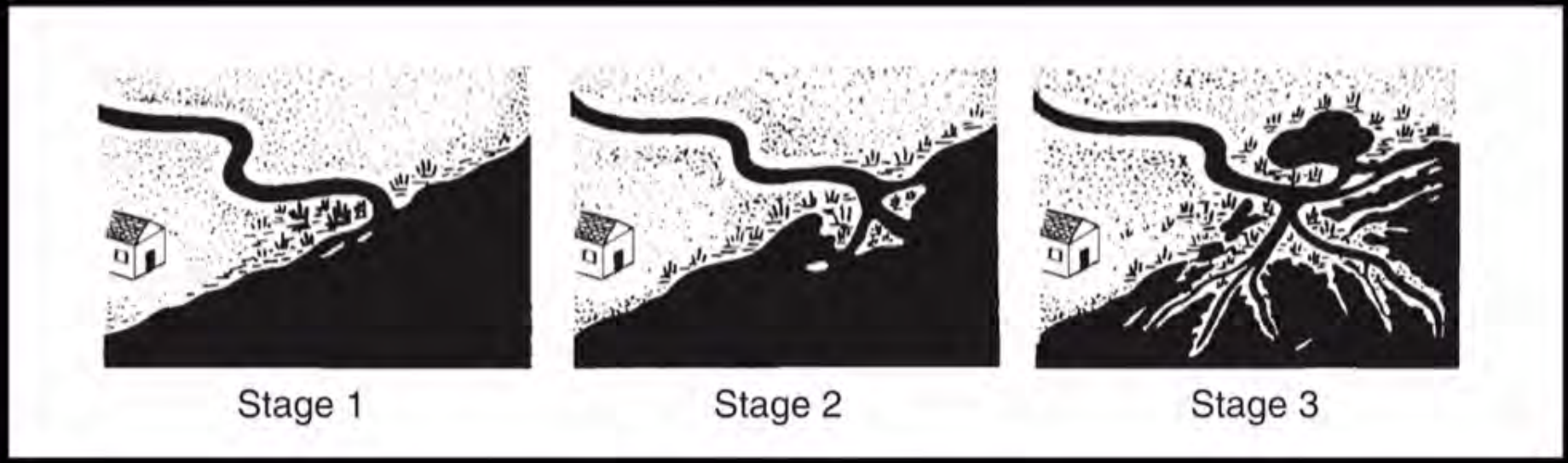

Padma River
Bhramputra River
??? River
India
Bangladesh
Ichimati River
Issue: Management Disparity & Ecosystem Health?

Border in a Desert

Where?


Shaṭṭ Al-ʿArab
Iraq
Iran
Kuwait
Euphrates
Tigris
Issue: Disputed Boundary

The sediment deposited as a stream enters a large body of water forms a delta.



River Erosion and Deposition

Mike Sammartano
120K subscribers

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River Islands

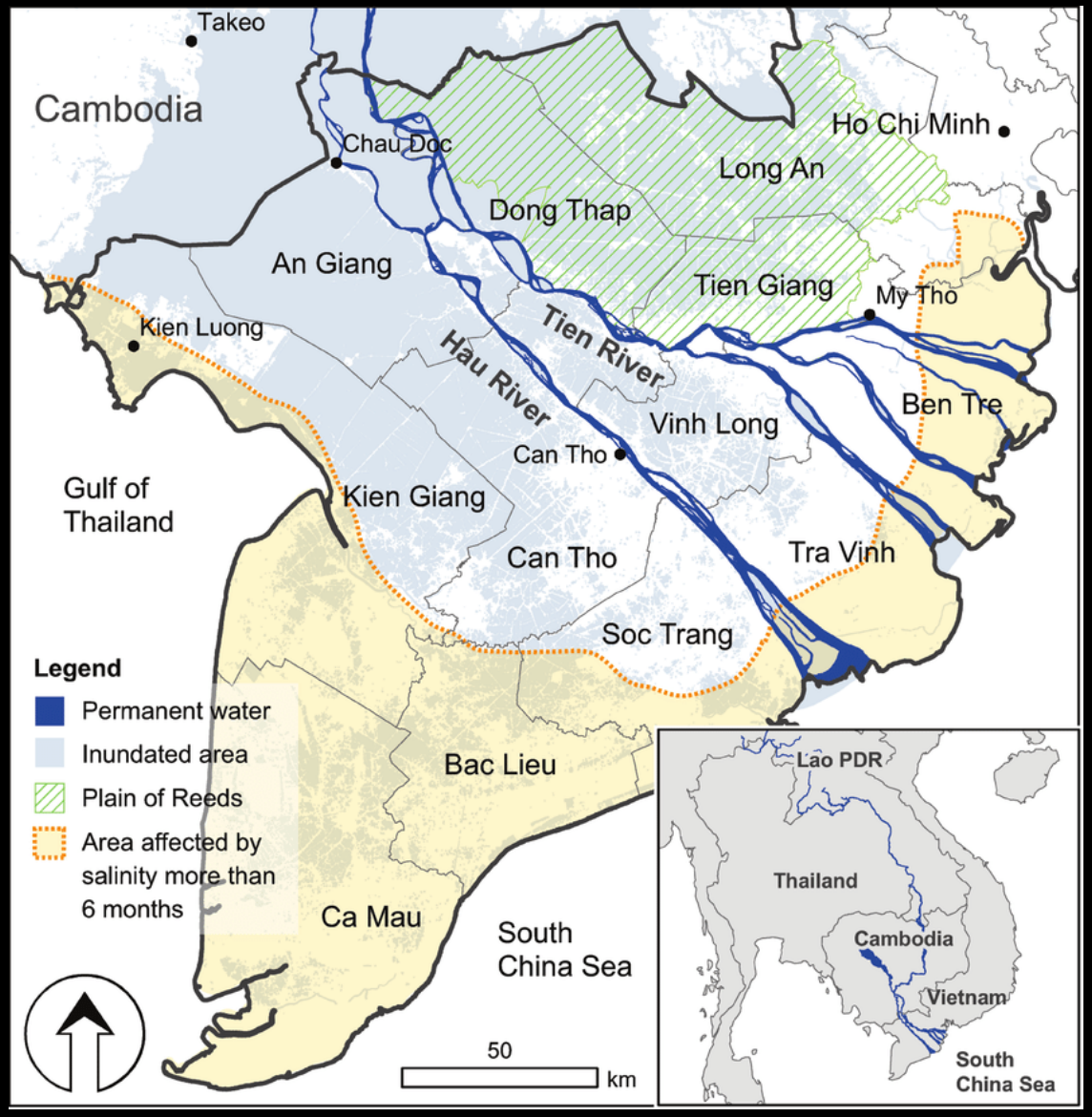
WE judged that three nights more would fetch us to Cairo, at the bottom of Illinois, where the Ohio River comes in, and that was what we was after. We would sell the raft and get on a steamboat and go way up the Ohio amongst the free States, and then be out of trouble.

Well, the second night ***a fog begun to come on, and we made for a towhead*** *to tie to, for it wouldn't do to try to run in a fog; but when I paddled ahead in the canoe, with the line to make fast, there warn't anything but little saplings to tie to.* [Mark Twin, Adverntures of Huckleberry Finn]

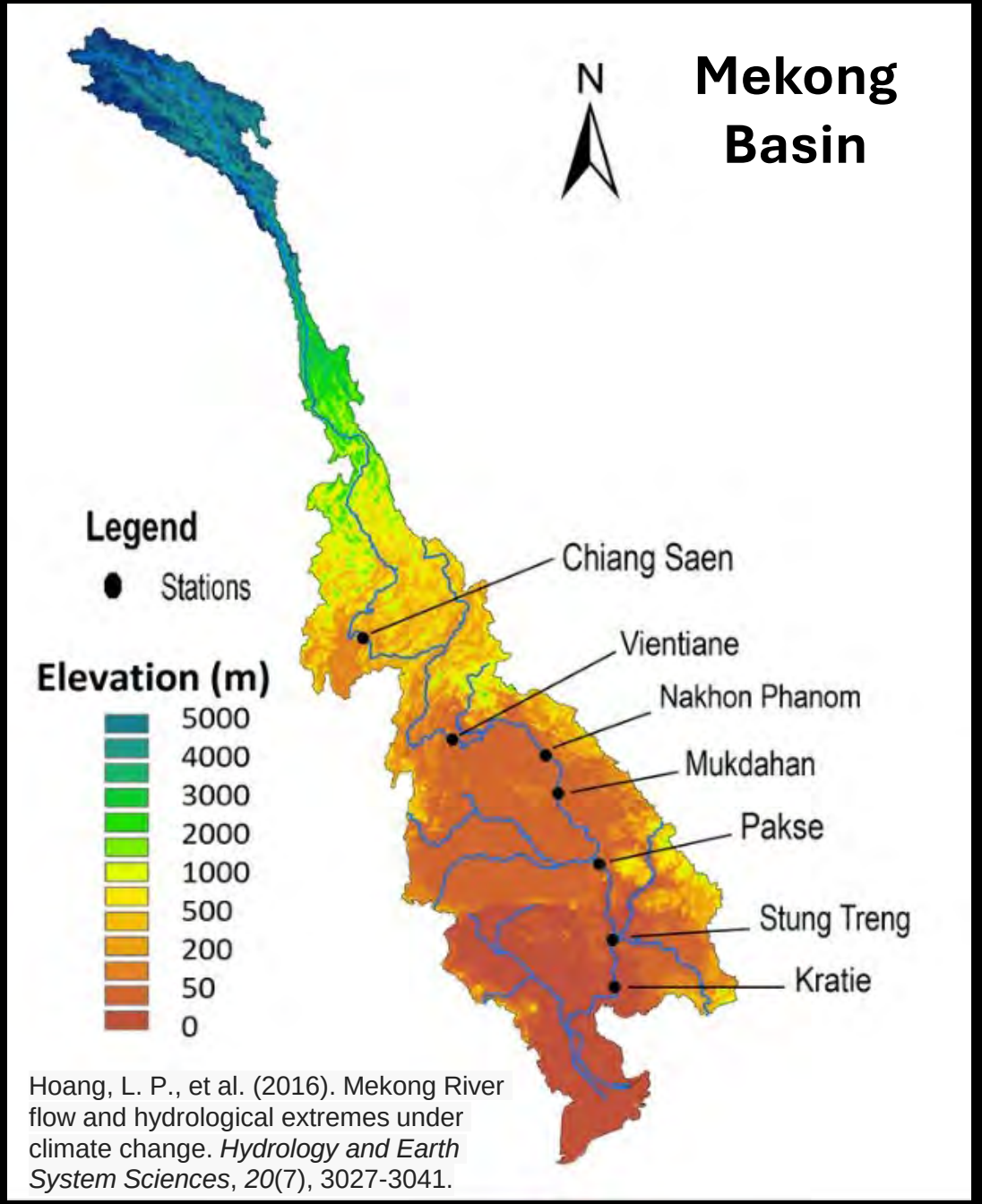
Towhead

Commerce
Unity
Miller City
Roth
Cache
Willard
Mississippi River
Mound City
Golden Lily
Klondike
Urbandale
Price Landing
ILLINOIS
Cairo
Cairo
Mississippi River
Alfalfa Center
Wickliffe
Image © 2024 Airbus

Mekong Delta

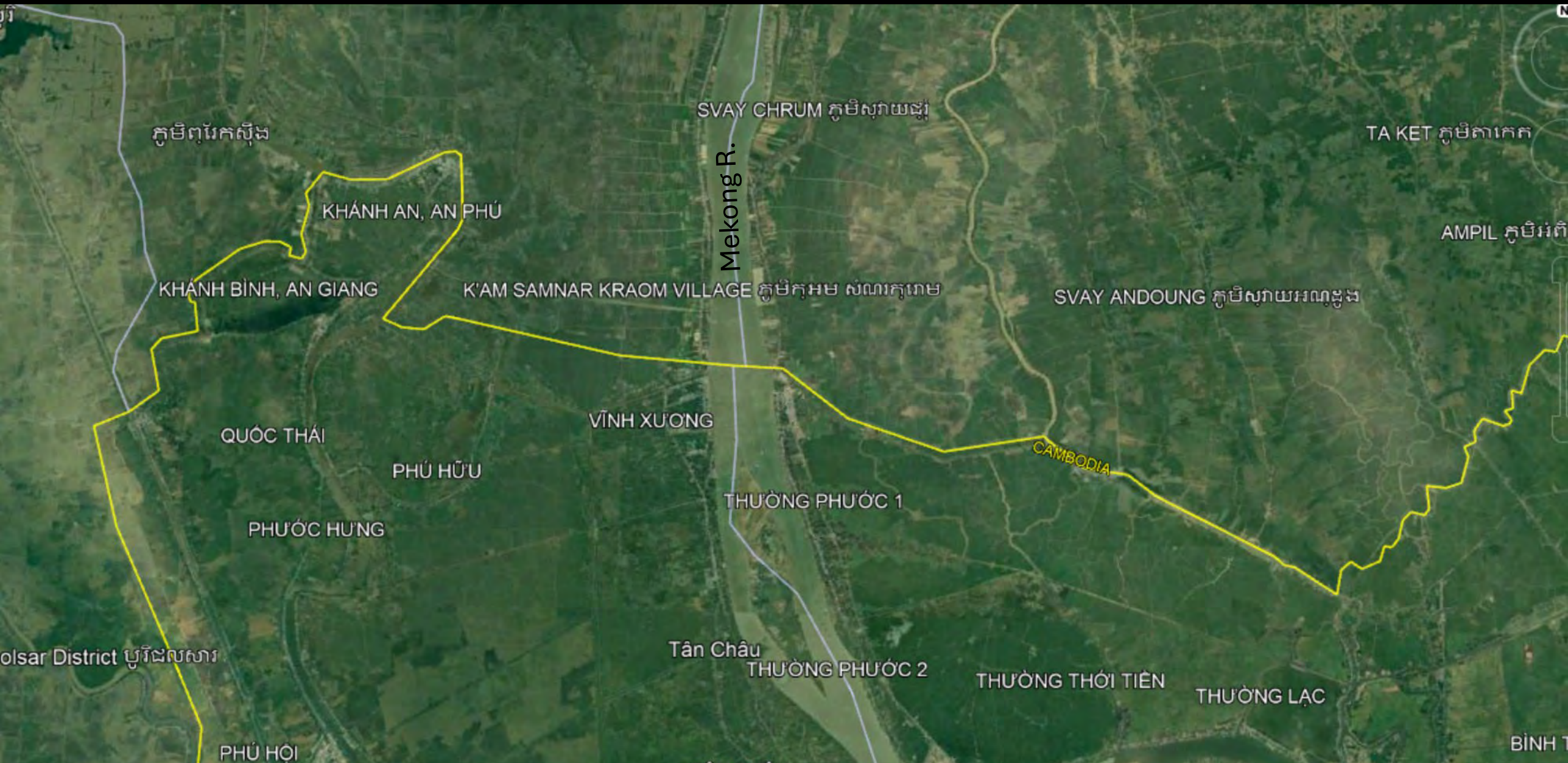


Tripadvisor.com



Hoang, L. P., et al. (2016). Mekong River flow and hydrological extremes under climate change. *Hydrology and Earth System Sciences*, *20*(7), 3027-3041.

Cambodia – Vietnam Border



Terms

Discharge (Q; m^3/s)
Streamflow

Slope (S; % or -): rate of decline
Component of energy

Density (p) of "water"
p = mass/volume

Sediment Concentration (Kg/m^3)
Affects density (p)

Gravitational acceleration
$g = 9.8\ m/s^2$

Stream power is the amount of energy a river exerts on the banks or bed of the river.

$\Omega=\rho g Q S$

Columbia River Estuary

No Delta?

Deep Valley (glacial activity)
Subduction Zone (high gradient)
Strong N/S current (pulls sediment away)

Portland Oregon

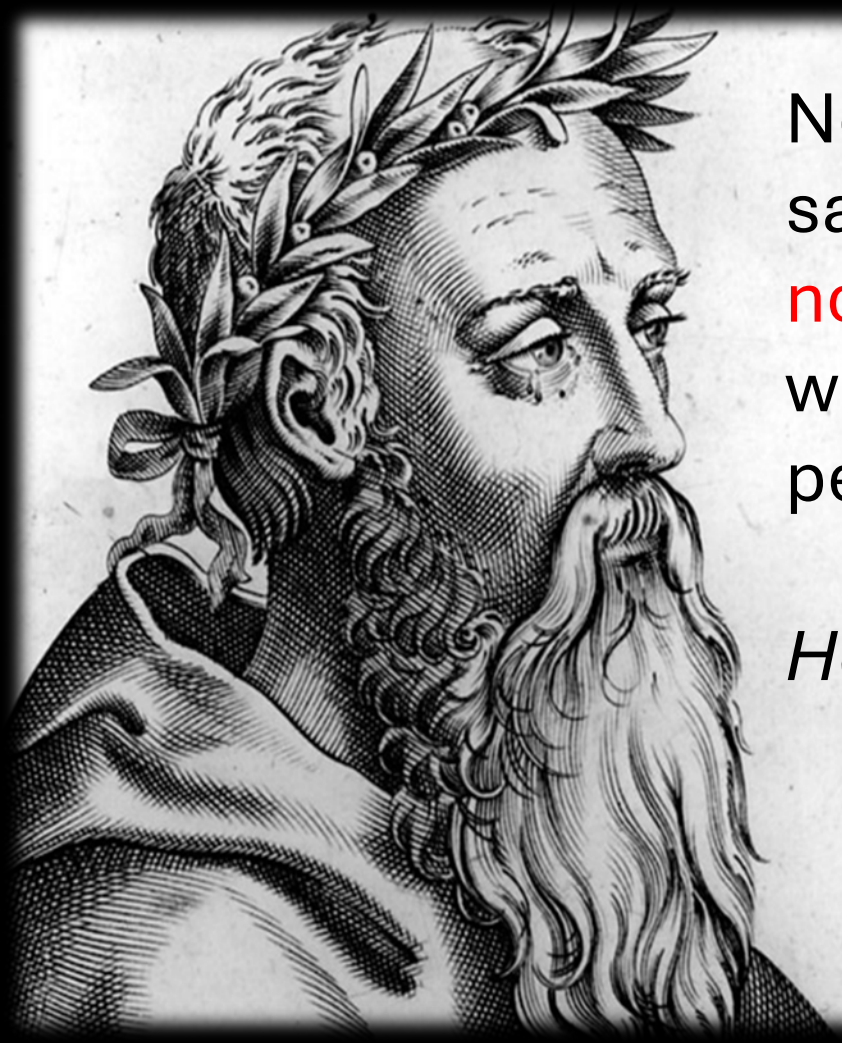
Stable Channels

Questions?

