The larger-scale context of Grand Canyon's Holocene record

1) meaning and fate of Holocene record?
2) alluvial vs bedrock river and the long profile

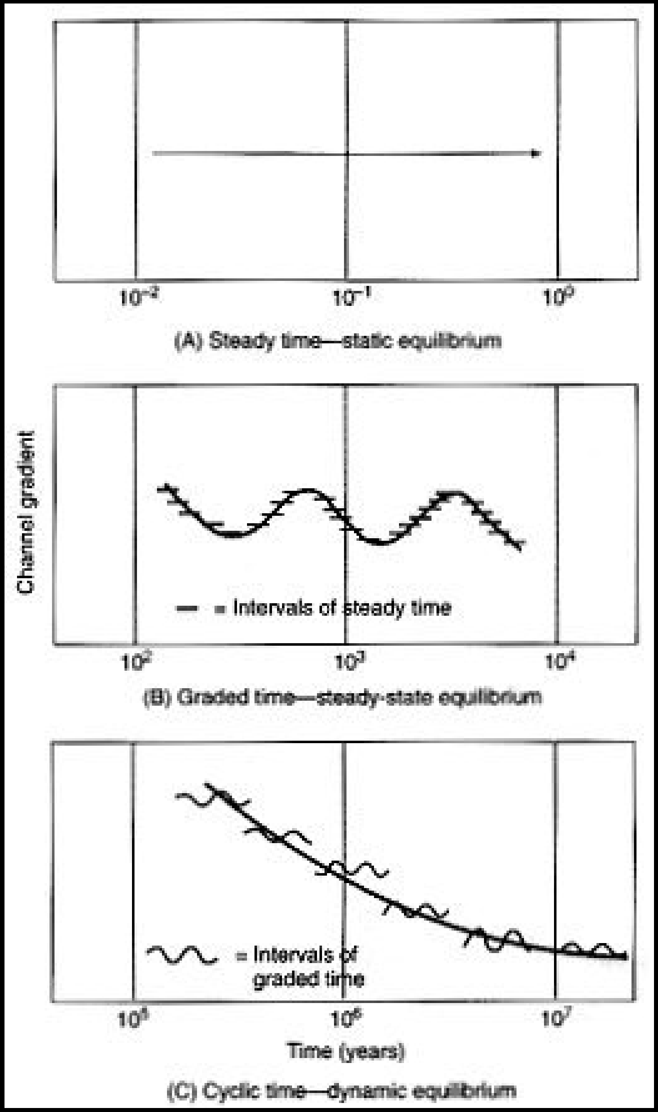
Schumm and Lichty, 1965, Time, Space, and Casuality in Geomorphology

The status of drainage basin variables during time spans of decreasing duration

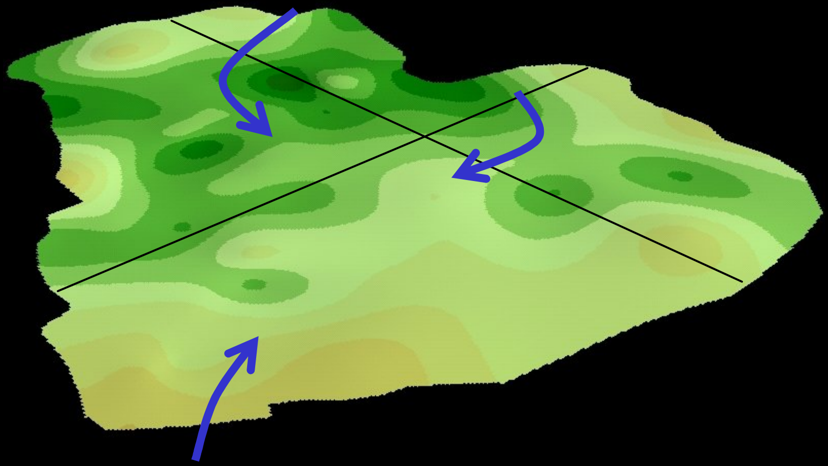
Drainage basin variables	Status of variables during designated time spans		
	Cyclic	Graded	Steady
1. Time	Independent	Not relevant	Not relevant
2. Initial relief	Independent	Not relevant	Not relevant
3. Geology (lithology, structure)	Independent	Independent	Independent
4. Climate	Independent	Independent	Independent
5. Vegetation (type and density)	Dependent	Independent	Independent
6. Relief or volume of system above base level	Dependent	Independent	Independent
7. Hydrology (runoff and sediment yield per unit area within system)	Dependent	Independent	Independent
8. Drainage network morphology	Dependent	Dependent	Independent
9. Hillslope morphology	Dependent	Dependent	Independent
10. Hydrology (discharge of water and sediment from system)	Dependent	Dependent	Dependent

Michael Church, 1999, *in* The Scientific Nature of Geomorphology

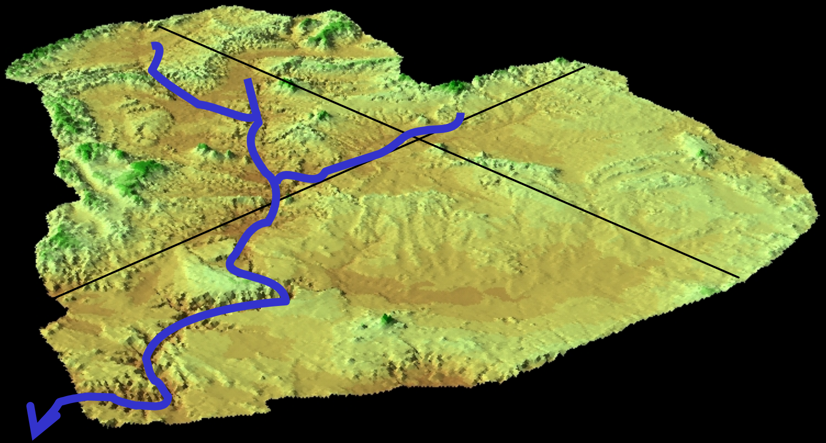
"…scientific theories are essentially constrained by their associated scales of space and time, and different kinds of theories are appropriate to describe phenomena at different scales."