Paradox of rivers as boundaries

- Rivers are conspicuous static features on “maps”
- River are not necessarily static natural boundaries
- Rivers are complex, in space and time.
- Many rivers are everchanging, dynamic in space and time
- Boundary choices: the river, the bank, the “center”.
- Thalweg: the deepest place in the valley or river.

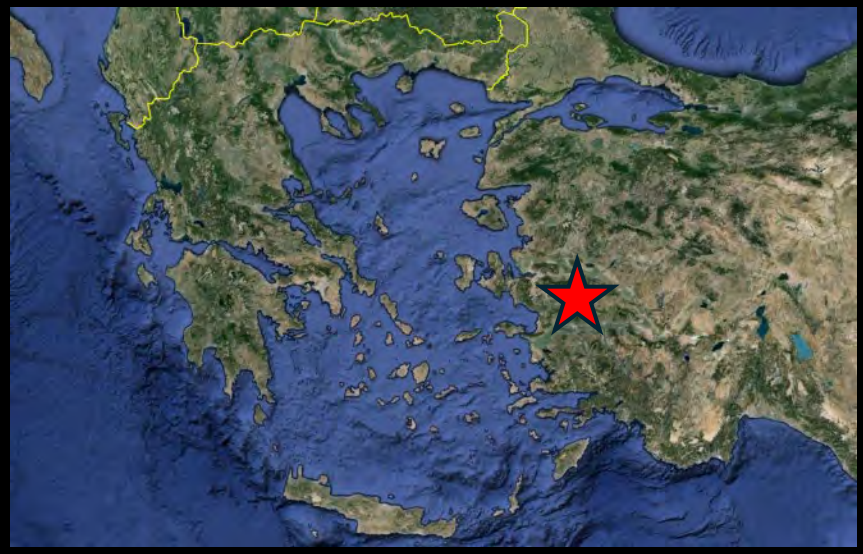
Questions?



No one ever steps in the same river twice, for it is not the same river and we are not the same person.

Herclitus

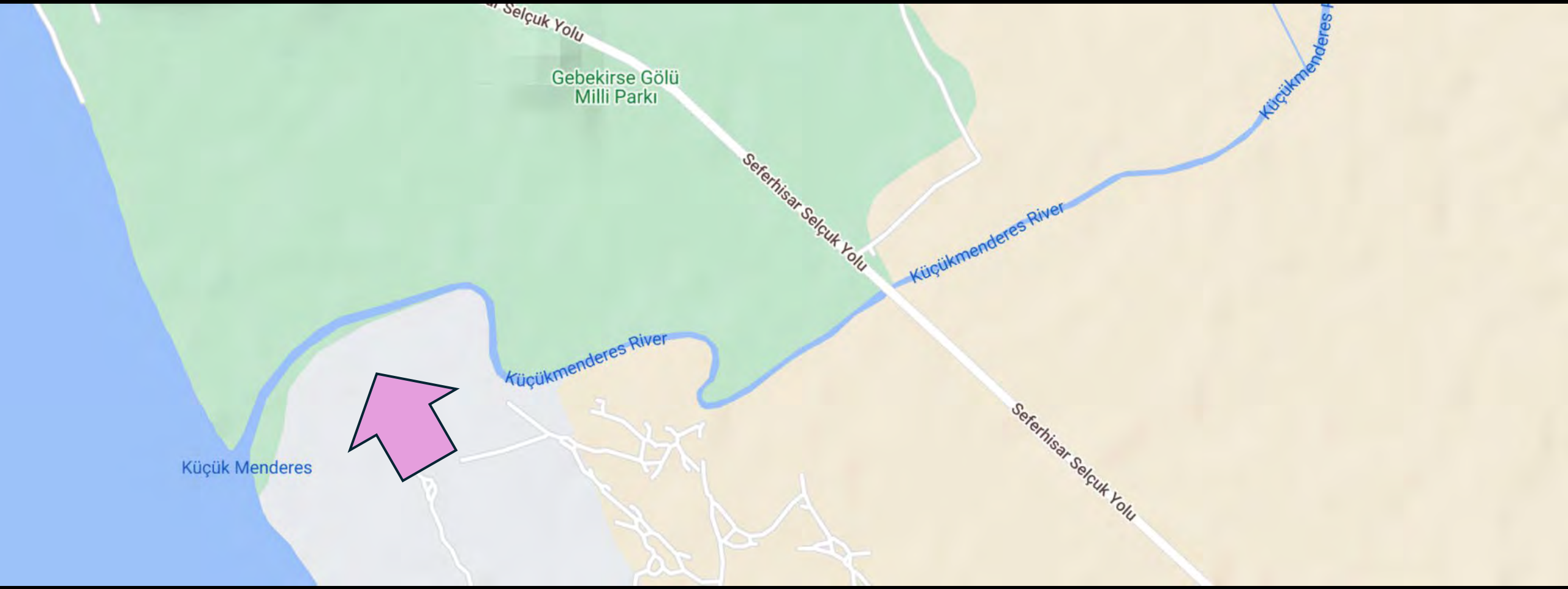
Heraclitus, the son of Blyson, was from the Ionian city of Ephesus, a port on the Kayster River, on the western coast of Asia Minor (modern-day Turkey).



πάντα ρει (*panta rhei)*

"*Everything Flows*"

Kayster River: meaning is the little meander

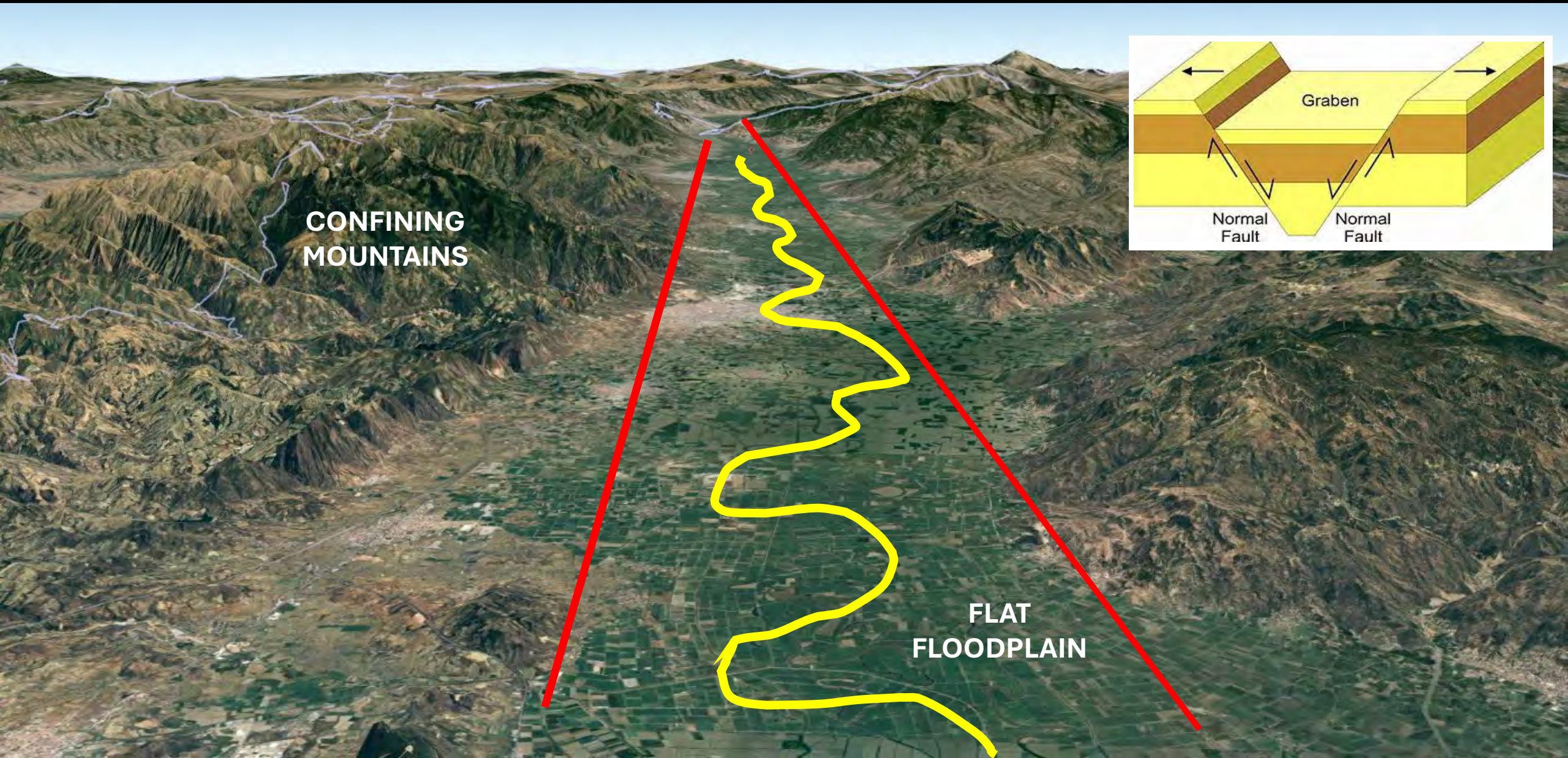


Meander: a winding path or courseway (noun); to bend or follow a windy pathway (verb). "Random" is almost implied.

Where’s the Big Meander?

Statue of river god Meander

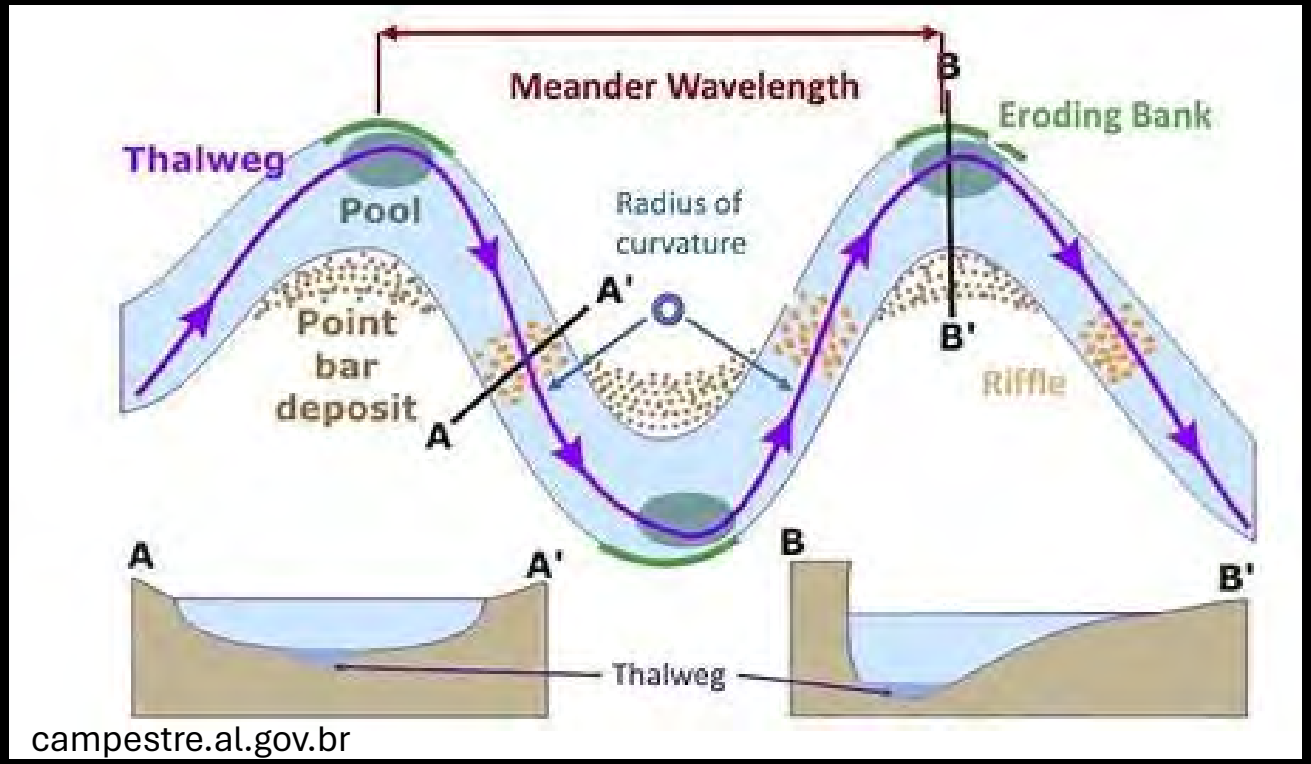
IDEALIZATION



Meandering Stream

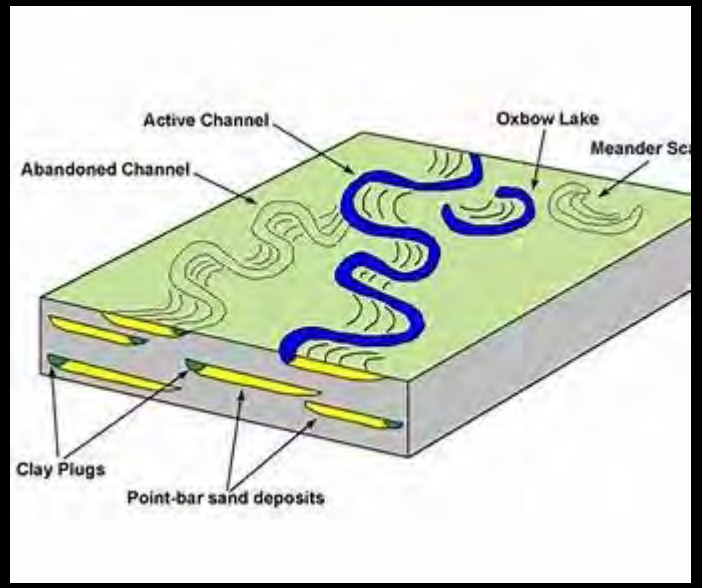
Rivers carry the products of erosion as well as water, and in meanders, some sediment is transported by scour and fill. Scour takes place on the outer banks of the bends and deposition on the inner banks … Friedkin showed that most of the sediment eroded from one bank is deposited on the point bar on the same side of the channel in the next bend downstream. Such scour and fill causes an increase in the amplitude of the meander or migration of the channel along the valley, o.r both, without the width of the channel changing…

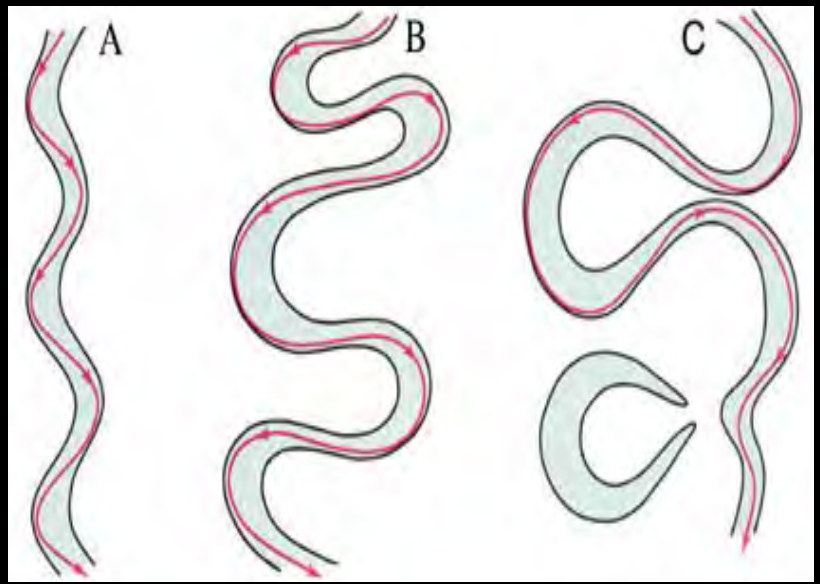
Callander, R A (1978). *River Meandering. Annual Review of Fluid Mechanics, 10(1), 129–158.* doi:10.1146/annurev.fl.10.010178.001021



campestre.al.gov.br

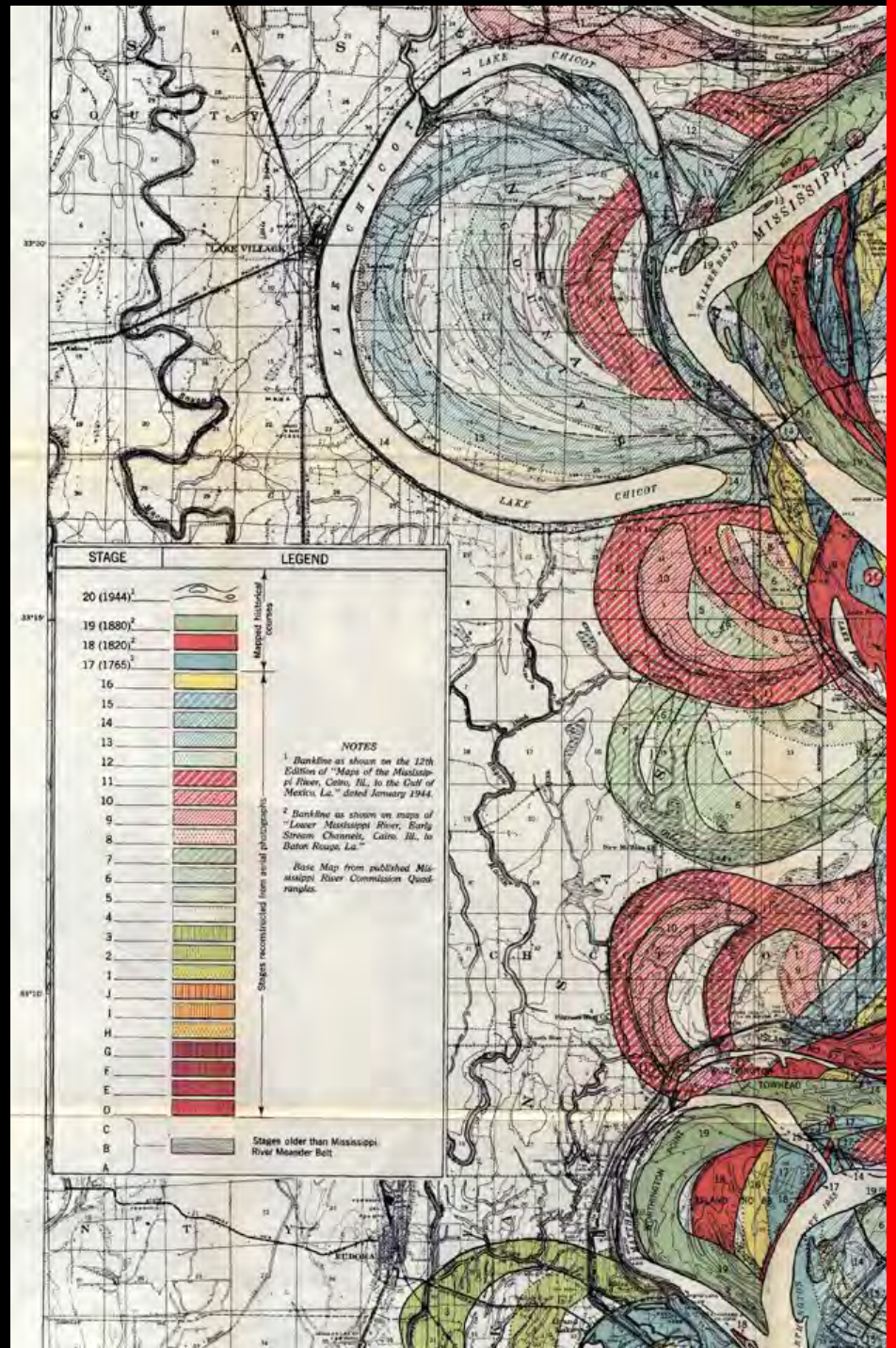
Sinuosity: degree of curviness or windiness in two dimensions





What is the implication of having a boundary (red line) defined by this river?

Mississippi River
Fisk (1944)



Source: http://www.adammandelman.net/wp-content/uploads/2012/03/Fisk-plate-22-1944.jpg

Entrenched meander

Time

It takes time for a subtle curve to become a acute meander

but

Some changes can be “fast”

Lan Na Kingdom (million rice fields)

King Meng Rai

King Meng Rai succeeded his father as ruler of the Nakhon Hiran Ngoen Yang (หิรัญนครเงินยางเชียงลาว), principality of Chiang Saen in 1259 and moved his state to Chiang Rai in 1262.

He worked for more than a decade to prepare the conquest of the Chiang Mai region where Mon rulers had centered their kingdom of Haripunjaya since the 9th century.

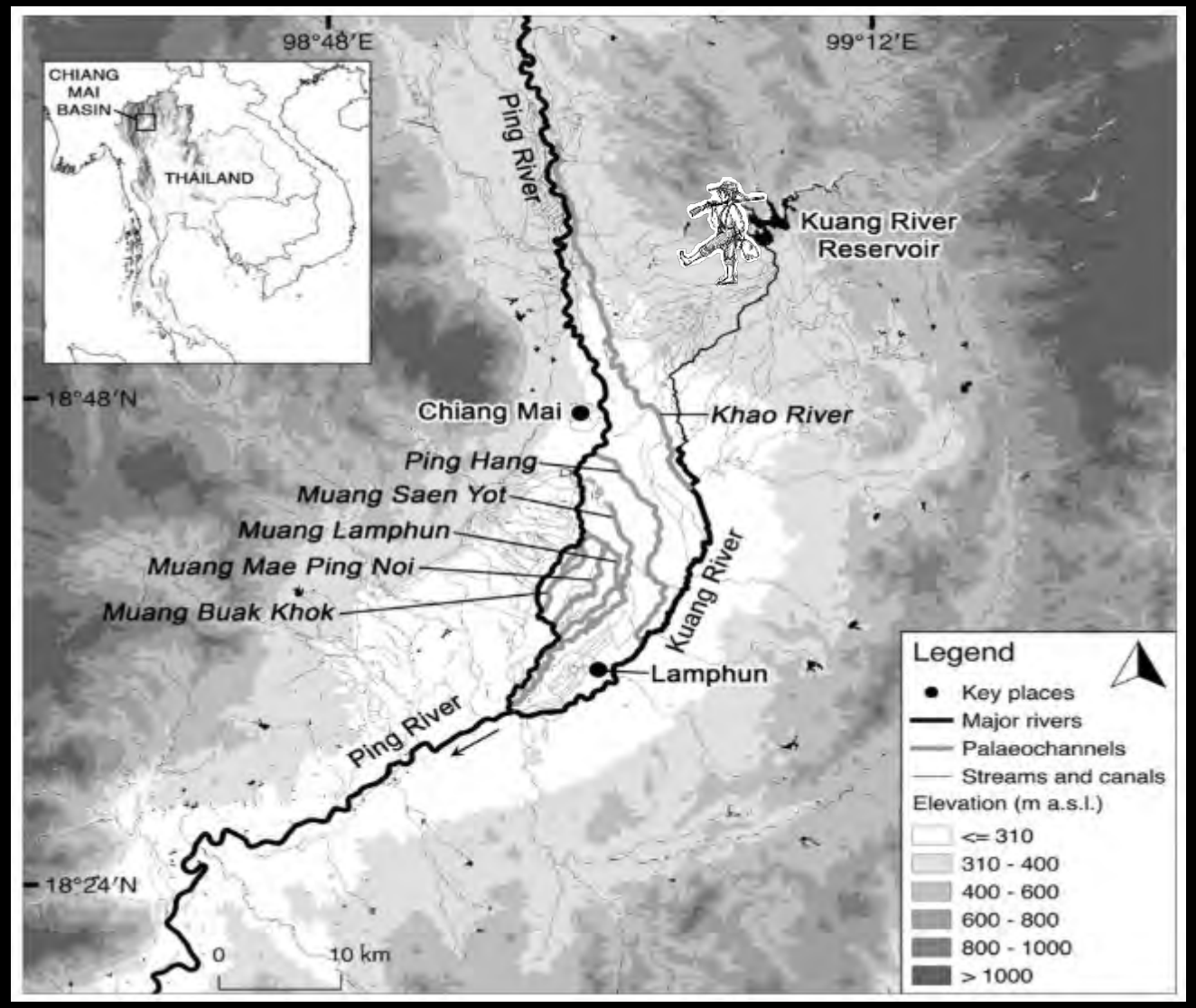
He captured Haripunjaya (now Lamphun) in 1281. In 1287 he made an alliance with Ramkhamhaeng of Sukhothai and the ruler of Phayao, hoping to take advantage of the Mongol capture of Pagan, the Burmese capital; and he may have assisted in the Shan conquest of Pagan in 1290.

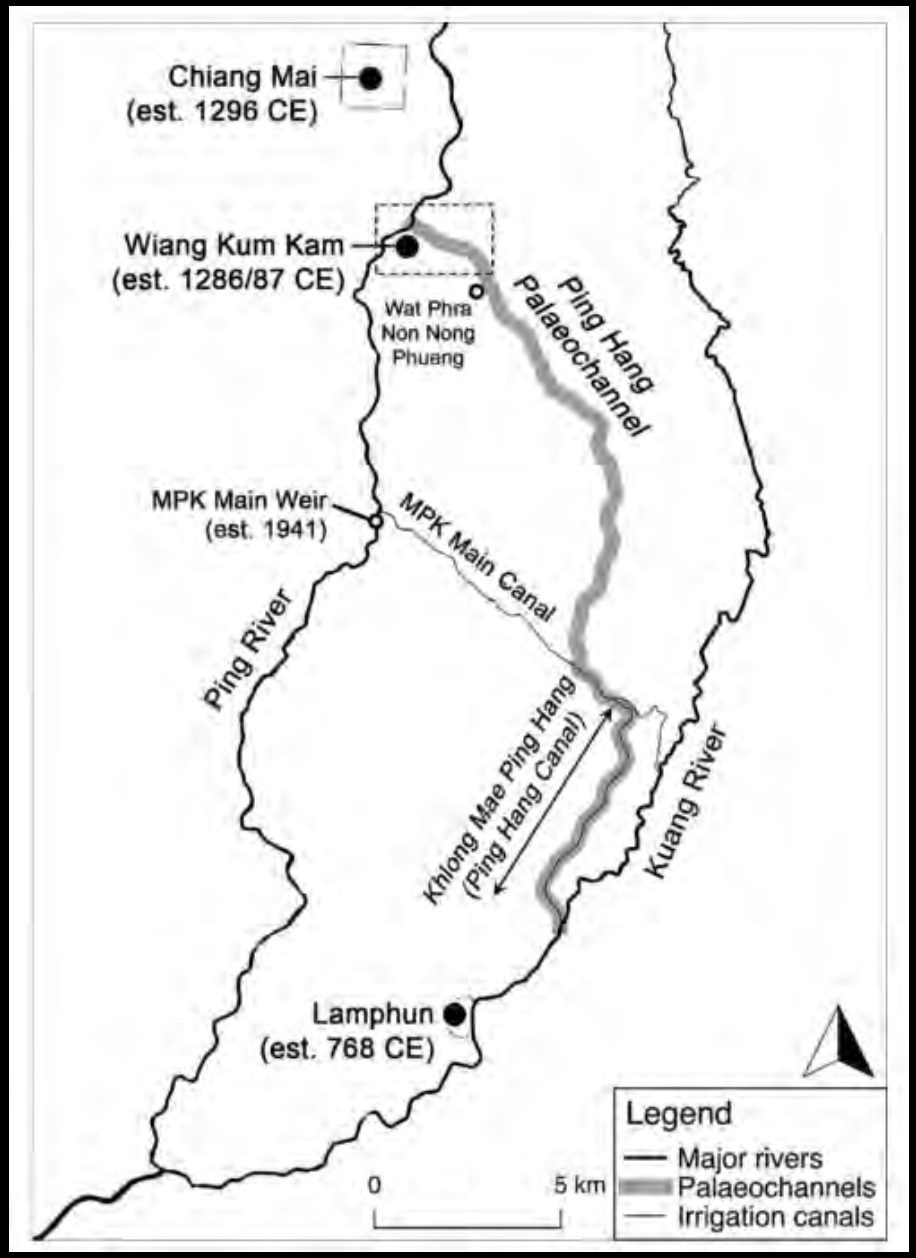
In 1296 he founded Chiang Mai, which became the capital of the kingdom of Lan Na (The Country of a Million Rice Fields), which remained a major power in the region until the 16th century.

First, he found Wiang Kum Kam

The (hi)Story of Wiang Kum Kam

Ancient Lanna capital (Chiang Mai) … the “Atlantis” of the Lanna Kingdom
Serene: Abandoned in 1500s in response to recurrent flooding
Major change in river course (Avulsion)
Adaptation: people moved


98°48′E
99°12′E
CHIANG MAI BASIN
THAILAND
Ping River
Kuang River Reservoir
18°48′N
Chiang Mai
Khao River
Ping Hang
Muang Saen Yot
Muang Lamphun
Muang Mae Ping Noi
Muang Buak Khok
Kuang River
Lamphun
Ping River
18°24′N
0
10 km
Legend
Key places
Major rivers
Palaeochannels
Streams and canals
Elevation (m a.s.l.)
<= 310
310 - 400
400 - 600
600 - 800
800 - 1000
> 1000


Chiang Mai
(est. 1296 CE)
Wiang Kum Kam
(est. 1286/87 CE)
Wat Phra Non Nong Phuang
Ping Hang Palaeochannel
MPK Main Weir
(est. 1941)
MPK Main Canal
Ping River
Khlong Mae Ping Hang
(Ping Hang Canal)
Kuang River
Lamphun
(est. 768 CE)
0
5 km
Legend
Major rivers
Palaeochannels
Irrigation canals

Teo (2018)