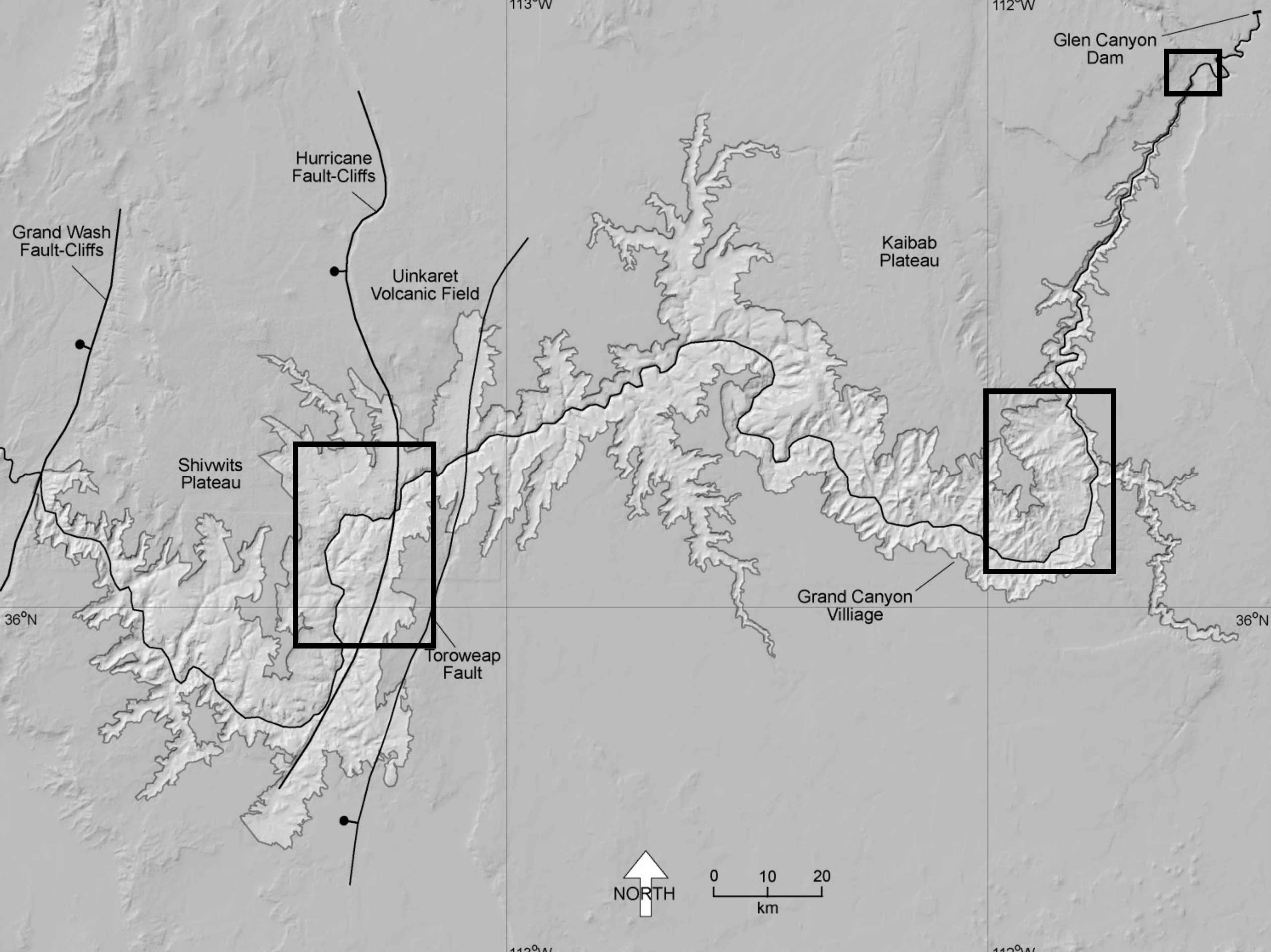


Middle Cenozoic (~30 Ma)



6 Ma, Colorado River integration

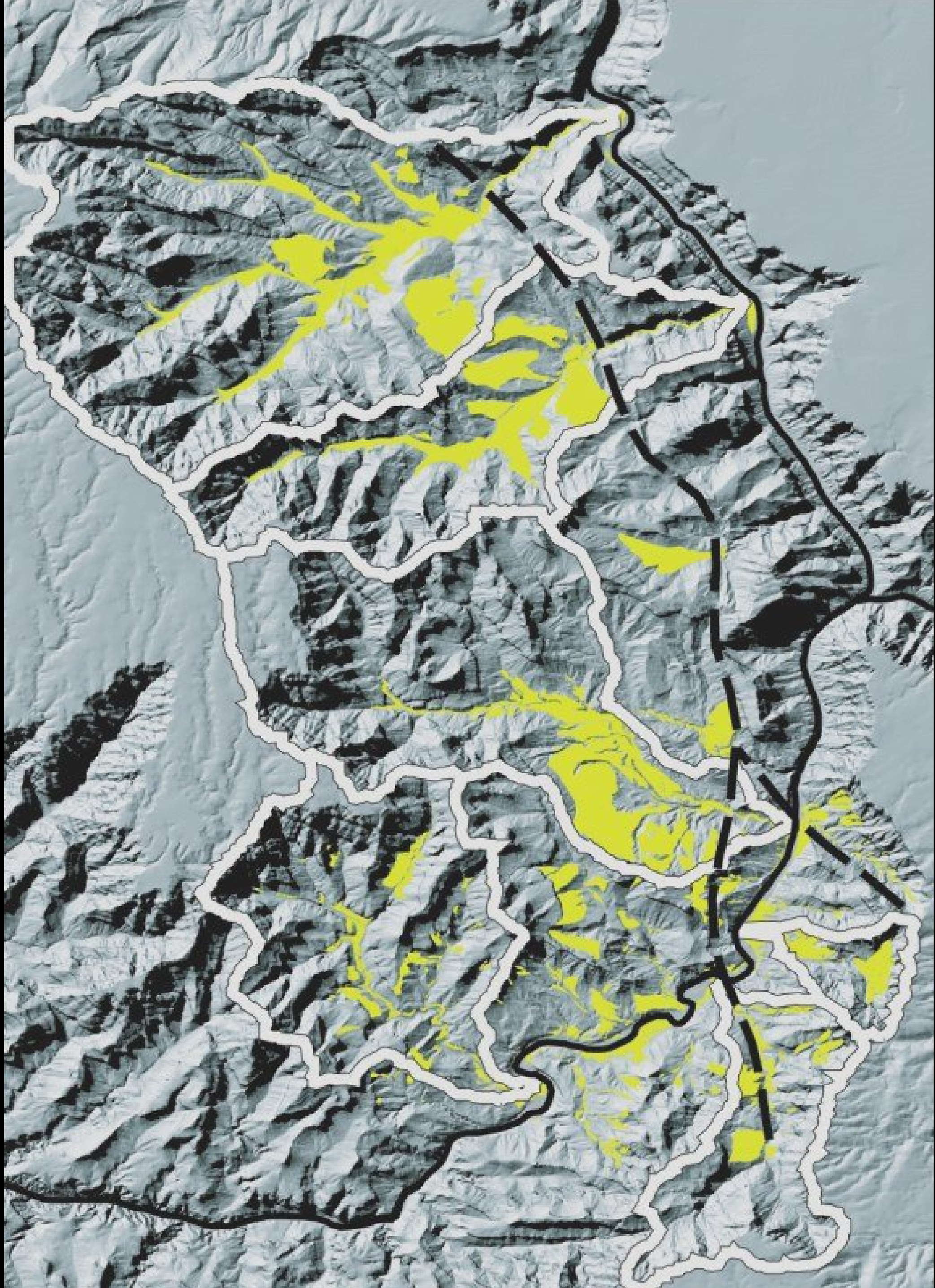



113°W
112°W
Glen Canyon Dam
Hurricane Fault-Cliffs
Grand Wash Fault-Cliffs
Uinkaret Volcanic Field
Kaibab Plateau
Shivwits Plateau
Toroweap Fault
Grand Canyon Villiage
36°N
36°N
NORTH
0
10
20
km
113°W
112°W

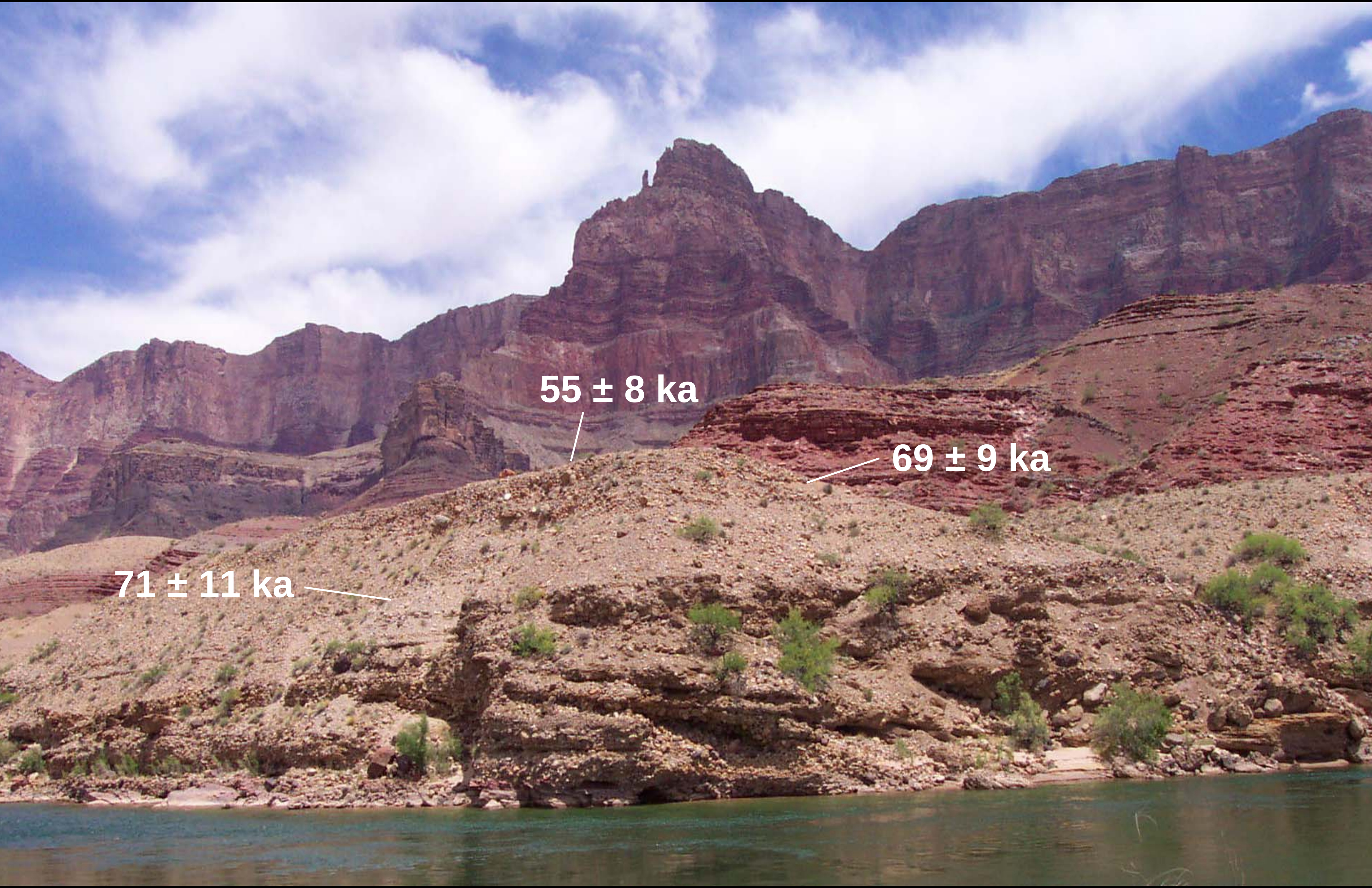
students:
Matt Anders
Scott Cragun
Ben DeJong

collaborators:
OSL – Tammy Rittenhour
U-series – Warren Sharp
Cosmogenic – John Gosse