Methods

Geochronology

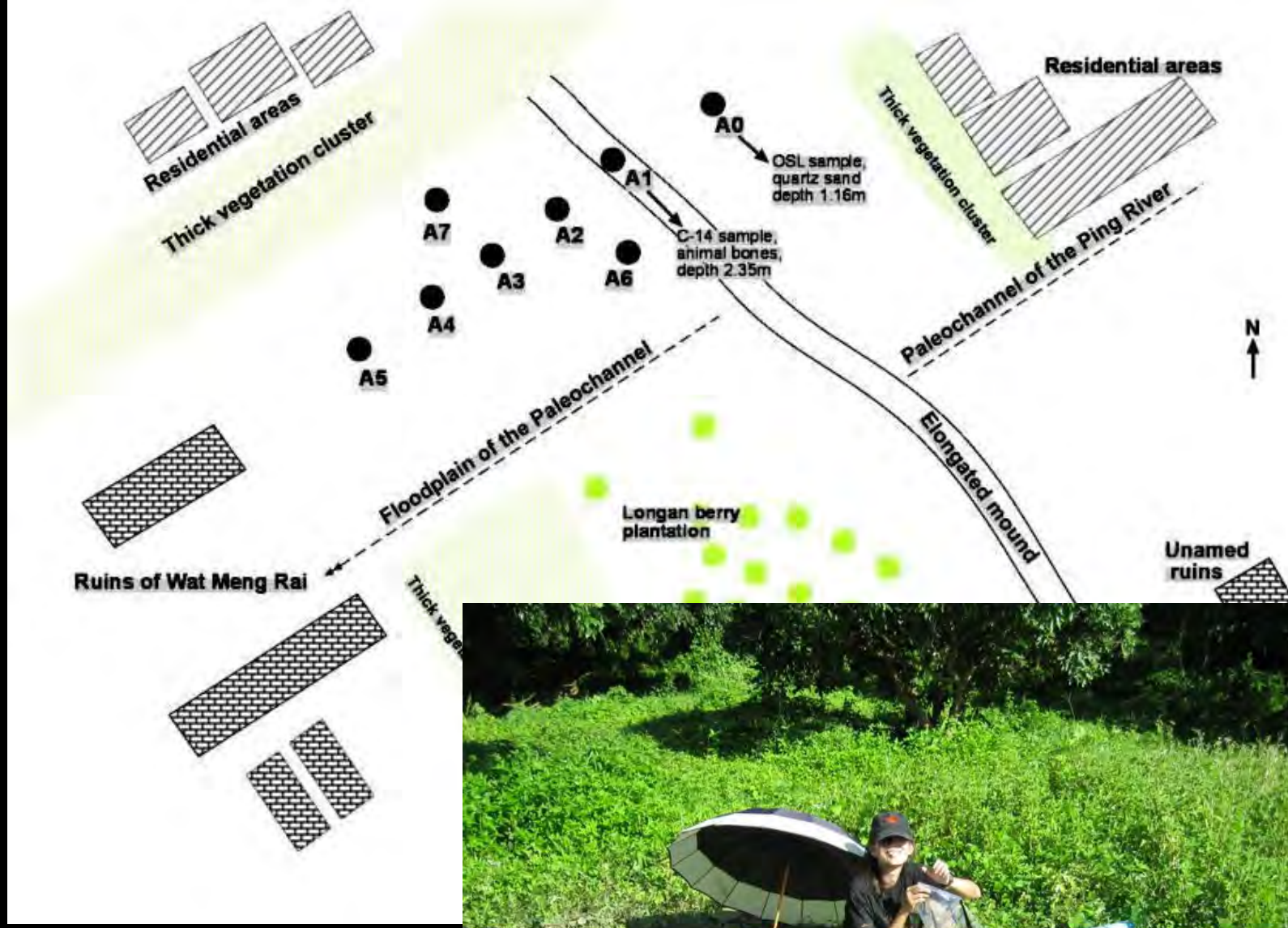
-Samples for OSL dating

- Interpretation of samples

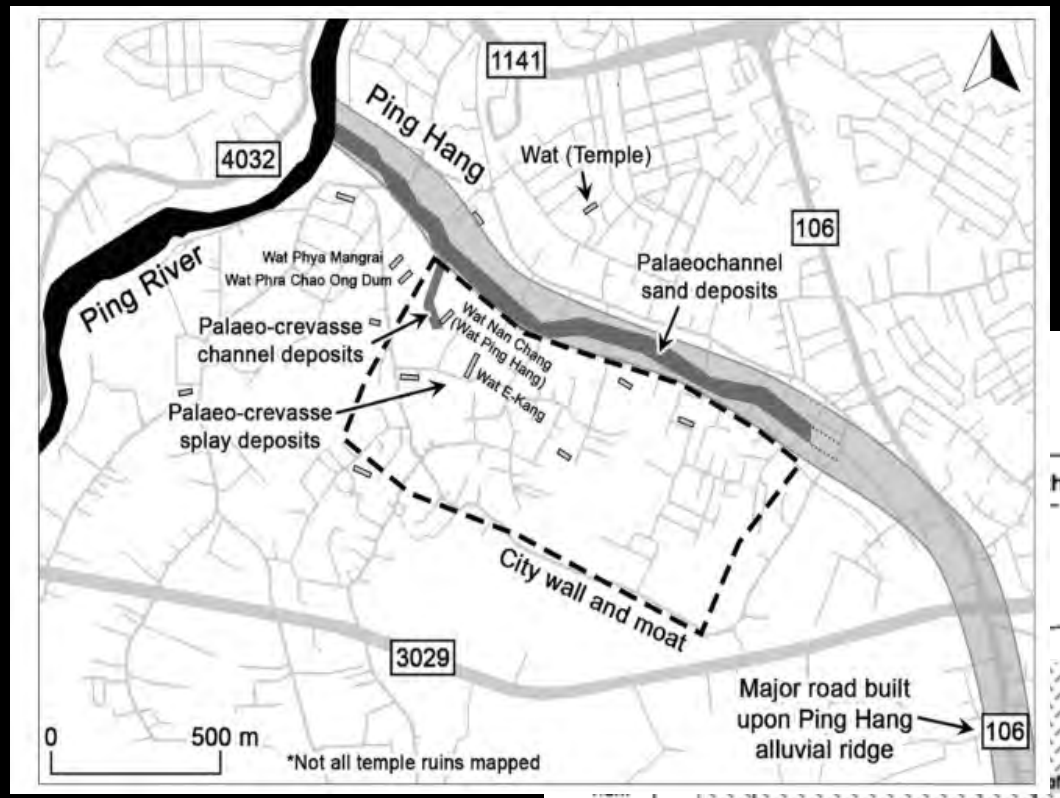
Paleostage Indicators

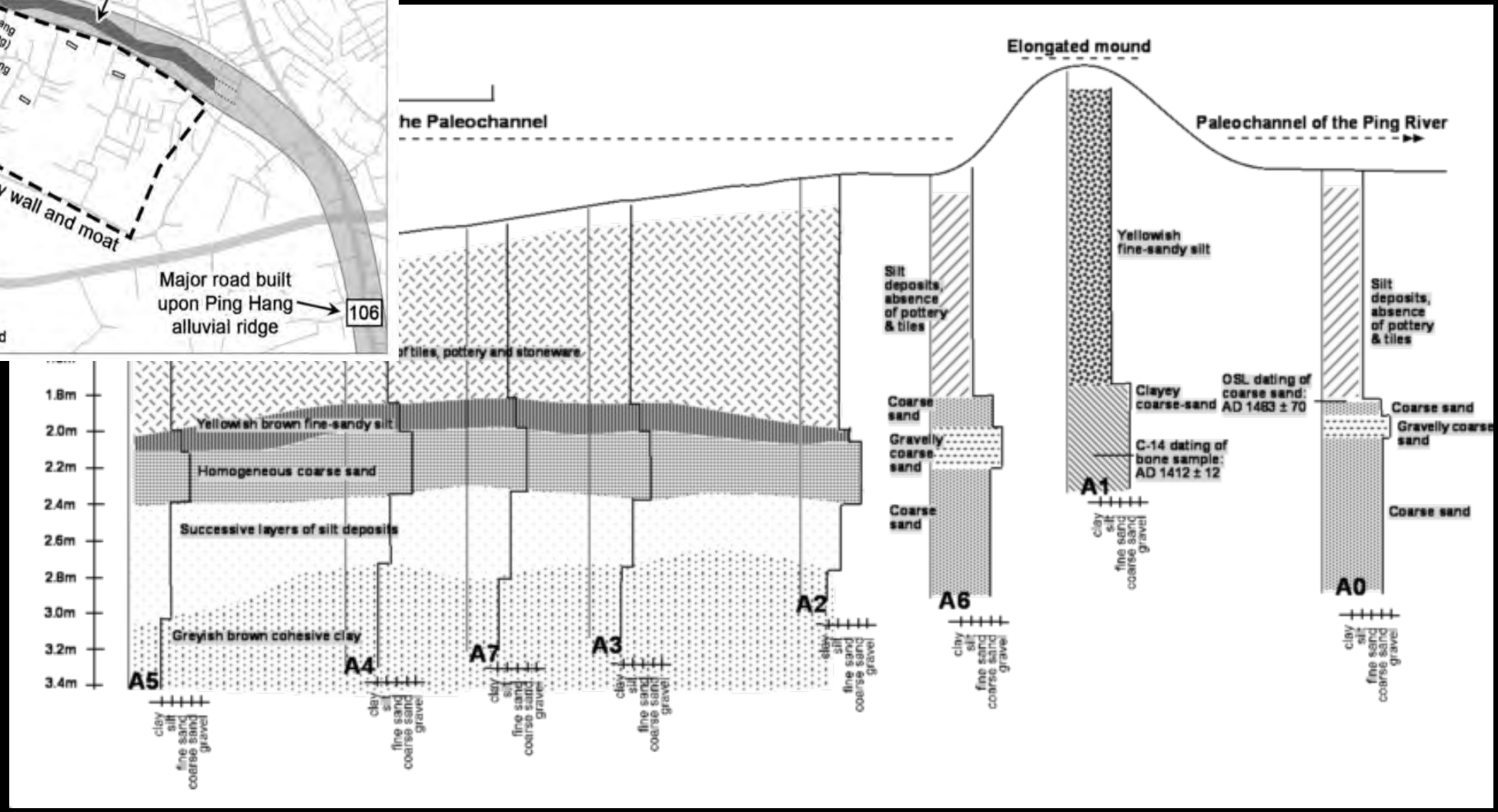
-Excavation of floodplain deposits

- Sediment grain-size analysis



Plain Stratigraphy





(hi)Story of Wiang Kum Kam

Wiang Kum Kam established in 1286 AD

→ King Mengrai moves to Chiang Mai in 1291 AD

↓

WKK continues to thrive as a fortified city

Plagued by persisting floods:
- Floodplain stratigraphy
- **<u>Adaptation</u>**: mitigation structures built (est. 1411 AD)

↓

High energy flood event (est. 1477 – 1512 AD):
-Breached dyke
- Deposition of coarse sand
- Choked Ping River, drastic avulsion of Ping River (OSL: est. 1412-1552 AD)

↓

<u>Abandonment</u> of WKK:
- Architectural discontinuities after 1500s
- No records of the city after 1500s
- Related to the 'devastating flood' in 1524/25 AD in the *Chiang Mai Chronicle*?

Why Rivers Move

Channel (in)Stability

Erosion & Deposition

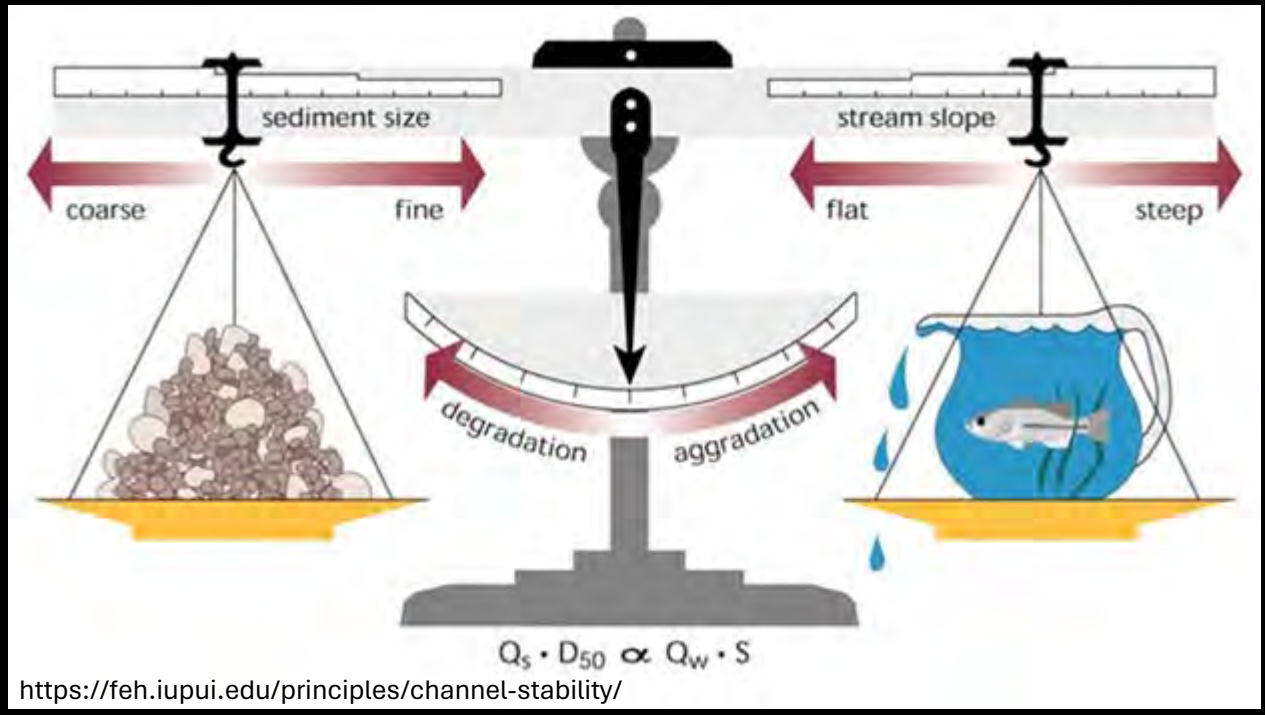
Stream Power

Lane's Scale (relationship)

Pulses of water/sediment

Dynamic Equilibrium

Triggers: Rainfall, Disturbance, Blockage



https://feh.iupui.edu/principles/channel-stability/

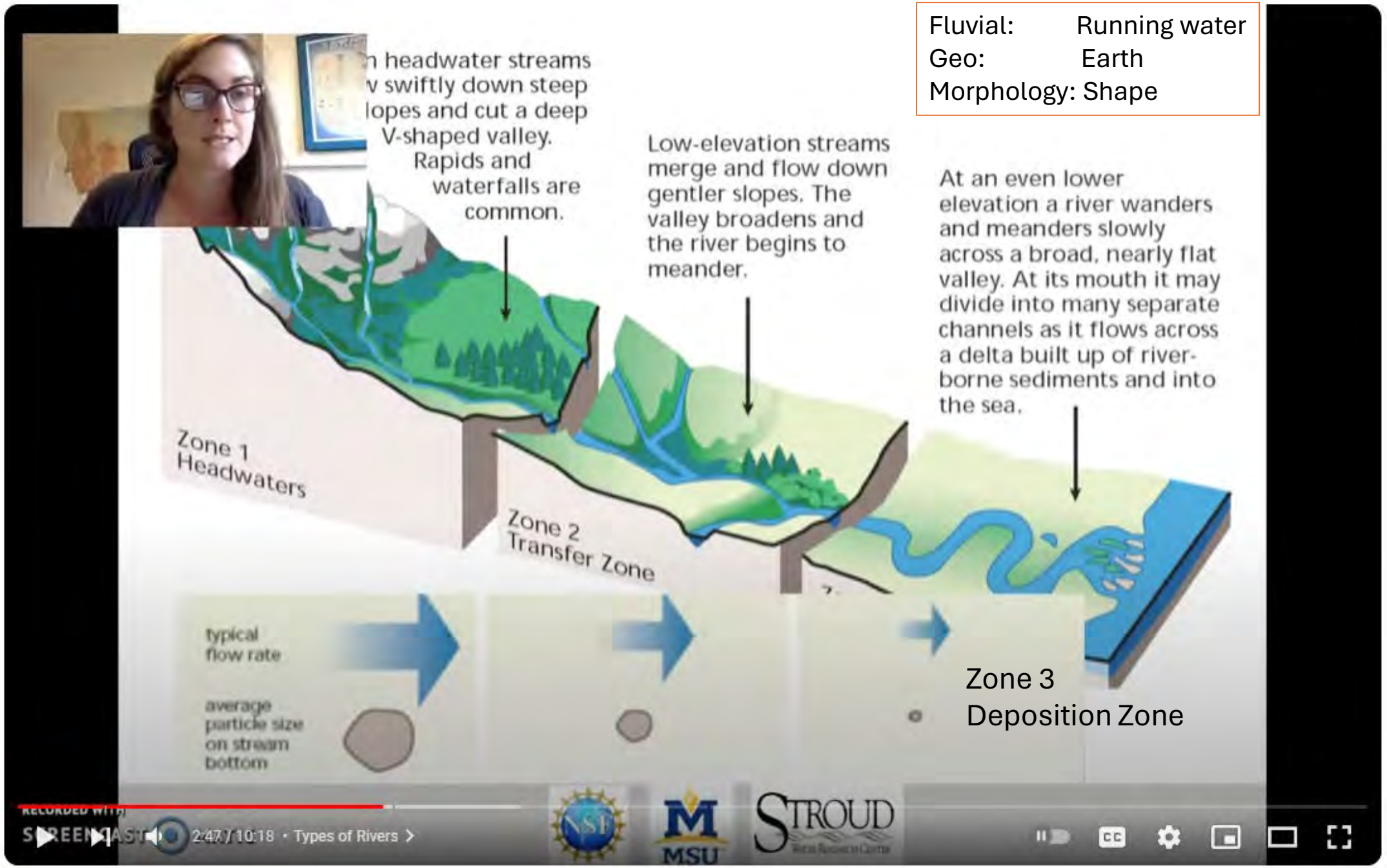
Why Rivers Move (youtube.com) 3:58

$$Q_s \cdot D_{50} \propto Q_w \cdot S$$

Lane, E. W., 1955. *The importance of fluvial morphology in hydraulic engineering.* Proceedings, American Society of Civil Engineers, Vol. 81, Paper 745, July.

Fluvial Geomorphology: An Introduction (youtube.com)

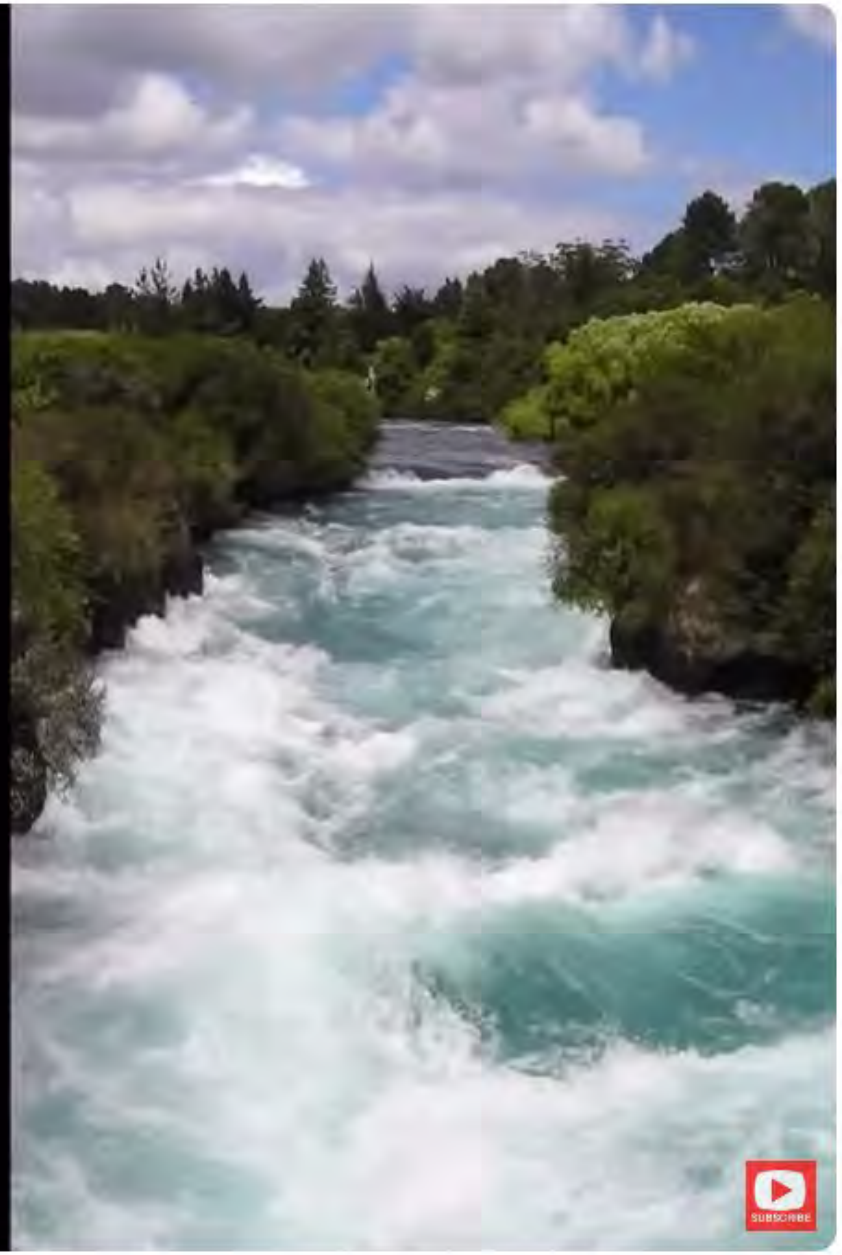
Fluvial: Running water
Geo: Earth
Morphology: Shape



Fluvial Geomorphology: An Introduction

Characteristics of YOUNG River Systems

- Steep slope
- Deep, narrow channel
- Fast flow velocity
- Straight, few meanders
- More erosion than deposition



River Erosion and Deposition

Mike Sammartano
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Characteristics of OLD River Systems

- Very gradual slope
- Shallow, wide channel
- Slow flow veocity
- Wide meanders (curves)
- More deposition than erosion

River Erosion and Deposition

where

Tropical Rivers

form

Orogenic Belts

Cratonic Areas

Sedimentary Basins

ELSEVIER

Geomorphology

Volume 70, Issues 3–4, 1 September 2005, Pages 187-206

Tropical rivers

E.M. Latrubesse [a], J.C. Stevaux [b], R. Sinha [c]

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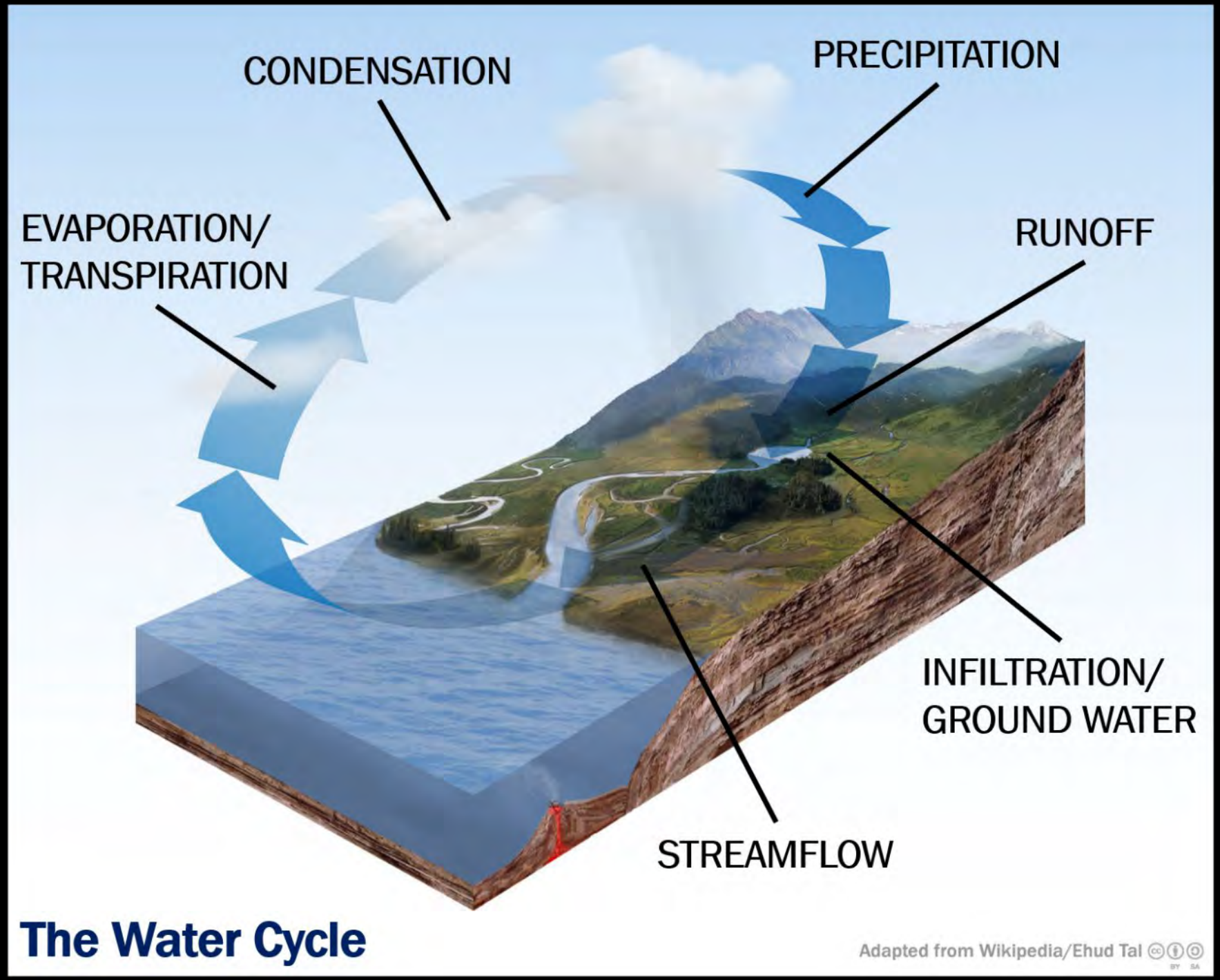
https://doi.org/10.1016/j.geomorph.2005.02.005 Get rights and content

Abstract

This paper presents an overview of tropical river systems around the world and identifies major knowledge gaps. We focus particularly on the rivers draining the wet and wet–dry tropics with annual rainfall of more than 700 mm/year. The size of the analyzed river basins varies from 10^4 to 6×10^6 km^2. The tropical rivers across the globe drain a variety of geologic–geomorphologic settings: (a) orogenic mountains belts, (b) sedimentary and basaltic plateau/platforms, (c) cratonic areas, (d) lowland plains in sedimentary basins and (e) mixed terrain. All of them show clearly high but variable peak discharges during the rainy season and a period of low flow when rainfall decreases. Some tropical rivers show two flood peaks, a principal and a secondary one, during the year. We computed

Hydrological Cycle



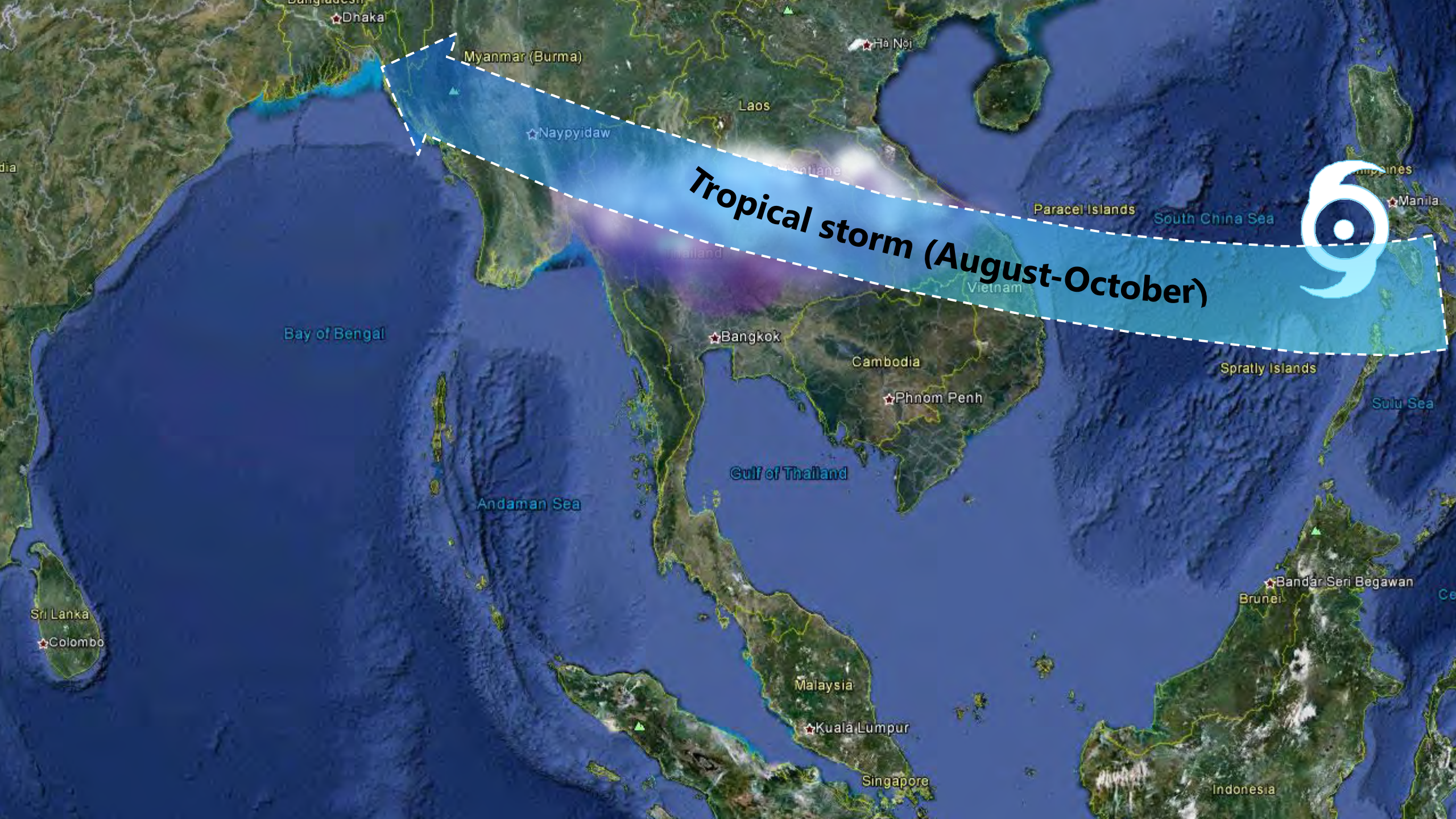
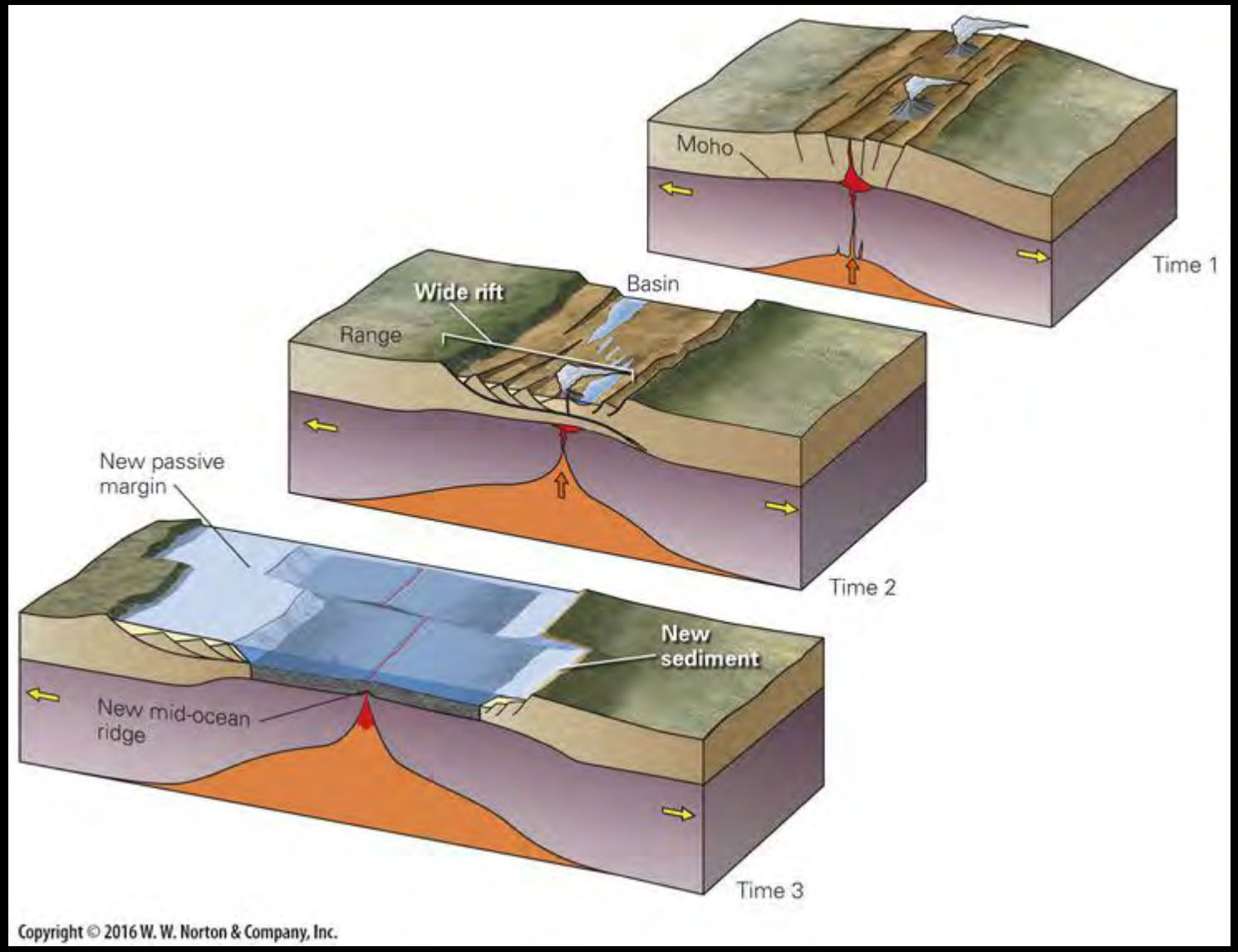
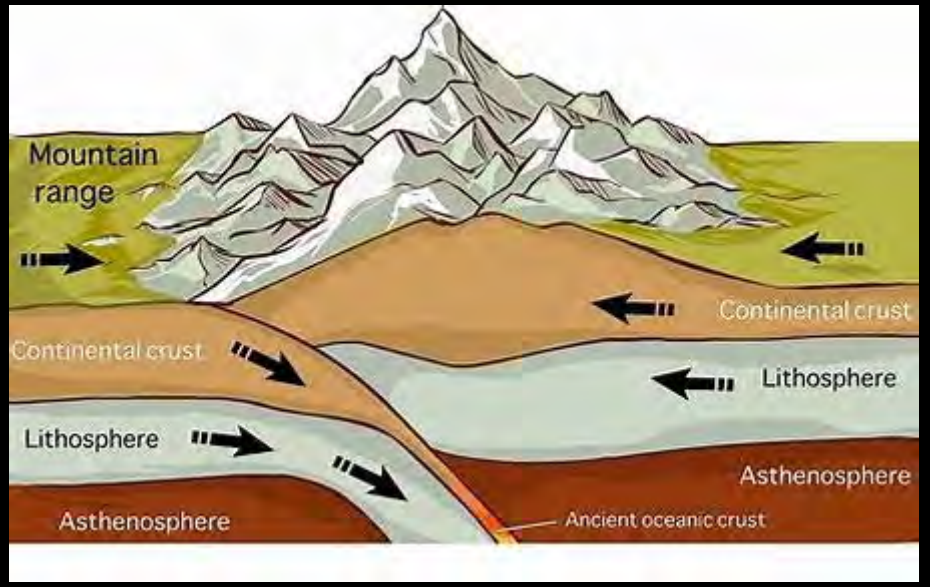

Tropical storm (August-October)
Dhaka
Myanmar (Burma)
Hà Nội
Laos
Naypyidaw
Vientiane
Paracel Islands
South China Sea
Manila
Thailand
Vietnam
Bay of Bengal
Bangkok
Cambodia
Phnom Penh
Spratly Islands
Sulu Sea
Gulf of Thailand
Andaman Sea
Bandar Seri Begawan
Brunei
Sri Lanka
Colombo
Malaysia
Kuala Lumpur
Singapore
Indonesia