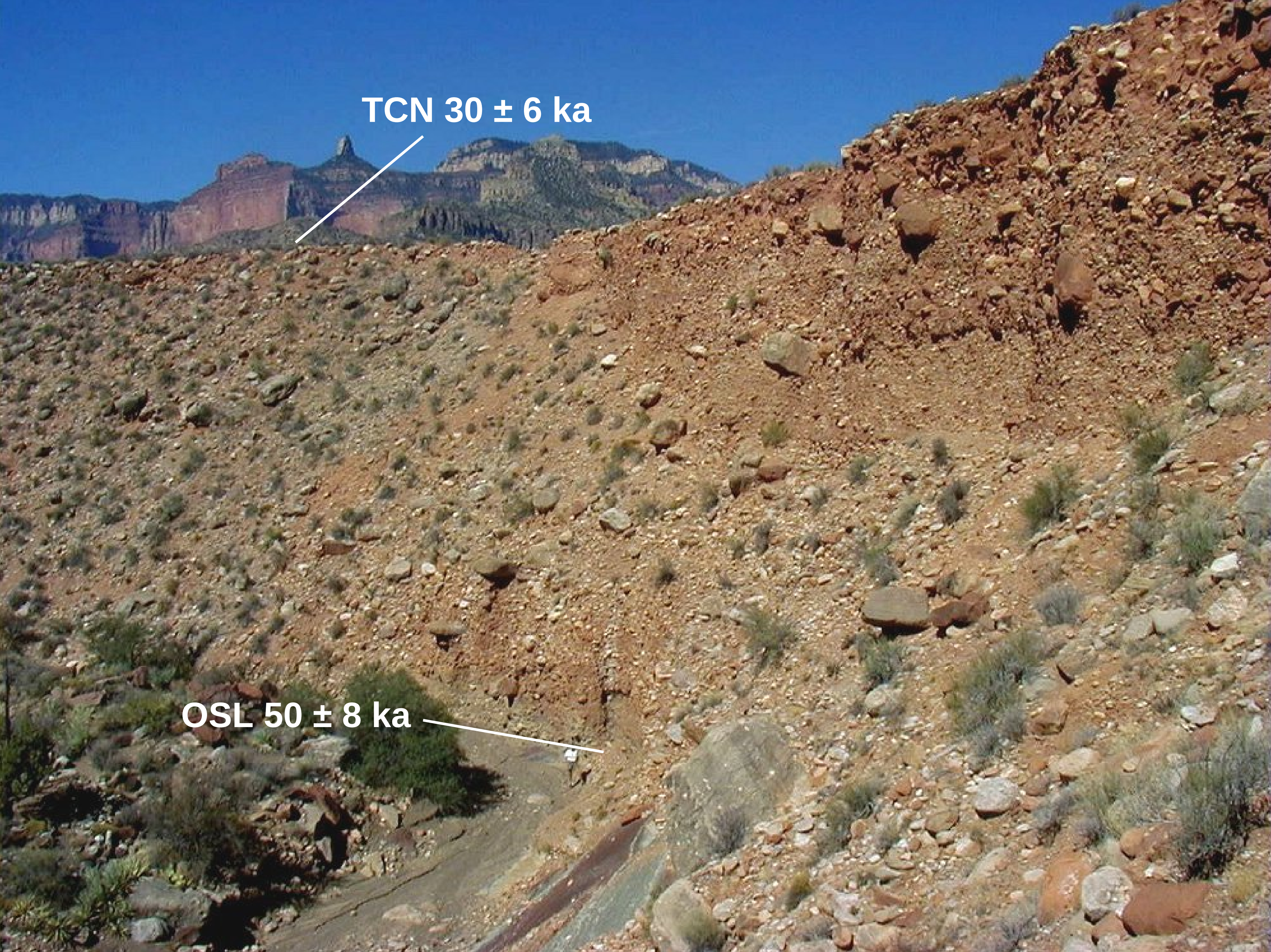
funding:
NSF, USU, GSA

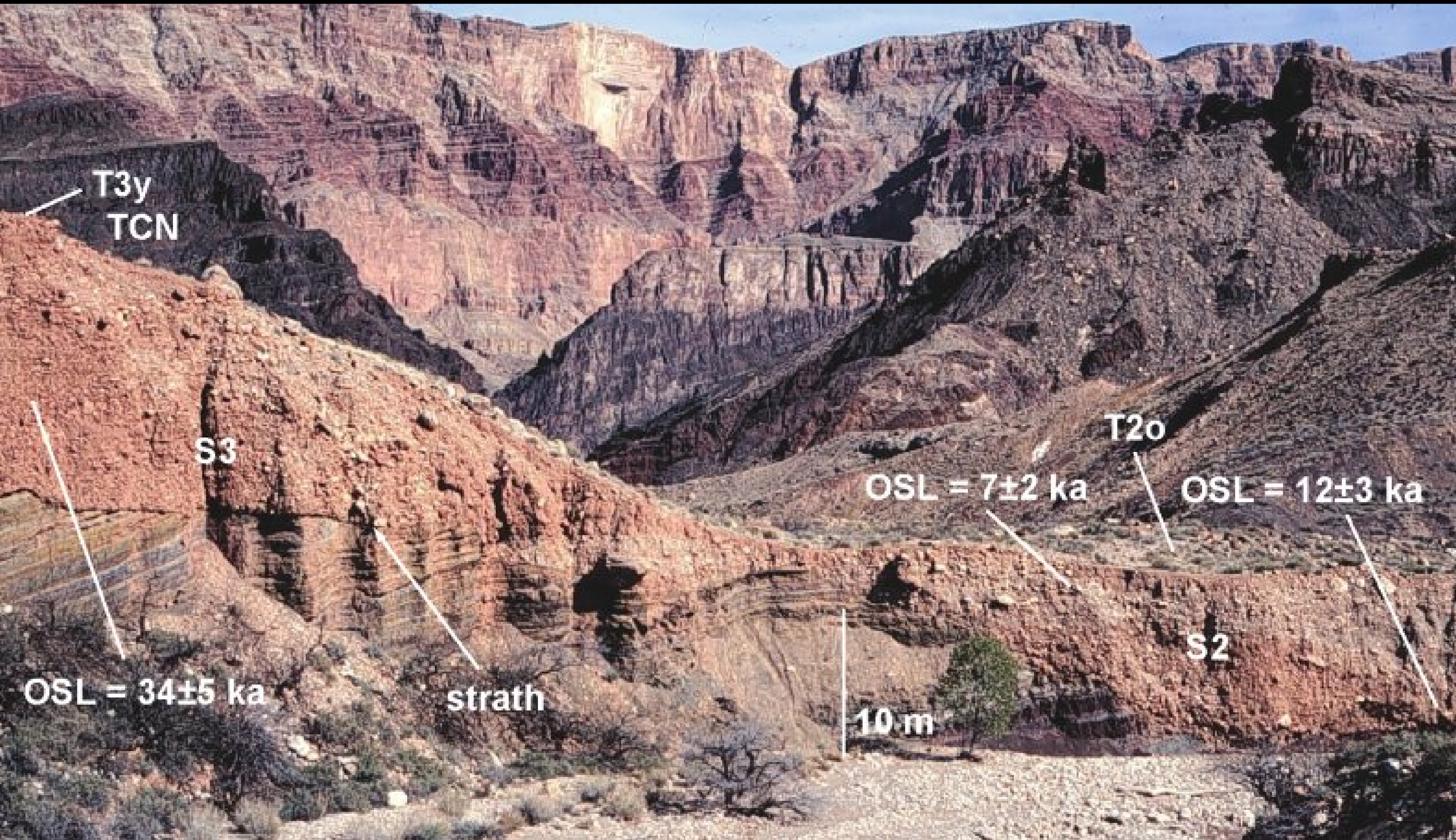



post-M4 hillslope deposits
upper M4 sand and travertine
118 ± 3 ka
travertine
151 ± 5 ka
travertine
talus
M4 gravel and sand
M4 strath ~ river level

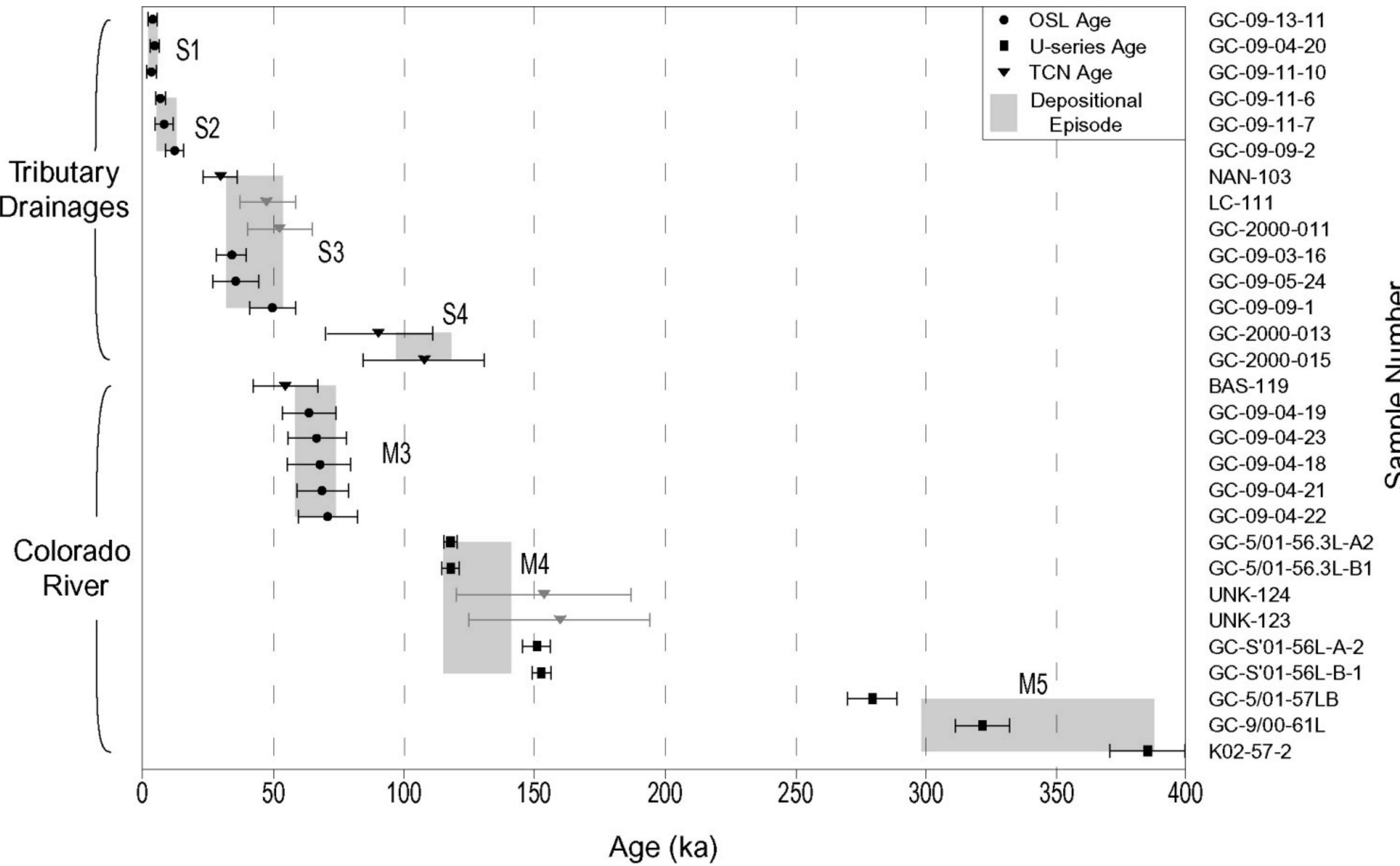


where is the LGM deposit?