Plate Tectonics

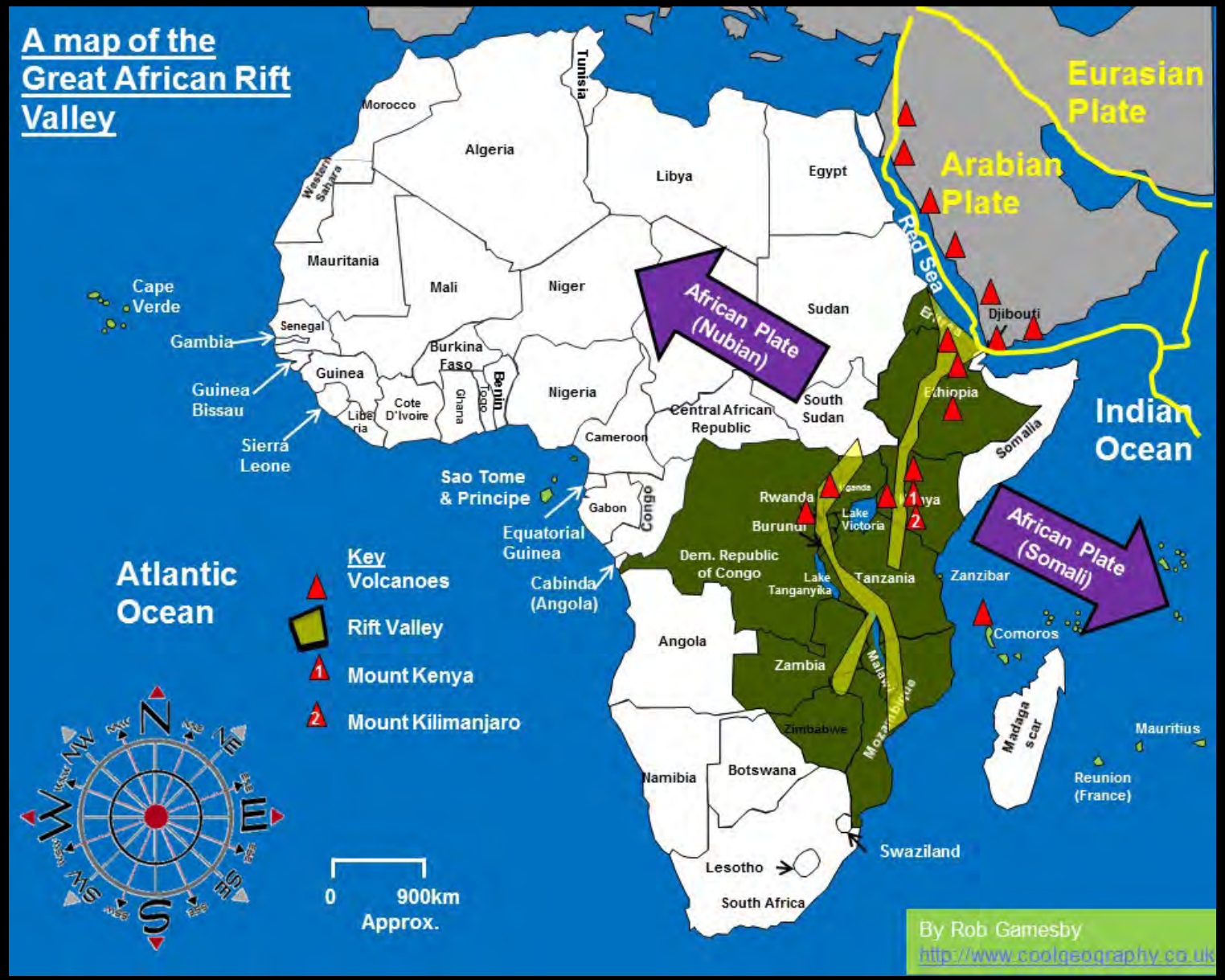
Animation





Credits: WorldAtlas; CosmosMagazine

African Rift System

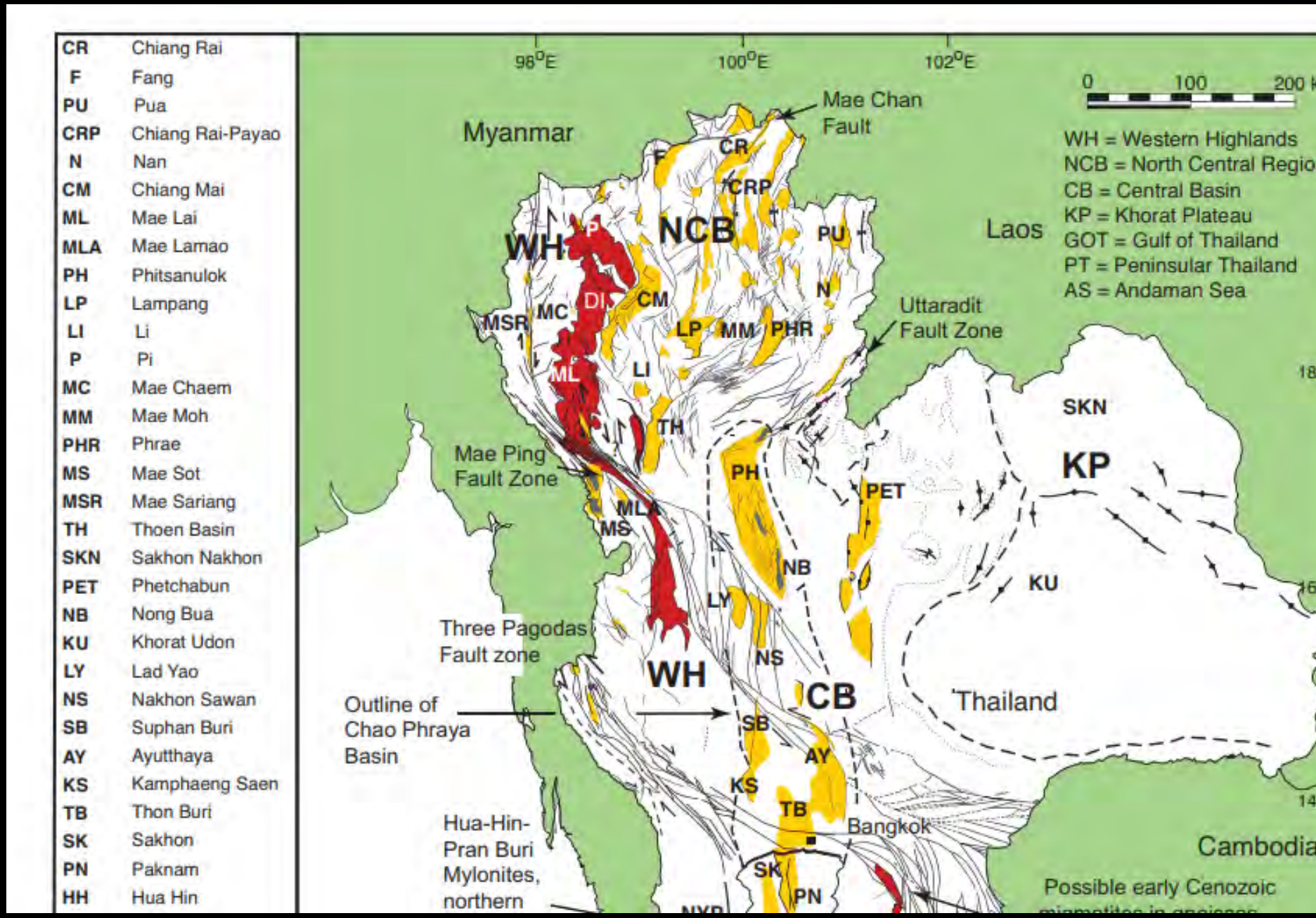


Jordan River

Rifts in Thailand?

Morley, C. K. (2015). Five anomalous structural aspects of rift basins in Thailand and their impact on petroleum systems. *Geological Society, London, Special Publications*, *421*(1), 143-168.

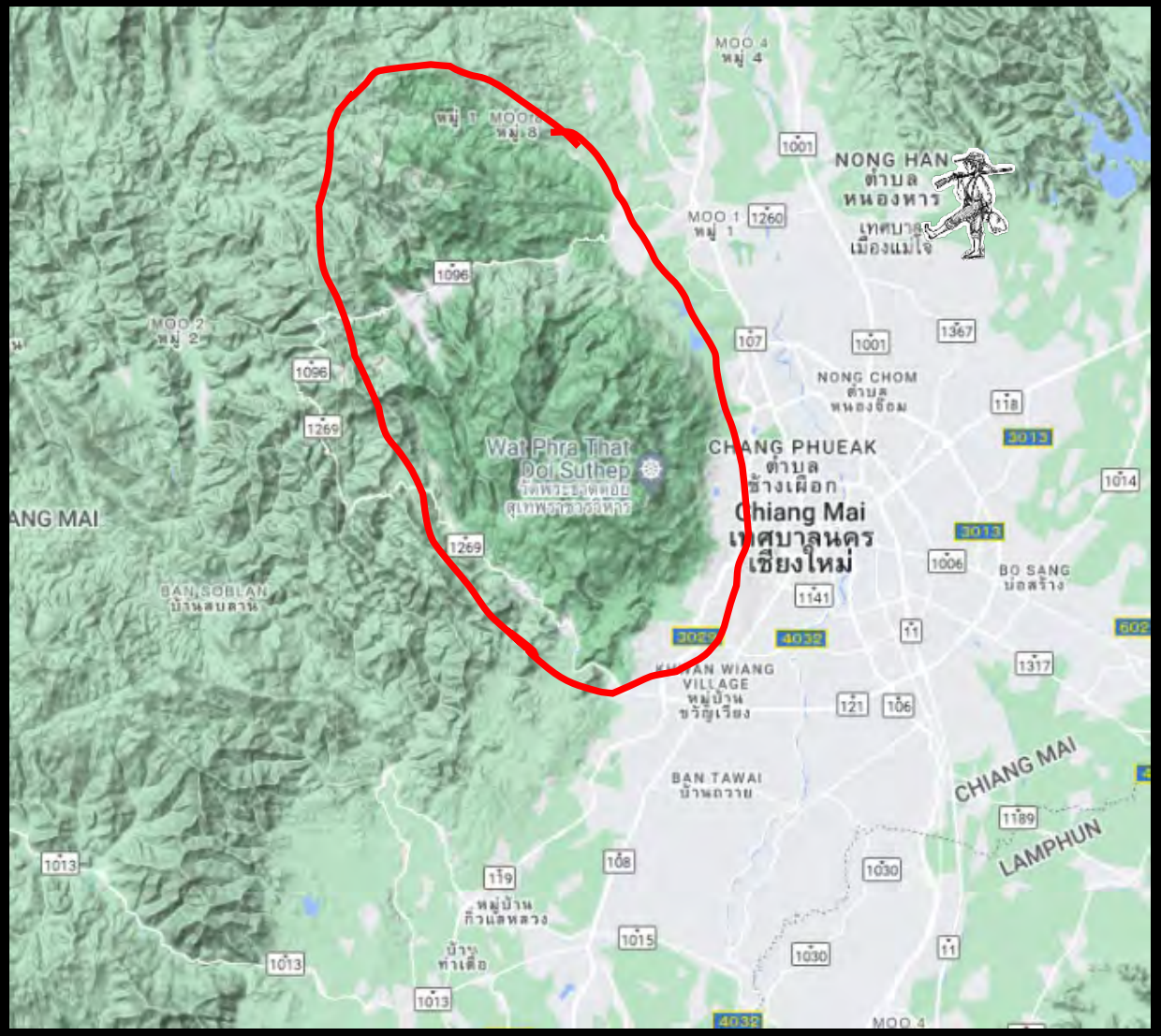
CR	Chiang Rai
F	Fang
PU	Pua
CRP	Chiang Rai-Payao
N	Nan
CM	Chiang Mai
ML	Mae Lai
MLA	Mae Lamao
PH	Phitsanulok
LP	Lampang
LI	Li
P	Pi
MC	Mae Chaem
MM	Mae Moh
PHR	Phrae
MS	Mae Sot
MSR	Mae Sariang
TH	Thoen Basin
SKN	Sakhon Nakhon
PET	Phetchabun
NB	Nong Bua
KU	Khorat Udon
LY	Lad Yao
NS	Nakhon Sawan
SB	Suphan Buri
AY	Ayutthaya
KS	Kamphaeng Saen
TB	Thon Buri
SK	Sakhon
PN	Paknam
HH	Hua Hin



20 km

Chiang Mai

Doi Suthep, Chiang Mai
Metamorphic Core Complex: inherited river system (Mae Sa)



Mekong

Evidence of Past Floods Mekong

AD 1912 ±30 (0.10 ±0.03ka, OSL, SG quartz)

AD 1894-1904 cal
AD 1953-1955 cal (40 ±20 yrsBP, AMS C-14 on soil charcoal)

AD 1882 ±50 (0.13 ±0.05 ka, OSL, SG quartz)

AD 1482 ±290 (0.53 ±0.29 ka, OSL, SG quartz)

Pottery shards

AD 72 ± 240 (1.94 ±0.24 ka, OSL, SA quartz)


Myanmar
Thailand
Laos

Anabranching

Braiding

NANSON, GERALD C.; KNIGHTON, A. DAVID (1996). *ANABRANCHING RIVERS: THEIR CAUSE, CHARACTER AND CLASSIFICATION. Earth Surface Processes and Landforms, 21(3), 217–239.* doi:10.1002/(sici)1096-9837(199603)21:3<217::aid-esp611>3.0.co;2-u

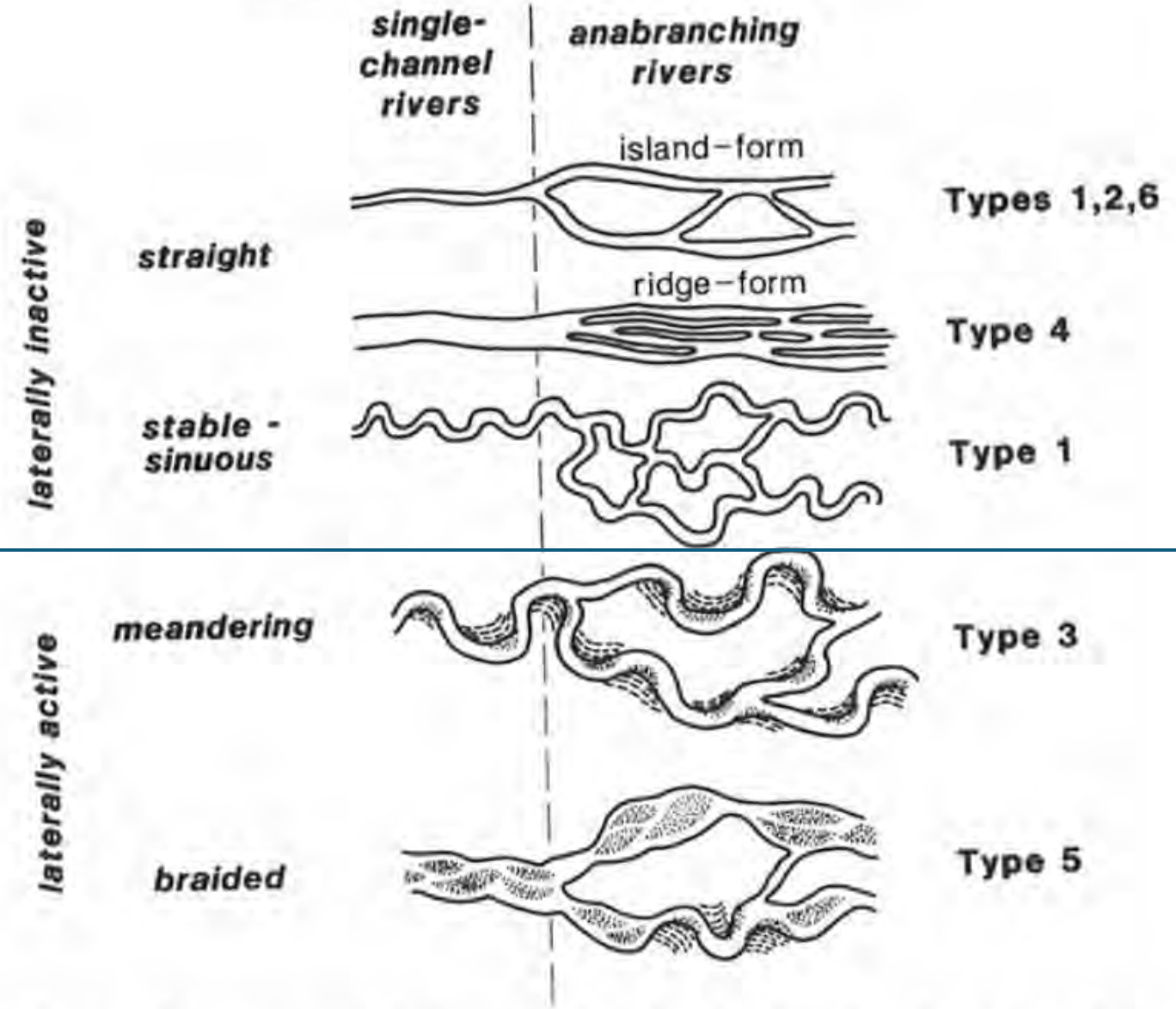
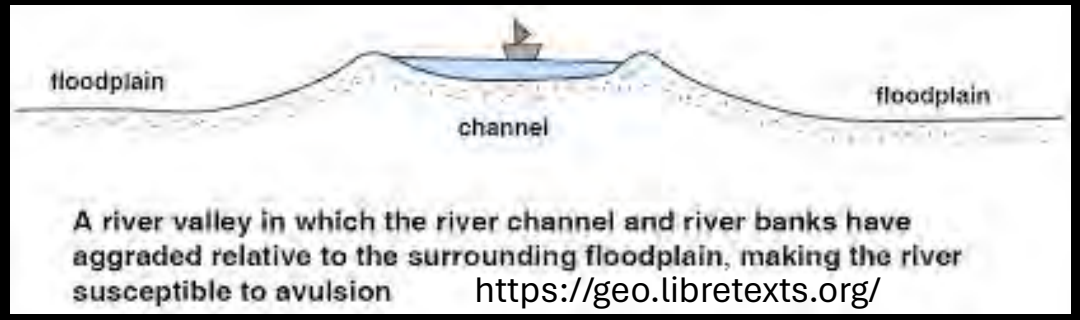


Figure 9. A proposed classification of river patterns including single-channel and anabranching forms. Laterally inactive channels consist of straight and sinuous forms whereas laterally active channels consist of meandering and braided forms

Magdelena

(linear basin; headwaters in active orogenic belts)

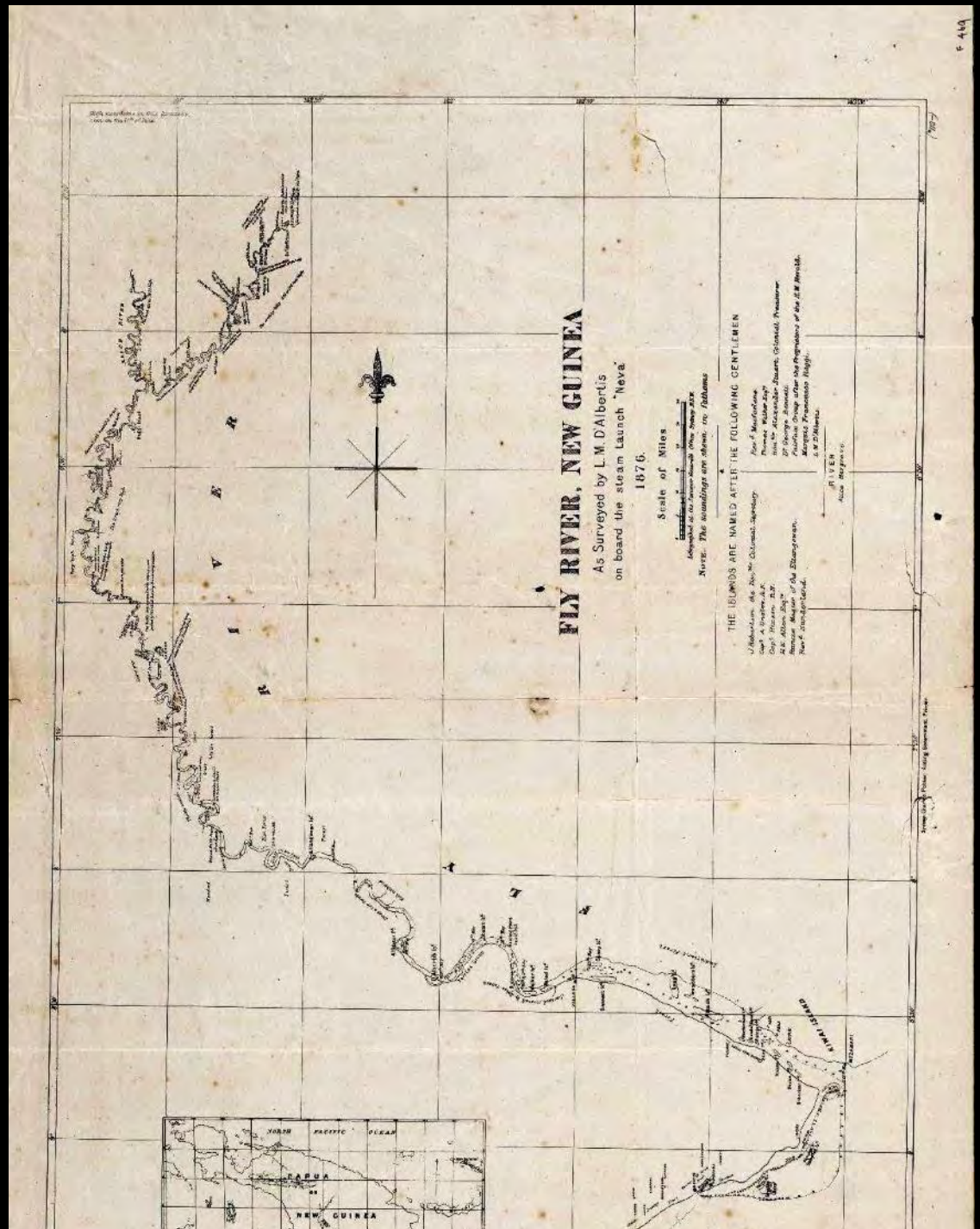


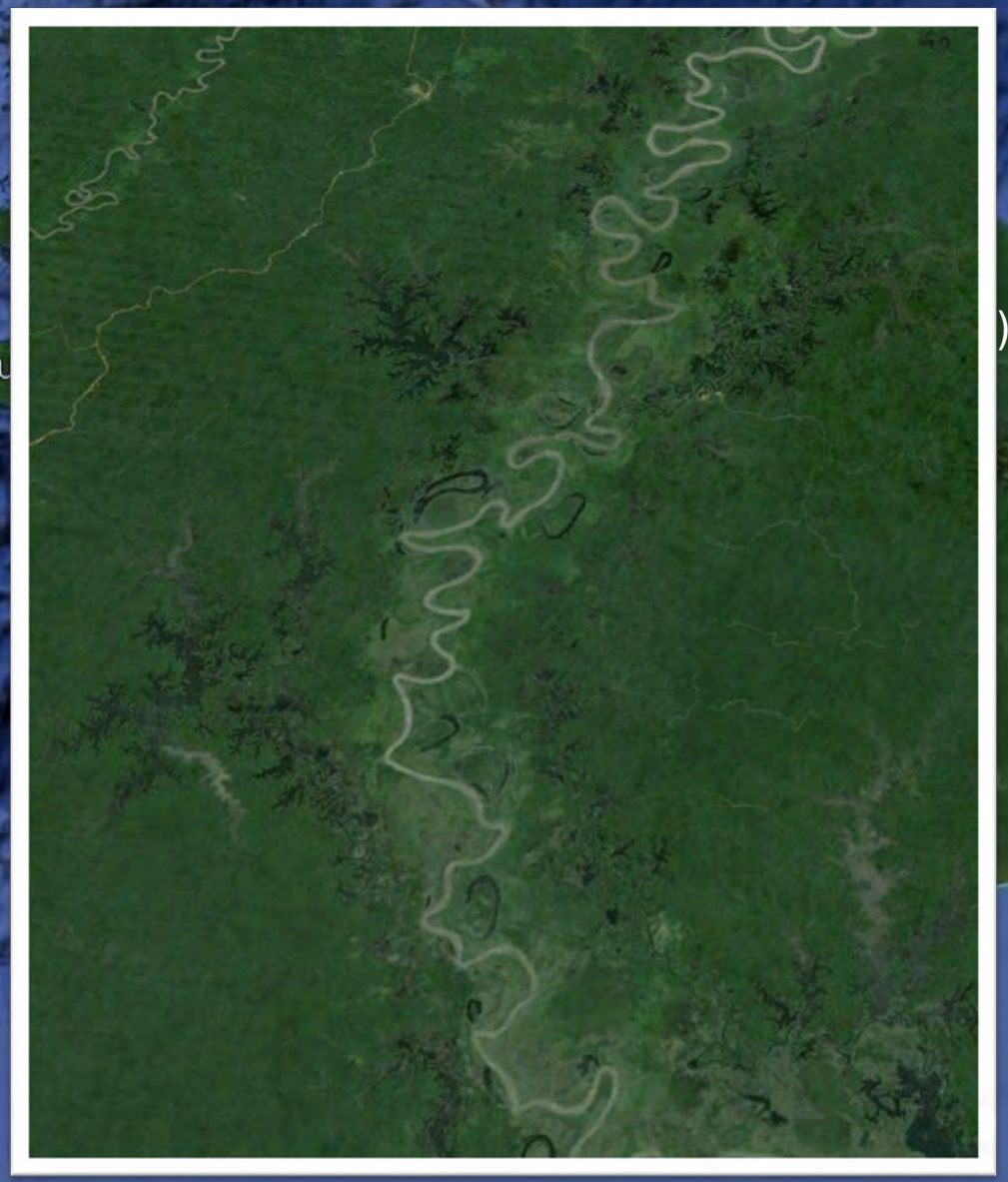
A river valley in which the river channel and river banks have aggraded relative to the surrounding floodplain, making the river susceptible to avulsion https://geo.libretexts.org/

Subsistence foreland; anastomosing pattern; high vertical aggradation

Fly River

(linear basin; headwaters in active orogenic belts)






Jayapura
Merauke

Ganga

(linear basin; headwaters in active orogenic belts)

Wide alluvial plane after debouching from the mountains

https://english.newstracklive.com/

GANGA

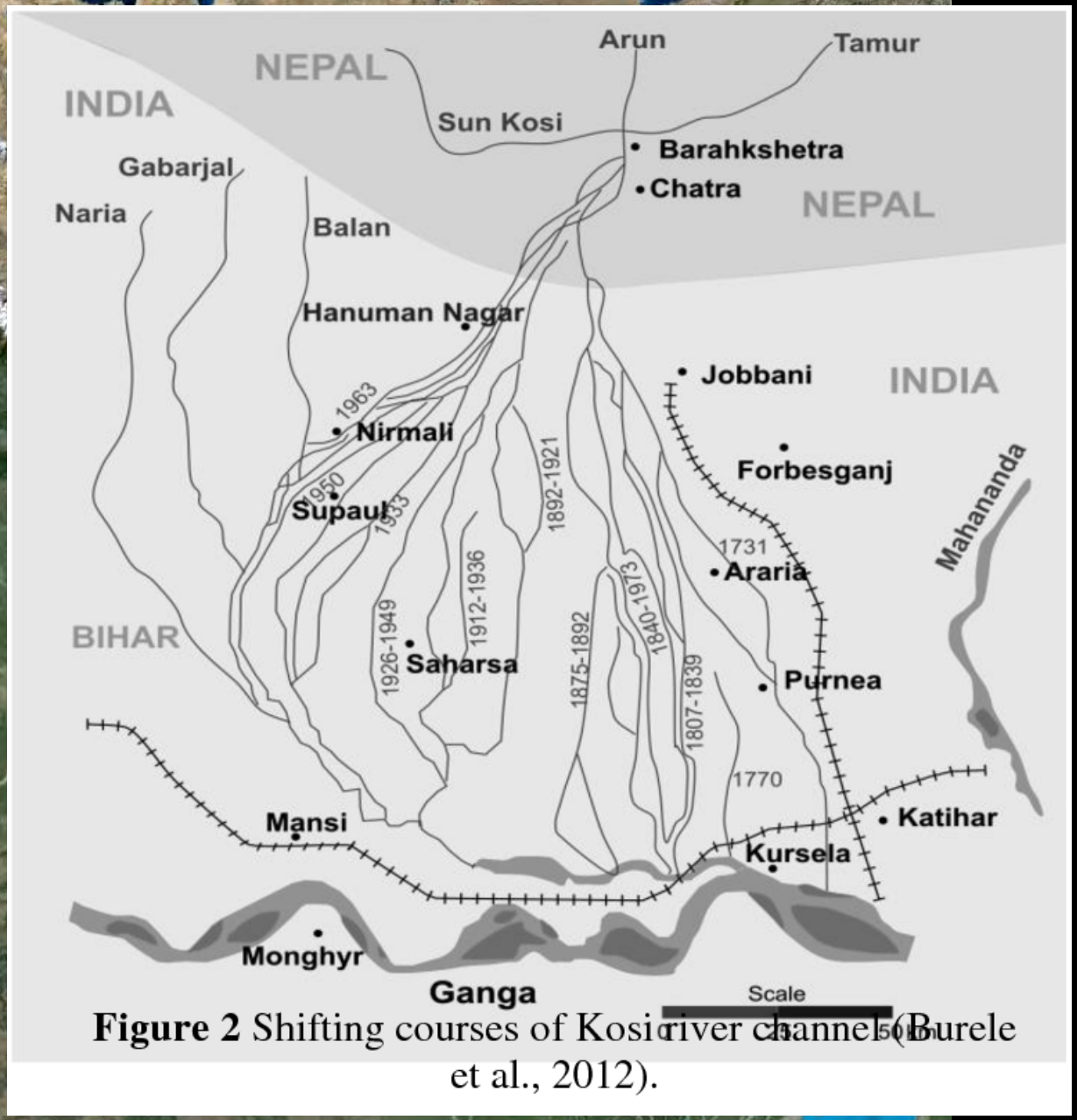


Figure 2 Shifting courses of Kosi river channel (Burele et al., 2012).

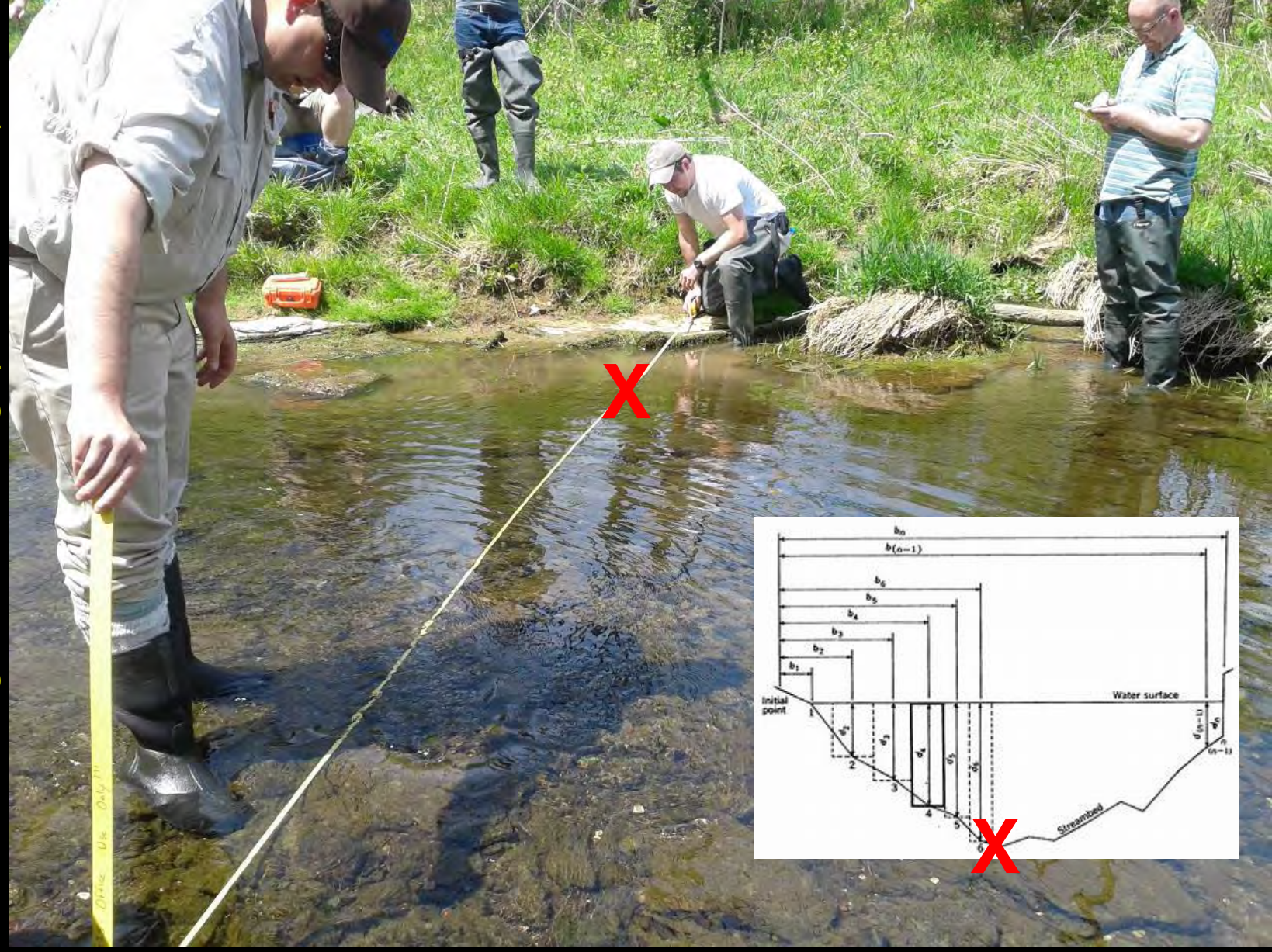
Kosi River Bihar (2022)

Kosi River Bihar (2013)

Much Ado About Thalwegs

Lowest point?
Fastest flow?

Measuring Stream discharge (water flow rate)



The term "thalweg" refers to the line of lowest elevation within a valley or watercourse, such as a river or stream. It represents the natural pathway that water follows as it flows downhill. In legal and geographic contexts, the thalweg is often used to define boundaries between states or jurisdictions, particularly in cases involving bodies of water.

Alt ways to measure the thalweg

- ANN (Aghamolaei, Z., & Hessami-Kermani, M. R. (2023). Developing a new Artificial Intelligence framework to estimate the thalweg of rivers. Water Resources Management, 37(15), 5893-5917)
- LiDAR (Guilbert, E., Jutras, S., & Badard, T. (2018). Thalweg detection for river network cartography in forest from high-resolution lidar data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 241-247.)
- Georeferenced Sonar (Swinson, K. W. (2012). Analysis of Georeferenced Sonar-Based Thalweg and Cross-Sectional River Depth Profile Measurements).

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Mapping Underwater Bathymetry of a Shallow River from Satellite Multispectral Imagery

by Shayan Salavitabar, S. Samuel Li * and Behzad Lak

Department of Building, Civil and Environmental Engineering, Concordia University, 1455 de Maisonneuve Boulevard West, Montreal, QC H3G 1M8, Canada

* Author to whom correspondence should be addressed.

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Submission received: 28 February 2022 / Revised: 17 March 2022 / Accepted: 21 March 2022 / Published: 23 March 2022

WorldView2 satellite images.