TCN 30 ± 6 ka
OSL 50 ± 8 ka

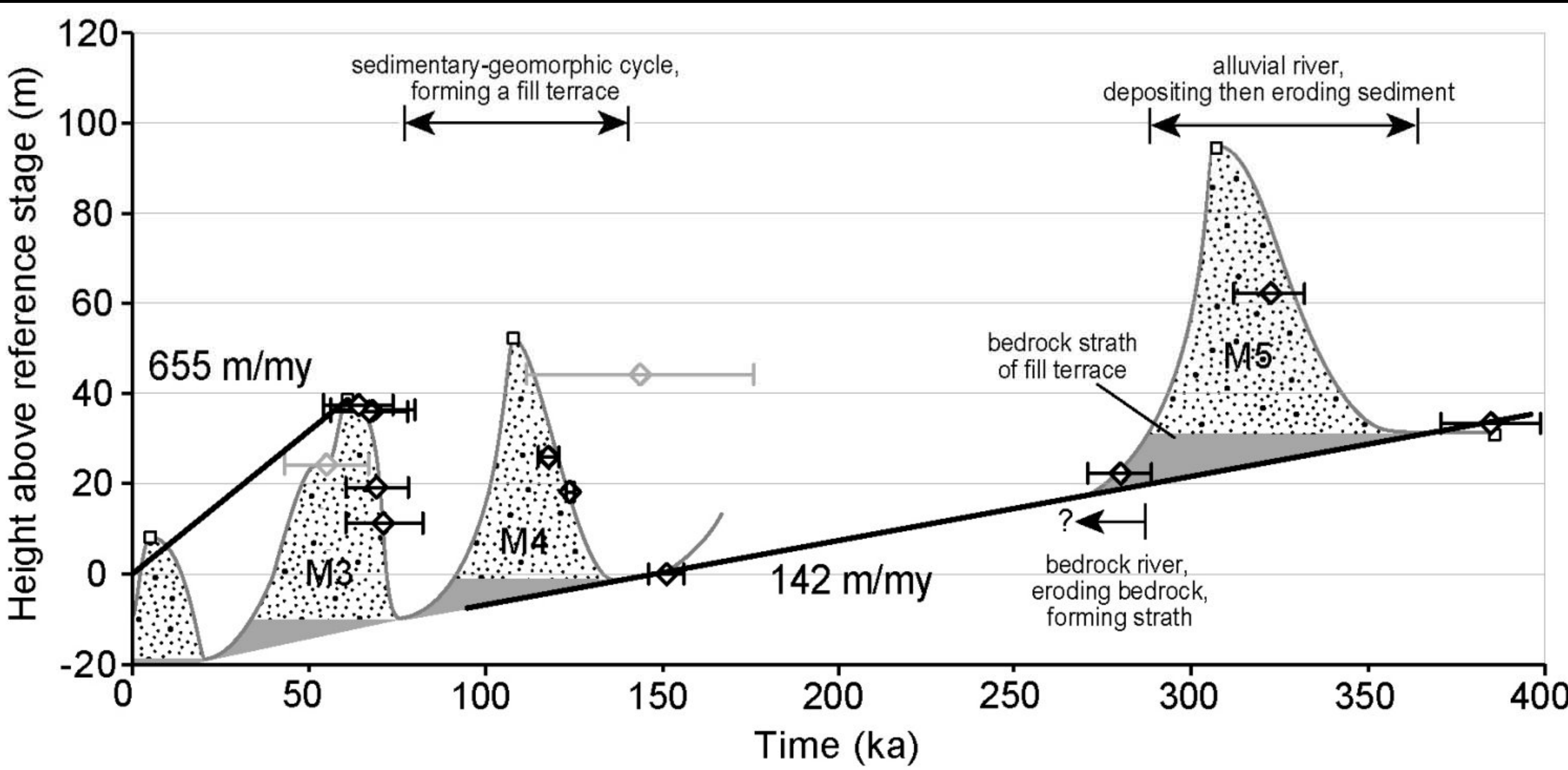

T3y
TCN
S3
T2o
OSL = 7±2 ka
OSL = 12±3 ka
S2
OSL = 34±5 ka
strath
10 m


S3
S2



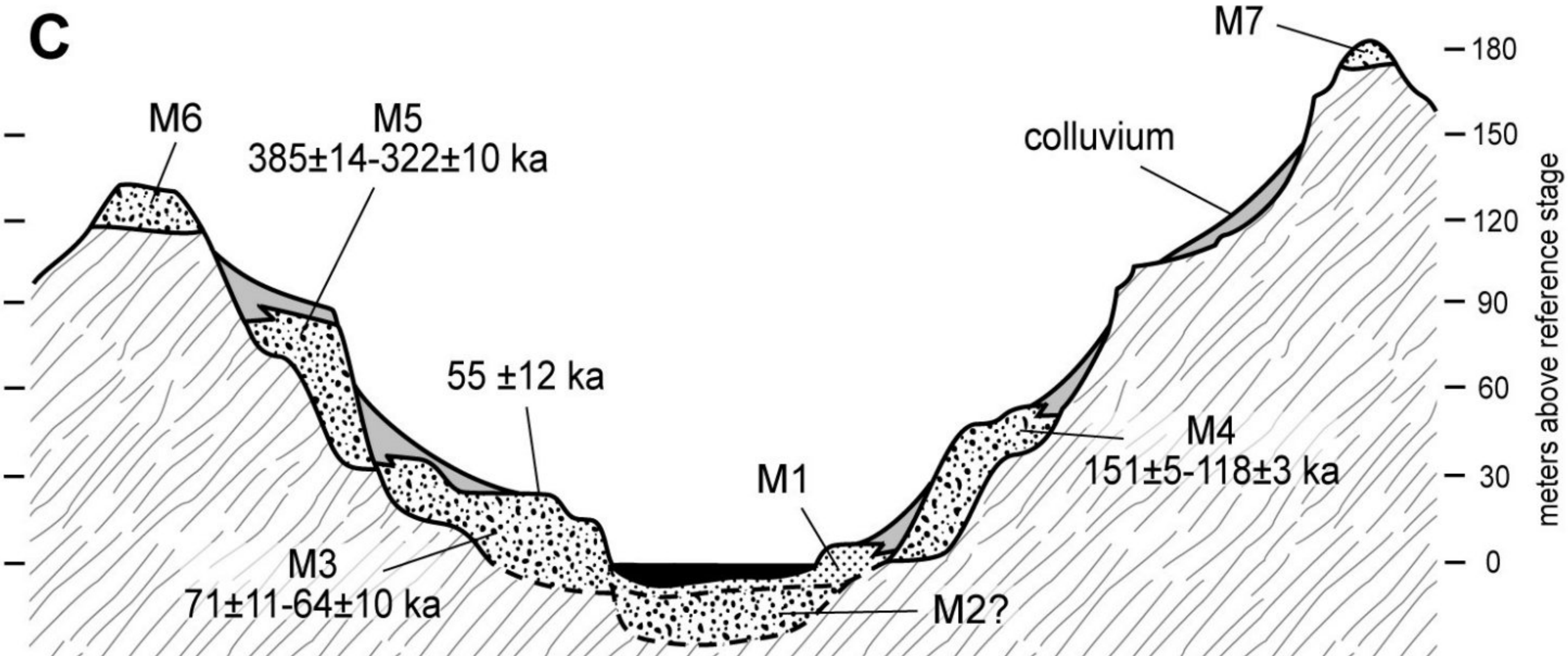
Tributary Drainages
Colorado River
S1
S2
S3
S4
M3
M4
M5
OSL Age
U-series Age
TCN Age
Depositional Episode
GC-09-13-11
GC-09-04-20
GC-09-11-10
GC-09-11-6
GC-09-11-7
GC-09-09-2
NAN-103
LC-111
GC-2000-011
GC-09-03-16
GC-09-05-24
GC-09-09-1
GC-2000-013
GC-2000-015
BAS-119
GC-09-04-19
GC-09-04-23
GC-09-04-18
GC-09-04-21
GC-09-04-22
GC-5/01-56.3L-A2
GC-5/01-56.3L-B1
UNK-124
UNK-123
GC-S'01-56L-A-2
GC-S'01-56L-B-1
GC-5/01-57LB
GC-9/00-61L
K02-57-2
Sample Number
0
50
100
150
200
250
300
350
400
Age (ka)

INCISION RATES



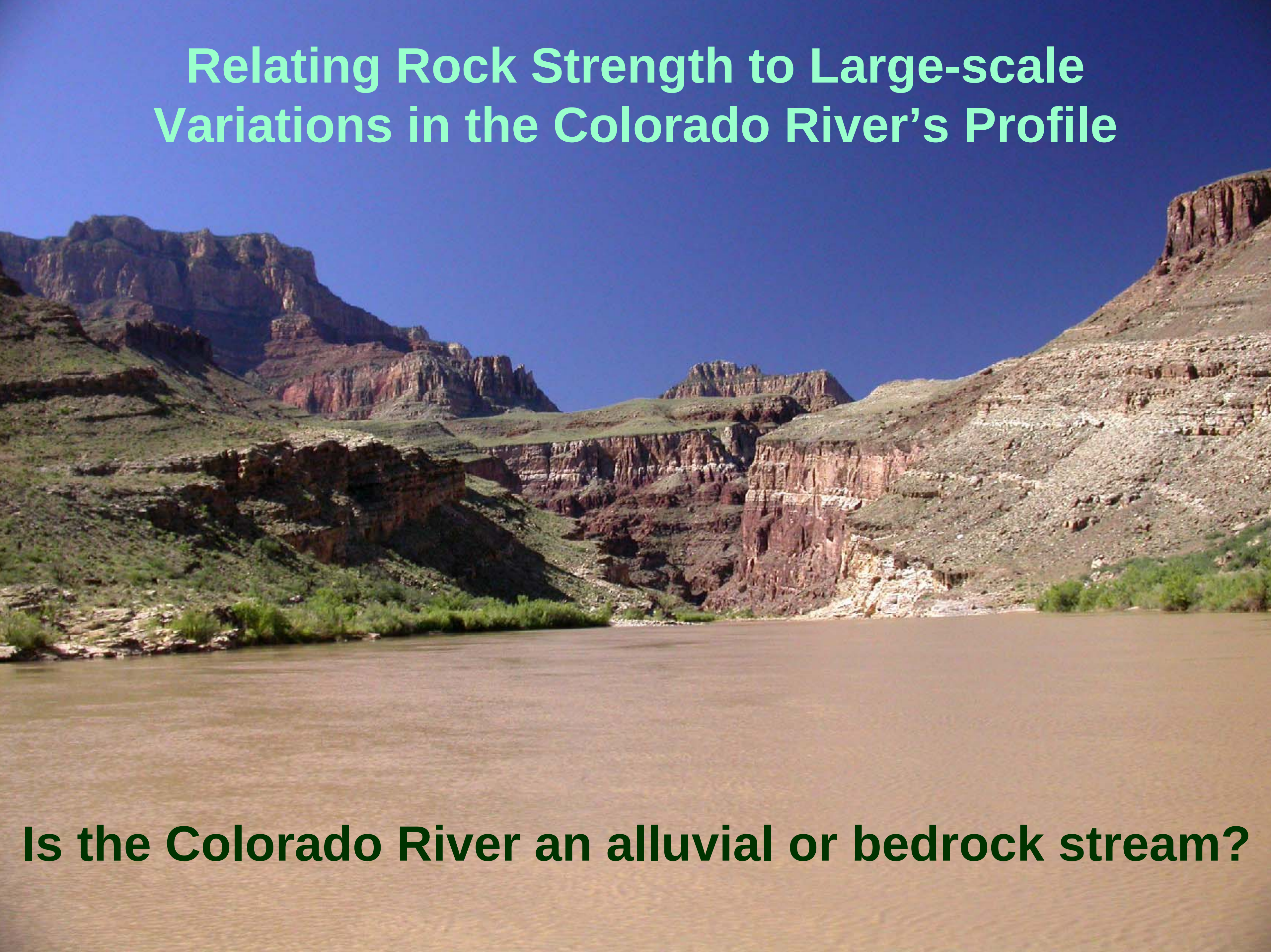
Where do the Holocene deposits fit in this context?