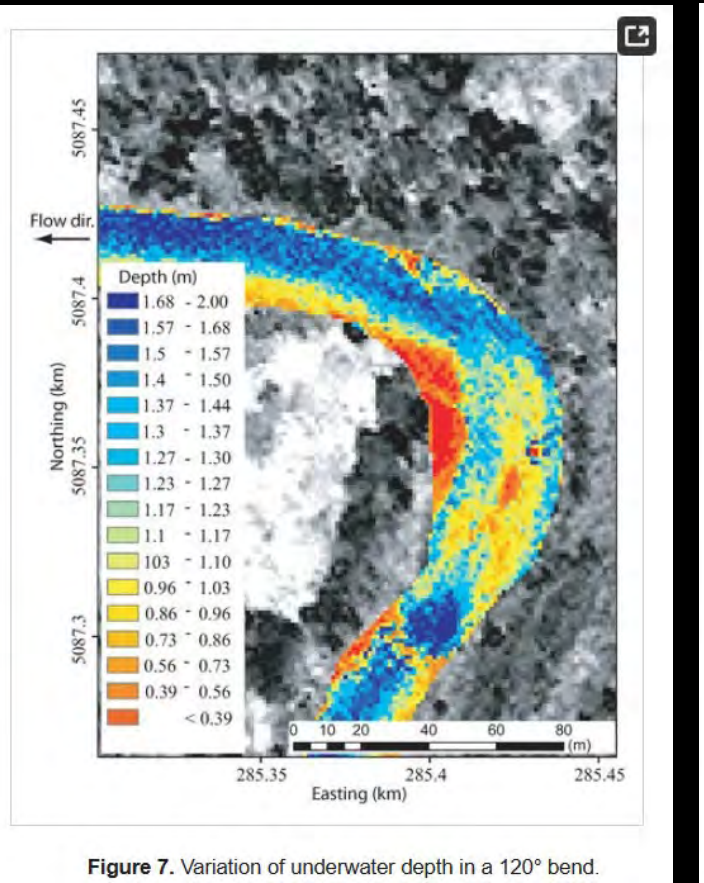
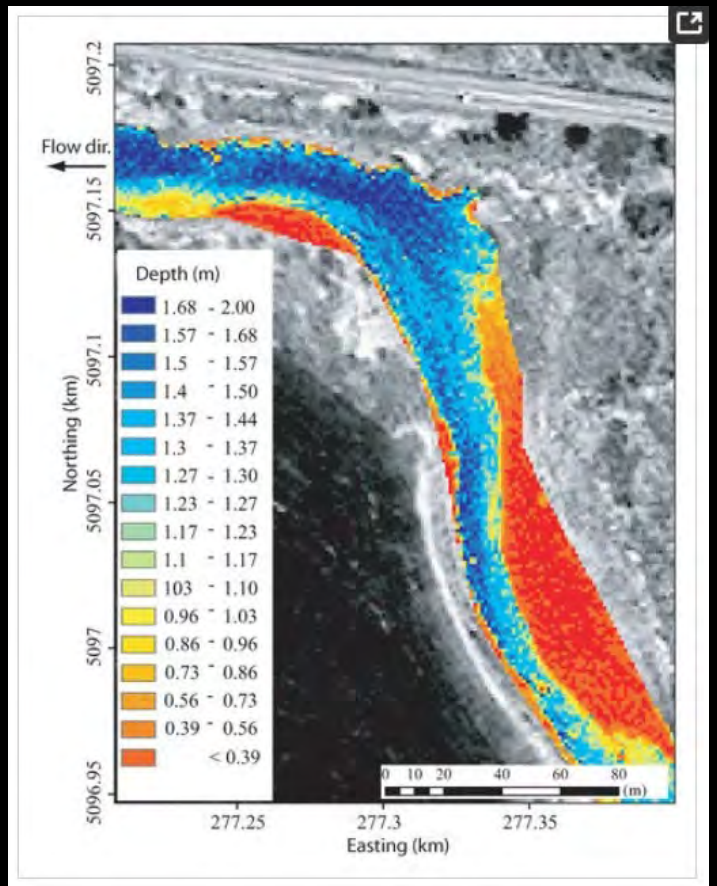
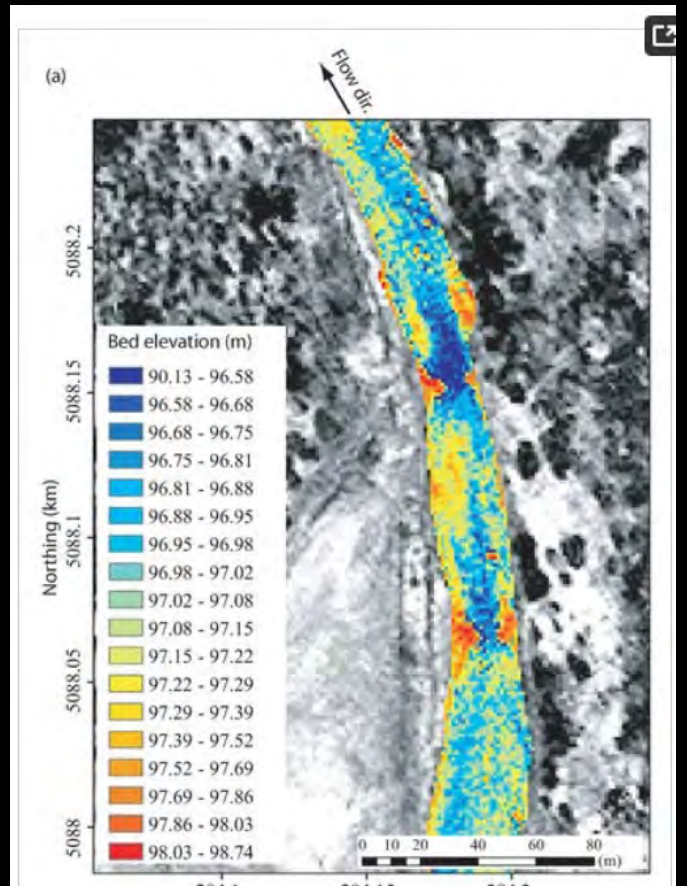


Figure 7. Variation of underwater depth in a 120° bend.

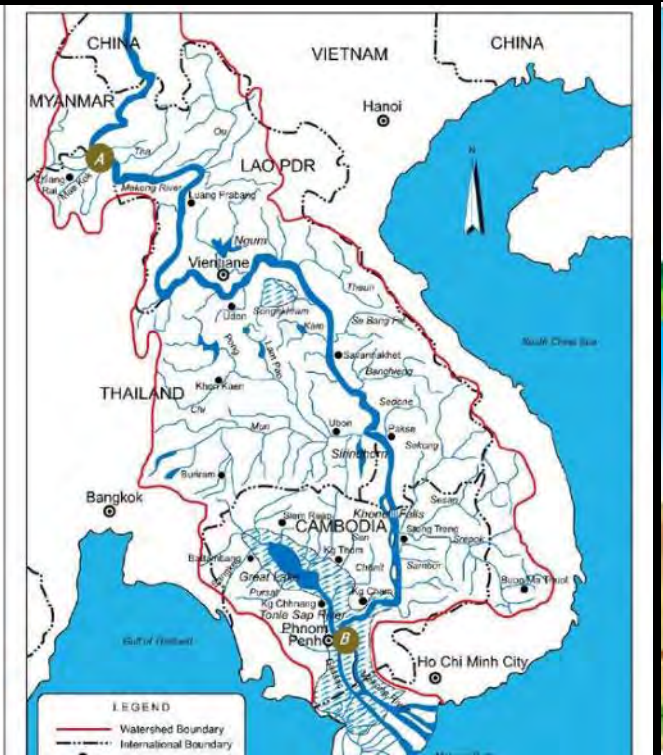


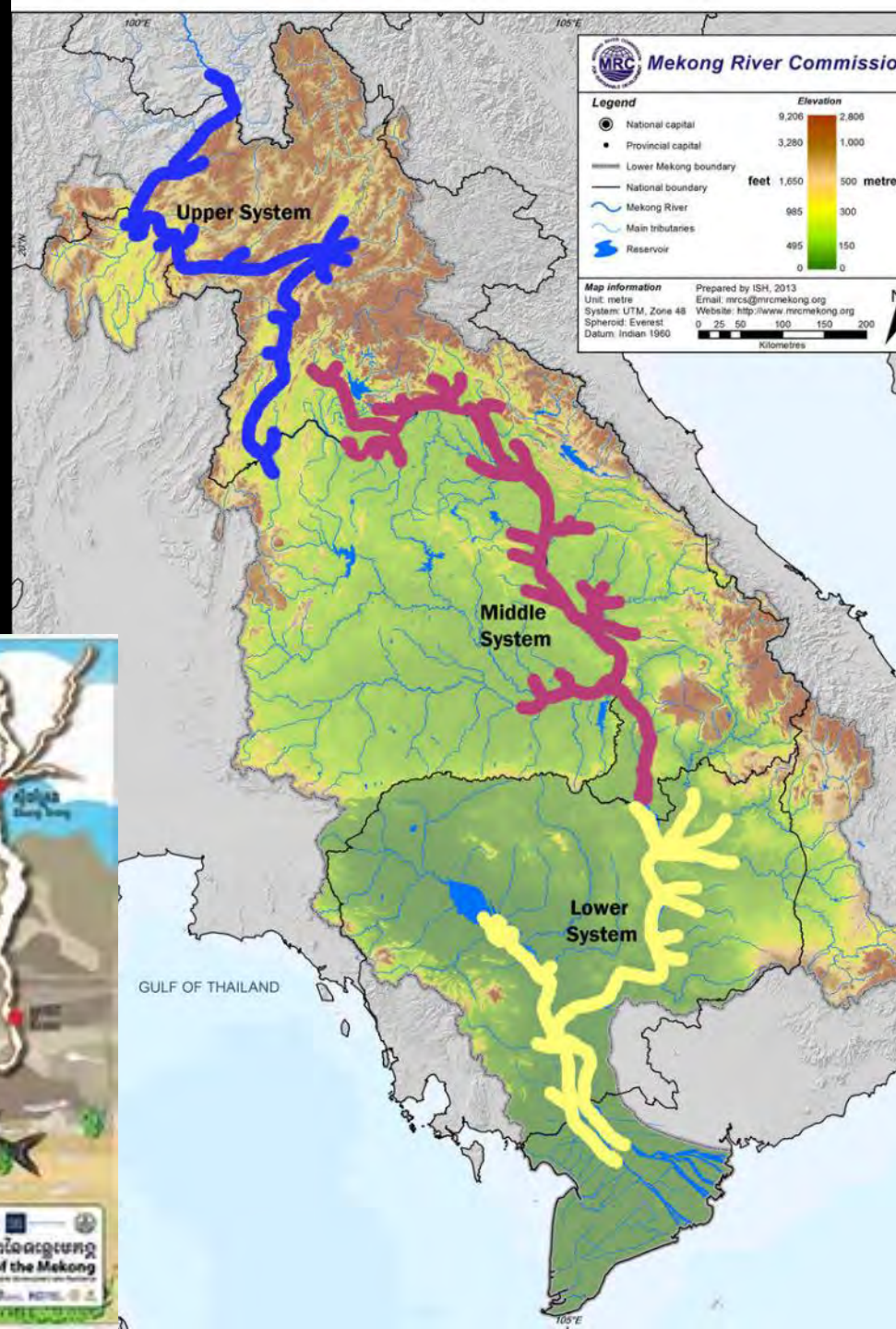


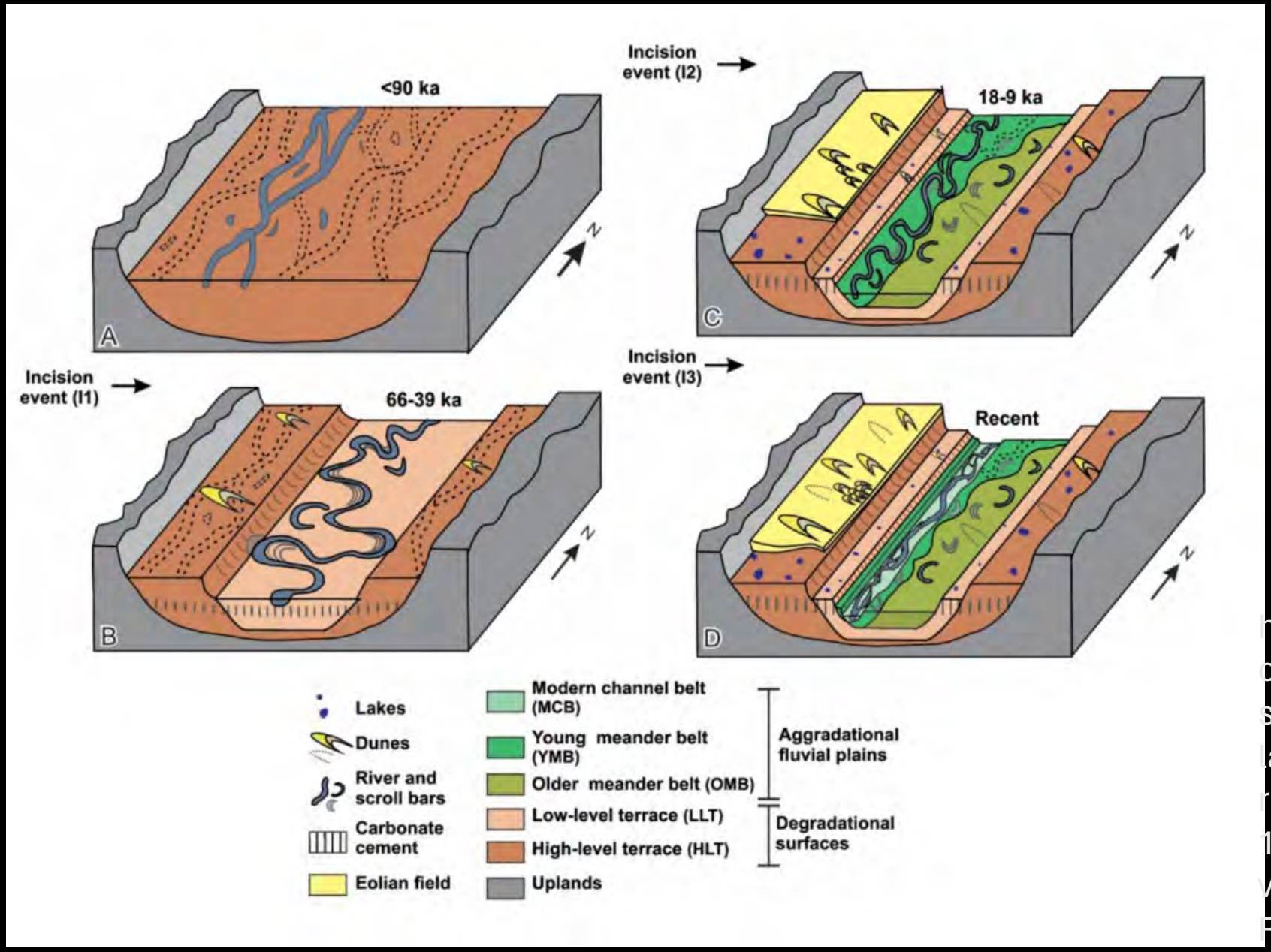
Mekong

Flow Reversal

30-90 m thalweg







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andscape-along-the-sao-francisco
iver%2F&psig=AOvVaw2PWPwbjftf
1410614764200O&source=images&
ved=0CBQQjhxqFwoTCMDD5ZnF3I
R

You will remember that I asked if you would be willing to offer a physical geographer's perspective on terms that are commonly used in river boundary definition. My idea is that I lead the 'river boundary definition' session using the attached set of slides as a framework - but from time to time I will stop and ask you for comments on features of the river channel / channel-shaping processes, including:

- thalweg
- bank
- main channel
- bed
- island
- accretion/avulsion

I appreciate that you may have mentioned some of these terms in your initial presentation, and a little overlap is fine. But the afternoon session is where I really want to dig in to the terms. Questions to think about might include:

- How do you go about identifying the thalweg? Is a hydrographic survey necessary or are there other (cheaper) approaches, even if those approaches involve some compromise in terms of precision? How stable are thalwegs over time?

- How do you identify the bank of a river? (This is critical to the identification of the median line, but my feeling is that its often a hugely challenging task - especially for surveyors who like a rules-based approached)

- Is there a clear definition of an avulsion, especially in terms of timescale, or is it more complex than it first appears?

If other points for discussion occur to you as you flick through my slides, please feel free to suggest them!

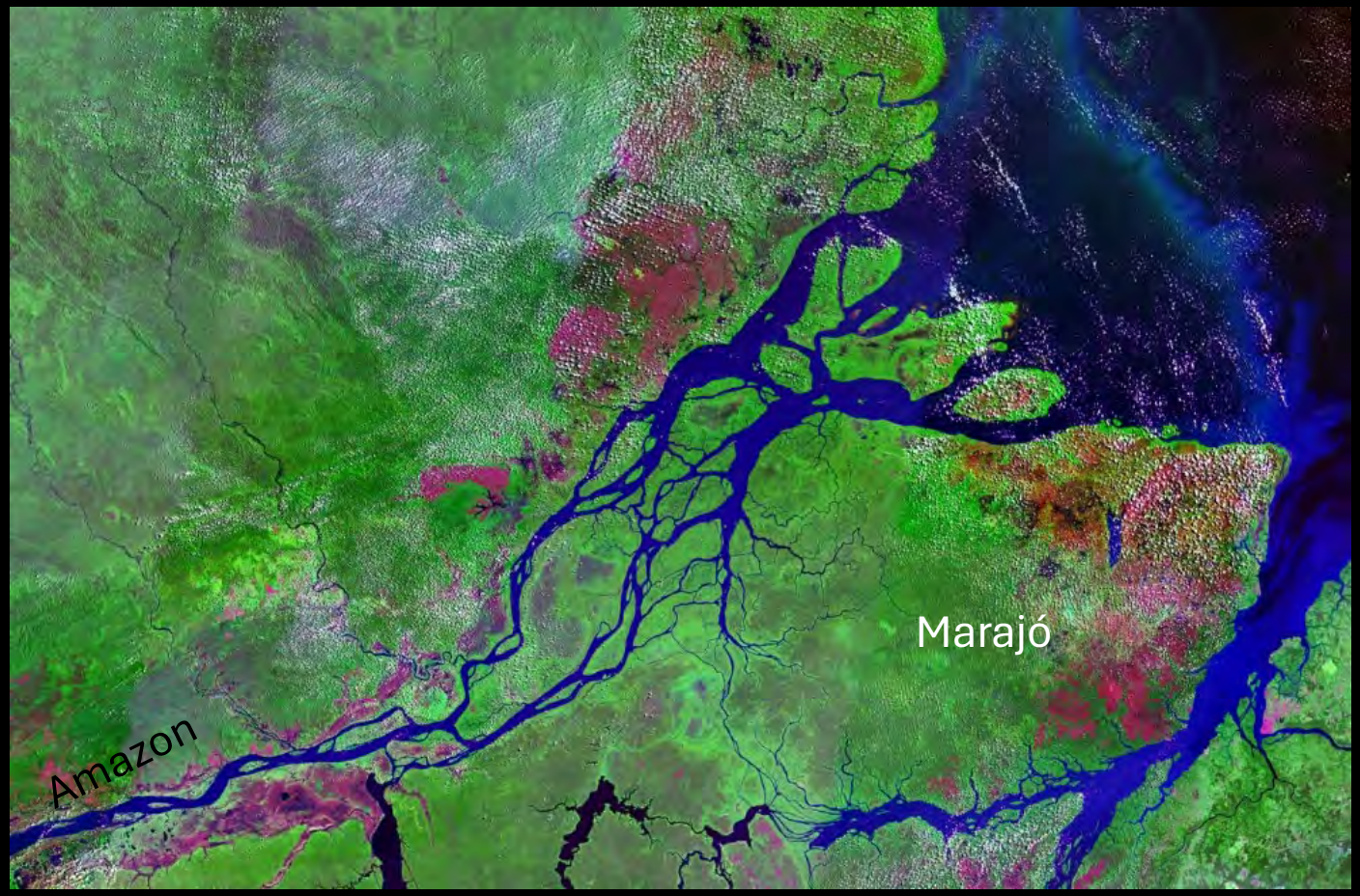
If there are any illustrations you would like to inset into the slide deck, just let me know. We can add graphics any time between now and the start of the workshop.

Mekong

(linear basin; headwaters in active orogenic belts)

https://www.rainforestcruises.com/guides/upper-vs-lower-mekong

Marajó, a large coastal island, Pará, Brazil.



Fun facts:

World's largest riverine "island"

Fun fact: small islands are affected by the *poroporca* bore tide.