MAINSTEM STRATIGRAPHY

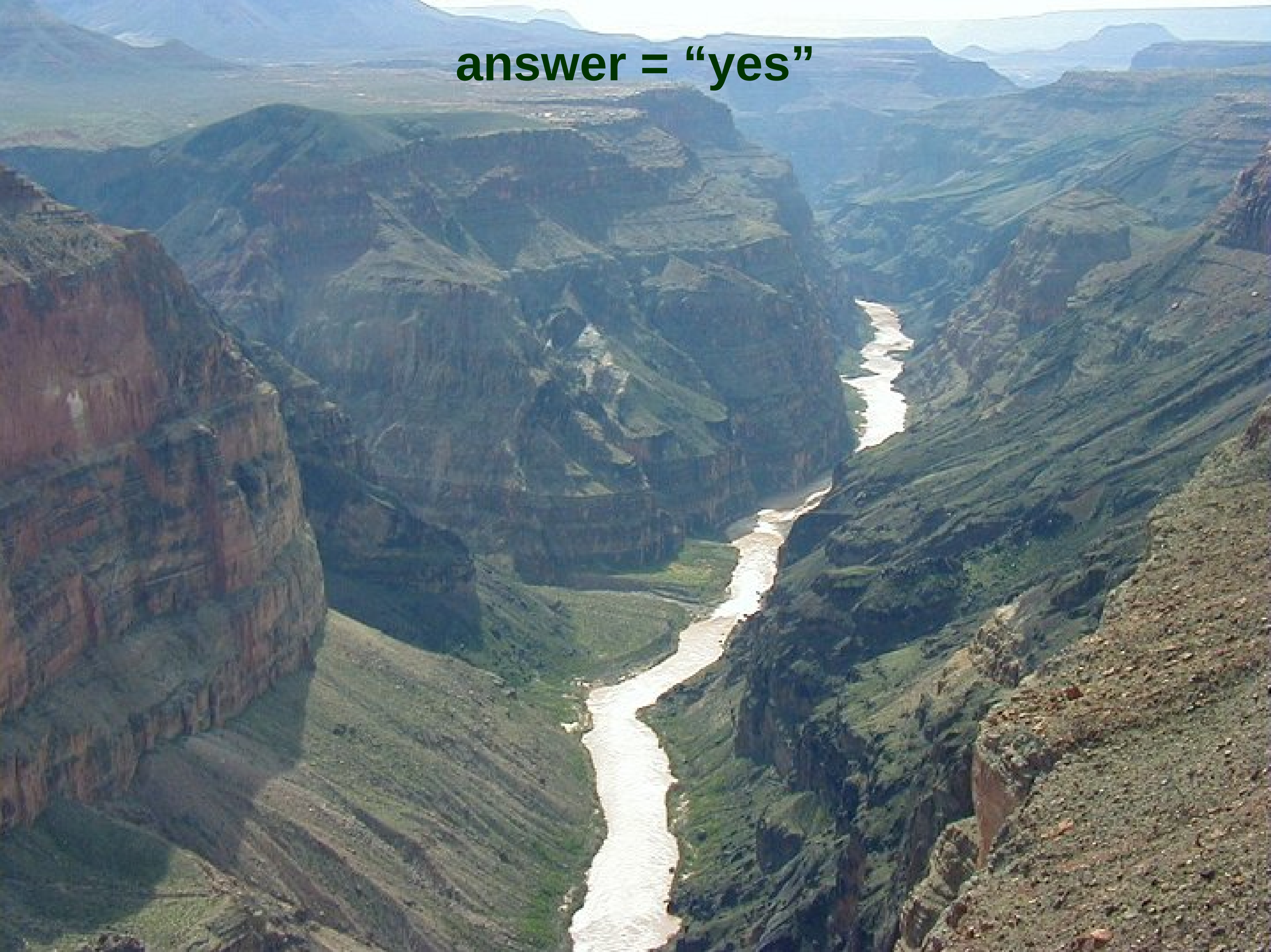


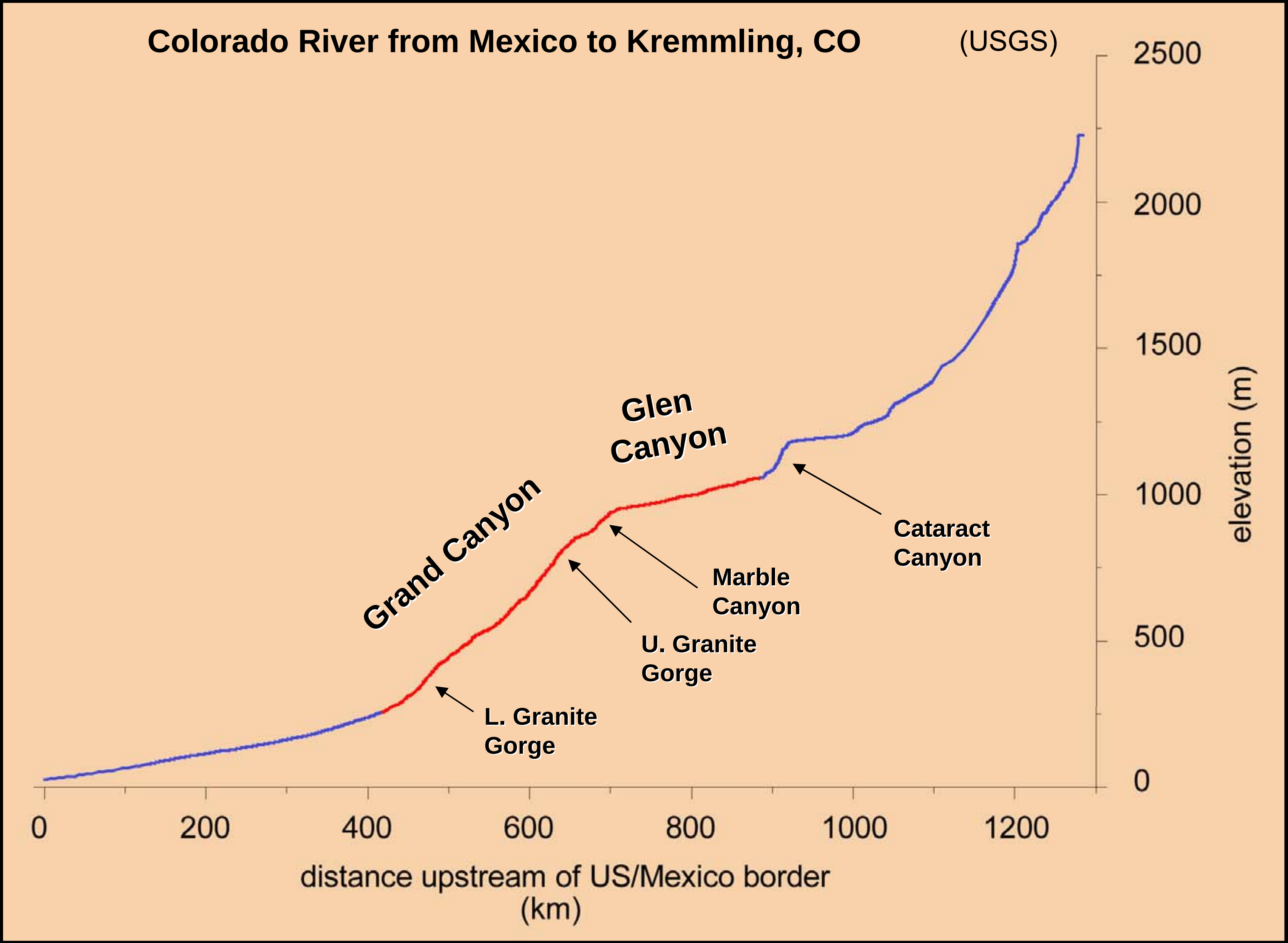
Where do the Holocene deposits fit in this context?

Relating Rock Strength to Large-scale Variations in the Colorado River's Profile



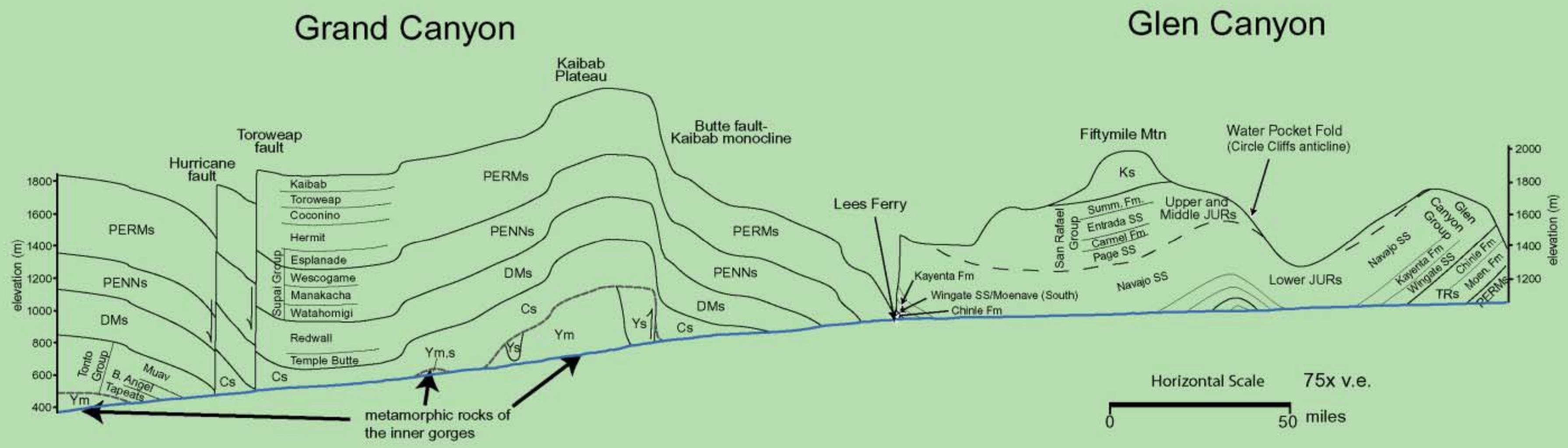
Is the Colorado River an alluvial or bedrock stream?


answer = “yes”



Colorado River from Mexico to Kremmling, CO
(USGS)
2500
2000
1500
1000
500
0
elevation (m)
0
200
400
600
800
1000
1200
distance upstream of US/Mexico border
(km)
Glen
Canyon
Grand Canyon
Cataract
Canyon
Marble
Canyon
U. Granite
Gorge
L. Granite
Gorge

18 bedrock reaches

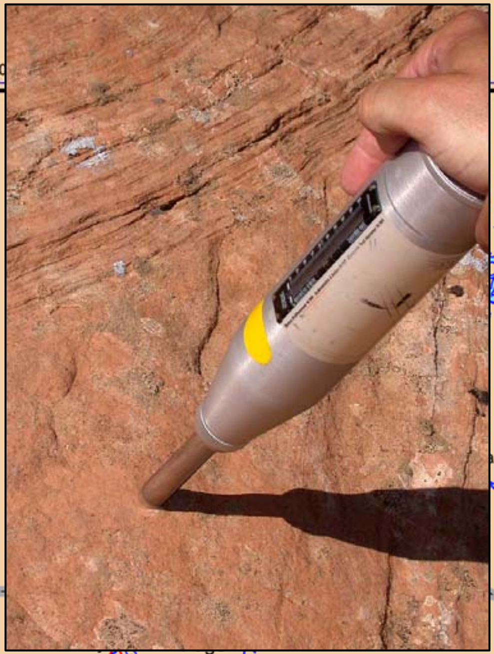


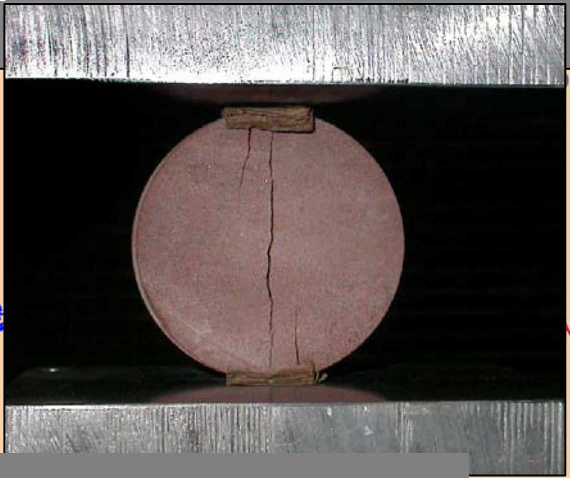
Outcrop-scale measurements:

1) **Schmidt hammer for *in situ* compressive strength; n = 3,670**

2) **Fracture spacing; n = 4,147**

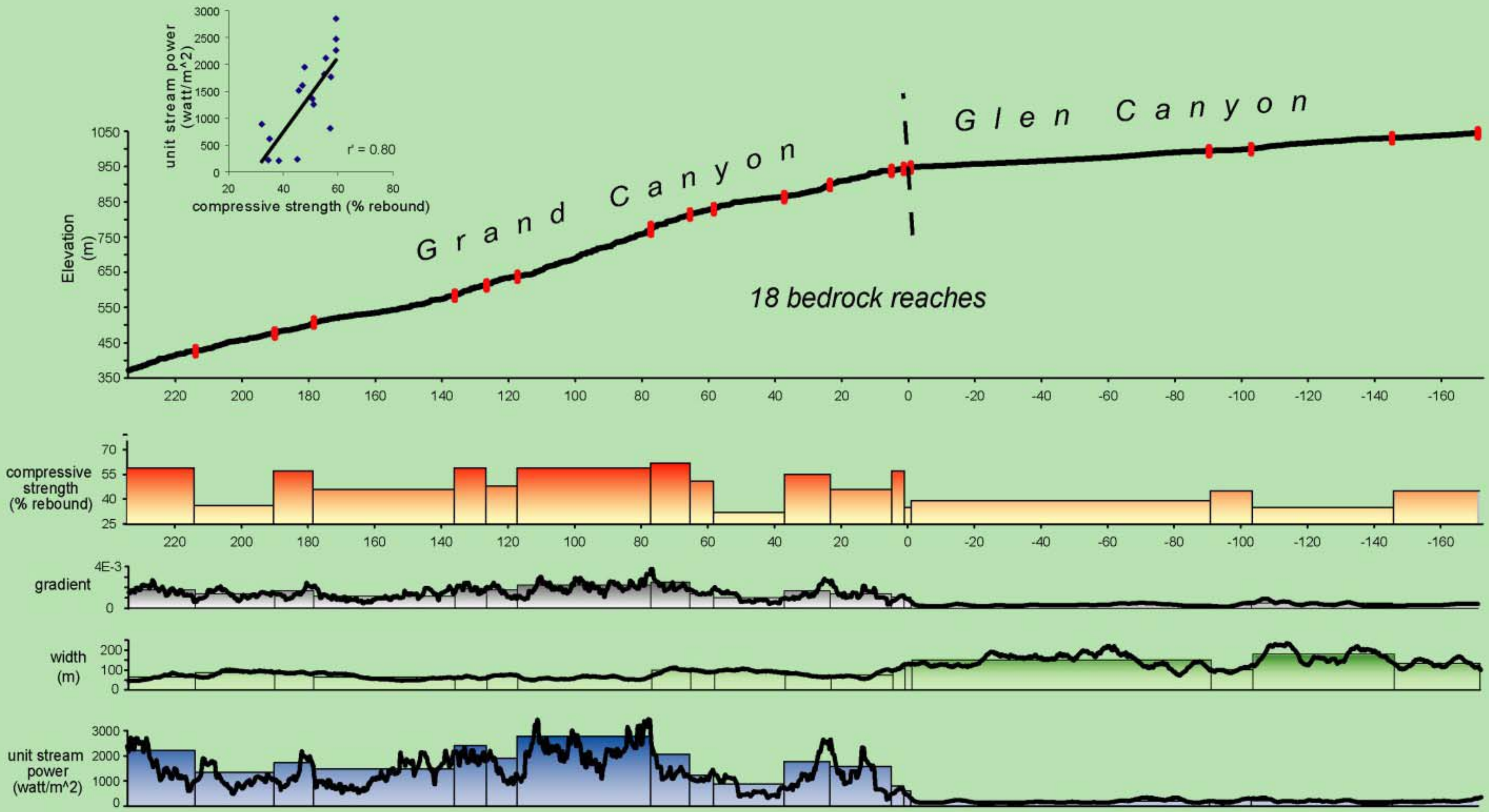
3) **Selby rock mass strength (1980); n = 84**





Laboratory:

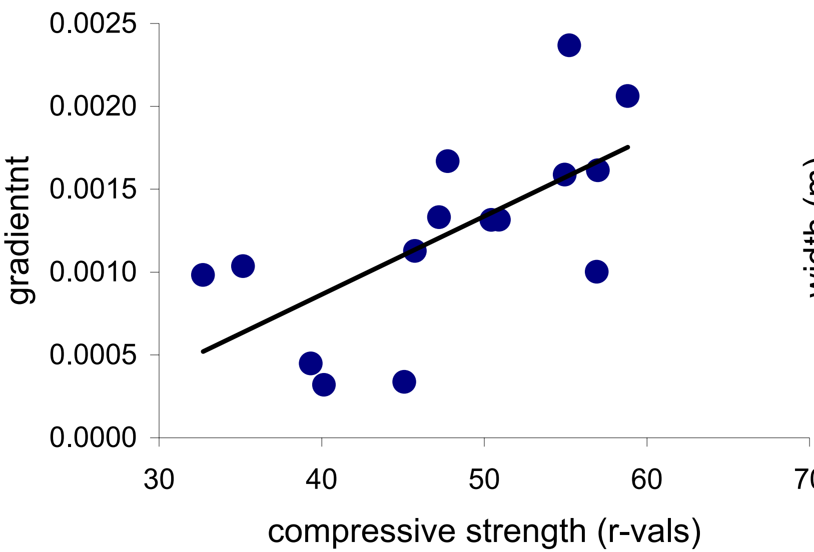
Brazilian splitting tests for tensile strength

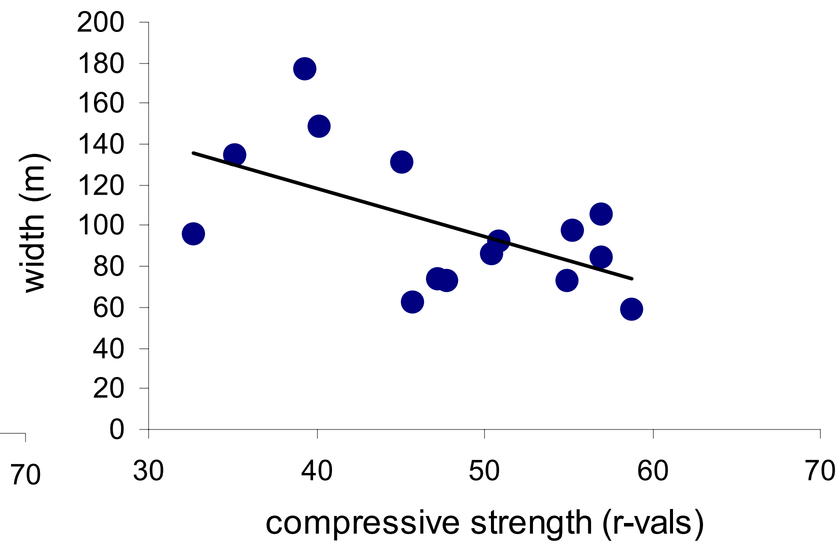


unit stream power (watt/m^2)
compressive strength (% rebound)
r² = 0.80
Elevation (m)
Grand Canyon
Glen Canyon
18 bedrock reaches
compressive strength (% rebound)
gradient
width (m)
unit stream power (watt/m^2)

Correlation Matrix (Spearman correlation coefficient; α = 0.05):

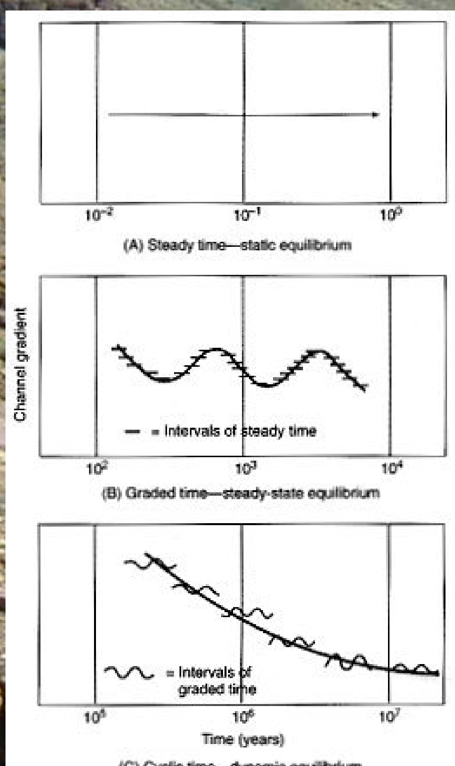
	compressive strength				
fracture spacing	-0.05	fracture spacing			
RMS	**0.87**	0.25	RMS		
gradient	**0.72**	-0.19	0.44	gradient	
width	**-0.51**	0.48	-0.12	**-0.74**	width
unit stream power	**0.69**	-0.30	0.35	**0.95**	**-0.86**

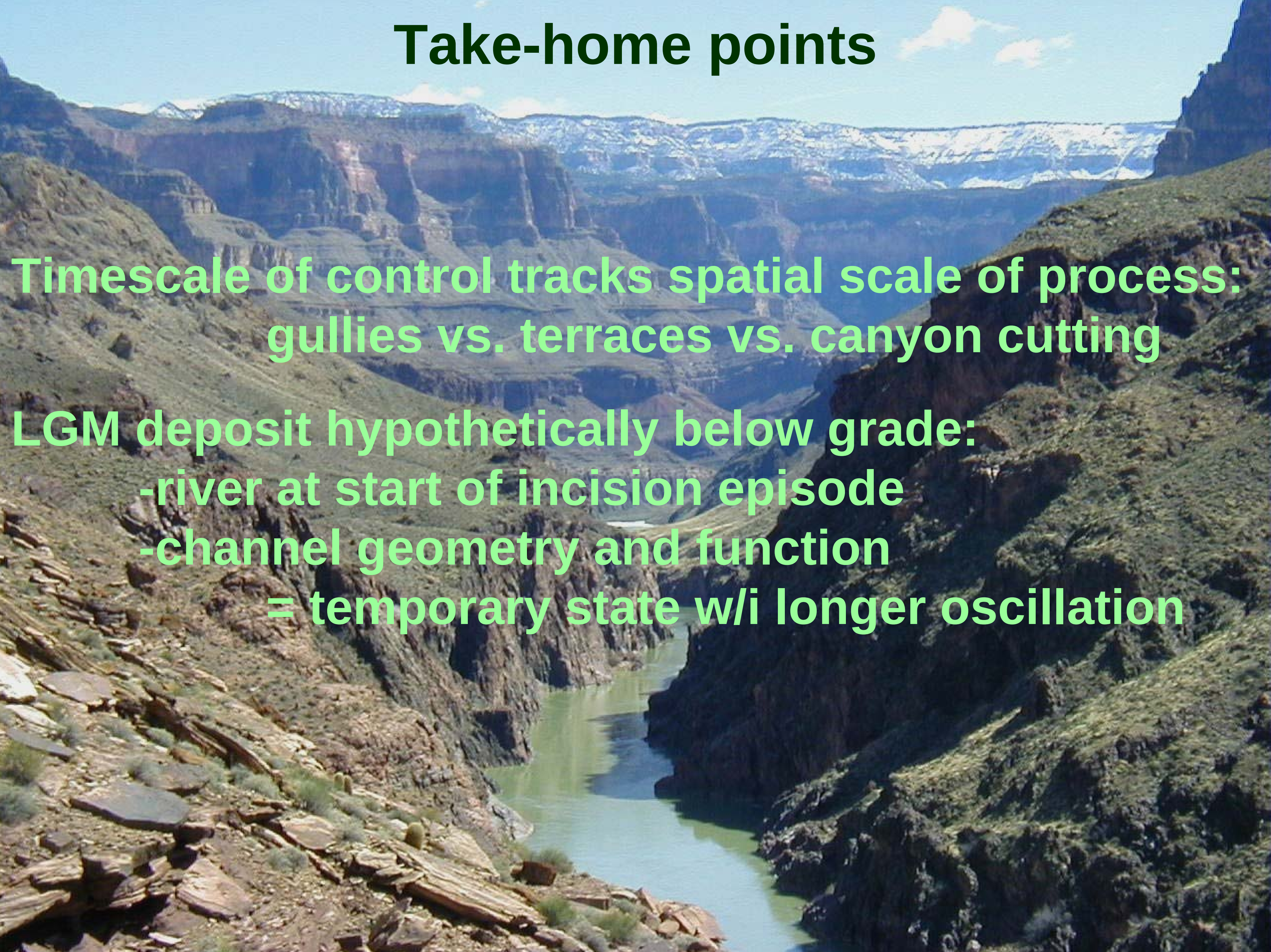




Take-home points

Timescale of control tracks spatial scale of process: gullies vs. terraces vs. canyon cutting





Take-home points

Timescale of control tracks spatial scale of process:
gullies vs. terraces vs. canyon cutting

LGM deposit hypothetically below grade:
-river at start of incision episode
-channel geometry and function
= temporary state w/i longer oscillation